10. World nuclear forces

Overview

At the start of 2022, nine states—the United States, Russia, the United Kingdom, France, China, India, Pakistan, Israel and the Democratic People's Republic of Korea (DPRK, or North Korea)—possessed approximately 12 705 nuclear weapons, of which 9440 were estimated to be in military stockpiles for potential use. About 3732 of these warheads were estimated to be deployed with operational forces (see table 10.1), and around 2000 of these were kept in a state of high operational alert.

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 may be 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, missile and aircraft delivery systems, and nuclear weapon production facilities (see sections I and II).

The nuclear arsenals of the other nuclear-armed states are considerably smaller (see sections III–IX), but all are either developing or deploying new weapon systems or have announced their intention to do so. China is in the middle of a significant modernization and expansion of its nuclear arsenal, and India and Pakistan also appear to be increasing the size of their nuclear weapon inventories. In 2021 the UK announced its intention to increase the cap for its nuclear stockpile. North Korea's military nuclear programme remains central to its national security strategy and it may have assembled up to 20 warheads.

The availability of reliable information on the status of the nuclear arsenals and capabilities of the nuclear-armed states varies considerably. The USA, the UK and France have declared some information. Russia refuses to publicly disclose the detailed breakdown of its strategic nuclear forces, even though it shares the information with the USA. China releases little information about force numbers or future development plans. The governments of India and Pakistan make statements about some of their missile tests but provide no information about the status or size of their arsenals. North Korea has acknowledged conducting nuclear weapon and missile tests but provides no information about the size of its nuclear arsenal. Israel has a long-standing policy of not commenting on its nuclear arsenal.

The raw material for nuclear weapons is fissile material, either highly enriched uranium or separated plutonium (see section X).

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Table 10.1. World nuclear forces, January 2022

All figures are approximate and are estimates based on assessments by the authors. The estimates presented here are based on publicly available information and contain some uncertainties, as reflected in the notes to tables 10.1–10.10.

State	Year of first nuclear test	Deployed warheads[a]	Stored warheads[b]	Total stockpile[c]	Retired warheads	Total inventory
United States	1945	1 744[d]	1 964[e]	3 708	1 720[f]	5 428
Russia	1949	1 588[g]	2 889[h]	4 477	1 500[f]	5 977
United Kingdom	1952	120	60	180	45[i]	225[j]
France	1960	280	10[k]	290	. .	290
China	1964	–	350	350	–	350
India	1974	–	160	160	. .	160
Pakistan	1998	–	165	165	. .	165
Israel	. .	–	90	90	. .	90
North Korea	2006	–	20	20	. .	20[l]
Total		**3 732**	**5 708**	**9 440**	**3 265**	**12 705**

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

Note: SIPRI revises its world nuclear forces data each year based on new information and updates to earlier assessments. The data for Jan. 2022 replaces all previously published SIPRI data on world nuclear forces.

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

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

[c] 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.

[d] This figure includes *c.* 1344 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 deployed outside the USA at North Atlantic Treaty Organization partner bases.

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

[f] This figure is for retired warheads awaiting dismantlement.

[g] This figure includes *c.* 1388 strategic warheads deployed on ballistic missiles and *c.* 200 deployed at heavy bomber bases.

[h] This figure includes *c.* 977 strategic and *c.* 1912 non-strategic warheads in central storage.

[i] This figure refers to 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 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. 2022. 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] The 10 warheads assigned to France’s carrier-based aircraft are thought to be kept in central storage and are not normally deployed.

[l] In previous editions of the SIPRI Yearbook, this figure referred to the number of nuclear warheads that North Korea could potentially build with the amount of fissile material it has produced. However, SIPRI’s estimate for Jan. 2022 is that North Korea has assembled up to 20 warheads. This is the first time that figures for North Korea have been included in the global totals.

I. United States nuclear forces

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As of January 2022, the United States maintained a military stockpile of approximately 3708 nuclear warheads, around 100 fewer than the estimate for January 2021. Approximately 1744 of these—consisting of about 1644 strategic and roughly 100 non-strategic (tactical) warheads—were deployed on ballistic missiles and bomber bases. In addition, about 1964 warheads were held in reserve and around 1720 retired warheads were awaiting dismantlement (30 fewer than the previous year's estimate), giving a total inventory of approximately 5428 nuclear warheads (see table 10.2).

These estimates are based on publicly available information regarding the US nuclear arsenal and SIPRI estimates.[1] In 2010 the USA for the first time declassified the entire history of its nuclear weapon stockpile size.[2] Both the annual US stockpile size and the annual number of dismantled warheads were declassified every subsequent year. However, the administration of President Donald J. Trump halted this transparency process in 2019, refusing to disclose any numbers for 2018–19.[3] In 2021 the administration of President Joe Biden restored nuclear transparency by declassifying both numbers for the entire history of the US nuclear arsenal until September 2020.[4] This effort revealed that the US nuclear stockpile consisted of 3750 warheads in September 2020, 3805 warheads in 2019 and 3785 warheads in 2018.[5] The US stockpile is expected to continue to decline gradually over the next decade as nuclear modernization programmes consolidate some nuclear weapon types.

In 2021 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.[6] The most recent data exchange, on 1 September 2021, listed the USA deploying 1389 warheads attributed to 665 ballistic missiles and heavy

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

[2] See e.g. US Department of Defense, 'Increasing transparency in the US nuclear weapons stockpile', Fact sheet, 3 May 2010.

[3] Kristensen, H. M., 'Trump administration again refuses to disclose nuclear stockpile size', FAS Strategic Security Blog, Federation of American Scientists, 3 Dec. 2020.

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

[5] US Department of State (note 4).

[6] For a summary and other details of New START see annex A, section III, in this volume. On the negotiation of the renewal of New START see chapter 11, section I, in this volume.

Table 10.2. United States nuclear forces, January 2022

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 300 kt	200[k]
Sea-based missiles (SLBMs)		*14/280*[l]				*1 920*[m]
UGM-133A Trident II D5(LE)						
	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 (NATO)	. .	1985	3 200	2 x B61-3, -4	30
PA-200	Tornado (NATO)	. .	1983	2 400	2 x B61-3, -4	30
Total stockpile						**3 708**[r]
Deployed warheads						1 744
Reserve warheads						1 964
Retired warheads awaiting dismantlement						**1 720**[s]
Total inventory						**5 428**[t]

. . = not available or not applicable; – = nil or a negligible value; ALCM = air-launched cruise missile; ICBM = intercontinental ballistic missile; kt = kiloton; NATO = North Atlantic Treaty Organization; 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 air bases.

[c] Approximately 1644 of these strategic warheads 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–US Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START) because the treaty attributes one 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 about 50 are deployed (45 were counted as deployed under New START as of Sep. 2021), with the remaining aircraft in overhaul.

[e] The estimate of *c*. 788 warheads assigned to strategic bombers is a decrease from the estimate of *c*. 848 warheads in *SIPRI Yearbook 2021*. The decrease is not the result of a recent retirement of weapons but of a reassessment of the number of warheads that are assigned to the bombers. 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 in the early 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 Subcommittee on Strategic Forces, US Senate Armed Services Committee, 28. Mar. 2007, p. 7. Since then, the number has probably decreased gradually to around 500 as some missiles and warheads have probably been taken out of service and not been replaced.

[h] Strategic gravity bombs are assigned to B-2A bombers only. The maximum yields of strategic bombs are 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 W78 replacement warhead (W87-1) programme.

[l] The first figure is the total number of nuclear-powered ballistic missile submarines (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 or 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*. 944 were deployed on submarines as of Sep. 2021; all the rest were in central storage. Although each D5 missile was counted under the 1991 Strategic Arms Reduction Treaty 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 two of the SSBNs on patrol in the Atlantic and Pacific oceans.

[p] Approximately 100 of the 200 tactical bombs are thought to be deployed across six NATO air bases outside the USA. The remaining bombs were in central storage in the USA. Older B61 versions will be dismantled once the B61-12 is deployed. The maximum yields of tactical 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] Of these 3708 weapons, *c*. 1744 were deployed on ballistic missiles, at bomber bases in the USA and at six NATO air bases outside the USA; all the rest were in central storage.

[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 restored transparency in 2021, 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 1720 warheads in the dismantlement queue.

[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 communications with officials; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and the authors' estimates.

bombers.[7] The numbers of deployed warheads presented here differ from the numbers reported under New START because the treaty attributes one 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.

The role of nuclear weapons in US military doctrine

According to the 2018 Nuclear Posture Review (NPR), 'The United States would only consider the employment of nuclear weapons in extreme circumstances to defend the vital interests of the United States, its allies, and partners.'[8] The NPR further clarifies that the USA reserves the right to first use of nuclear weapons in a conflict, and could use nuclear weapons in response to 'significant non-nuclear strategic attacks' on 'the US, allied, or partner civilian population or infrastructure, and attacks on US or allied nuclear forces, their command and control, or warning and attack assessment capabilities'.[9]

The USA under the Biden administration continued to implement the 2018 NPR throughout 2021, including several large-scale nuclear weapon programmes initiated under the administration of President Barack Obama and accelerated and expanded by the Trump administration, which cover modernization programmes for all three legs of the nuclear triad (see 'Strategic nuclear forces' below).

The 2018 NPR's justification for the development of two nuclear 'supplements'—the W76-2 low-yield warhead and a nuclear sea-launched cruise missile (SLCM-N)—reflected important doctrinal changes in US nuclear

[7] US Department of State, 'Notification containing data for each category of data contained in part two of the protocol', 1 Sep. 2021, retrieved by request from the US Department of State, Bureau of Arms Control, Verification and Compliance, 26 Jan. 2022.

[8] US Department of Defense (DOD), *Nuclear Posture Review 2018* (DOD: Arlington, VA, Feb. 2018), p. 21.

[9] US Department of Defense (note 8), p. 21.

planning. According to the NPR, the W76-2 is intended to provide the USA with a prompt low-yield capability aimed at deterring Russia from what the NPR suggested was a greater willingness to use nuclear weapons first—an alleged doctrinal shift that independent experts have questioned.[10] Both the W76-2 and SLCM-N appear intended to restrengthen US non-strategic nuclear weapon capabilities, which had reduced in importance for the US military since the end of the cold war. This included, according to the NPR, the option of responding to non-nuclear strategic attacks, which would constitute first use of nuclear weapons—the very act that the NPR criticizes Russia for including in its alleged doctrine.[11]

Strategic nuclear forces

US offensive strategic nuclear forces include heavy bomber aircraft, land-based intercontinental ballistic missiles (ICBMs) and SSBNs. These forces, together known as the triad, changed little during 2021.[12] SIPRI estimates that a total of 3508 nuclear warheads were assigned to the triad, of which an estimated 1644 warheads were deployed on ballistic missiles and at heavy bomber bases.

Aircraft and air-delivered weapons

As of January 2022, the US Air Force (USAF) operated a fleet of 152 heavy bombers: 45 B-1Bs, 20 B-2As and 87 B-52Hs.[13] Of these, 66 (20 B-2As and 46 B-52Hs) were nuclear-capable and 45 (11 B-2As and 34 B-52Hs) were counted as deployed under New START as of 1 September 2021.[14] 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

[10] US Department of Defense (note 8), pp. 8, 53–55. See also e.g. Ven Bruusgaard, K., 'Here's why US tactical nukes are a bad idea', *National Interest*, 10 Dec. 2018; Oliker, O. and Baklitskiy, A., 'The Nuclear Posture Review and Russian "de-escalation": A dangerous solution to a nonexistent problem', War on the Rocks, 20 Feb. 2018; and Oliker, O., 'Russia's nuclear doctrine: What we know, what we don't, and what that means', Center for Strategic and International Studies (CSIS), 5 May 2016.

[11] 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)', *Arms Control and International Security Papers*, vol. 1, no. 11 (23 July 2020), p. 3; and US Department of Defense (note 8), p. xiii. For further detail on the Nuclear Posture Review see Kristensen, H. M., 'US nuclear forces', *SIPRI Yearbook 2019*.

[12] The reduction in bomber weapons compared with *SIPRI Yearbook 2021* is not the result of new cuts but of new stockpile numbers causing a reassessment of the estimate.

[13] In Sep. 2021 the US Air Force retired 17 B-1B heavy bombers; the remaining 45 B-1Bs will be decommissioned once the B-21 enters service in the mid 2020s.

[14] US Department of State (note 7).

delivery on relatively short notice.[15] Both the B-2As and B-52Hs are currently undergoing modernization intended to improve their ability to receive and transmit secure nuclear mission data.[16]

The development of the next-generation long-range strike bomber, known as the B-21 Raider, was well under way by the end of 2021 and the first two test aircraft were being constructed.[17] In July 2021 the USAF released its visual rendering of the B-21, indicating a flying-wing design similar to that of the B-2, along with a fact sheet noting that the B-21 would eventually be able to conduct uncrewed operations.[18] The B-21 will be capable of delivering two types of nuclear weapon: the B61-12 guided nuclear gravity bomb, which is scheduled to begin full-scale production in May 2022 and is also designed to be deliverable from shorter-range non-strategic aircraft (see below); and the long-range standoff weapon (LRSO) ALCM, which is in development. In June 2021 the acting administrator of the National Nuclear Security Administration (NNSA) noted in US Senate testimony that the W80-4 warhead—being developed for the LRSO—would probably be delayed due to the ongoing Covid-19 pandemic, and the first production unit was not expected until US financial year 2025.[19]

The B-21 is scheduled to enter service in the mid 2020s. At the end of 2021, six were in production, with roll-out and first flight expected in mid 2022.[20] The new bomber will replace the B-1B bombers—which are not nuclear-capable—at Dyess Air Force Base (AFB) in Texas and Ellsworth AFB in South Dakota. This, along with the reinstatement of nuclear-weapon storage capability at Barksdale AFB in Louisiana, will result in the number of US bomber bases with such capability increasing from two in 2021 to five by the early 2030s.[21] In June 2021 the USAF announced that Ellsworth AFB would

[15] The estimate of *c.* 788 warheads assigned to strategic bombers is a decrease from the estimate of *c.* 848 warheads in *SIPRI Yearbook 2021*. The decrease is not the result of a recent retirement of weapons but of a reassessment of the number of warheads that are assigned to the bombers.

[16] US Department of Defense (DOD), *Fiscal Year (FY) 2021 Budget Estimates: Air Force: Justification Book*, vol. 3a, Research, Development, Test & Evaluation, Air Force, vol. III, part 1 (DOD: Arlington, VA, Feb. 2020), pp. 109–82, 203–21.

[17] Tirpak, J., 'Second B-21 under construction as bomber moves toward first flight', *Air Force Magazine*, 15 Jan. 2021.

[18] US Air Force, US Secretary of the Air Force Public Affairs, 'Air Force releases new B-21 Raider artist rendering', Press release, 6 July 2021; and US Air Force, 'B-21 Raider', Fact sheet, 6 July 2021.

[19] Verdon, C., Statement, US Senate Armed Services Committee hearing on Department of Energy and National Nuclear Security Administration on Atomic Energy Defense Activities in Review of the Defense Authorization Request for Fiscal Year 2022 and the Future Years Defense Program, 24 June 2021; and 'NNSA assessing Covid-related delays to warhead refurbs; results in spring', Exchange Monitor, 8 Feb. 2022.

[20] Hadley, G., 'Six B-21s in production, fuel control software already tested', *Air Force Magazine*, 9 Feb. 2022.

[21] Dawkins, J. C., Commander, 8th Air Force and Joint-Global Strike Operations Center, Barksdale AFB, '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.

be the first base to receive the B-21.[22] The USAF plans to acquire at least 100 (but possibly as many as 145) B-21 bombers by the mid 2030s.[23] However, funding decisions made by the US Congress will determine the final number.

Land-based missiles

As of January 2022, the USA deployed 400 Minuteman III ICBMs in 450 silos across three missile wings, with the 50 empty silos kept in a state of readiness for reloading with stored missiles if necessary.[24] Each Minuteman III ICBM was armed with either a 335-kiloton W78 or a 300-kt W87 warhead. Missiles carrying the W78 can be uploaded with up to two more warheads for a maximum of three multiple independently targetable re-entry vehicles (MIRVs). ICBMs with the W87 can only be loaded with one warhead. SIPRI estimates that there are 800 warheads assigned to the ICBM force, of which 400 are deployed on the missiles.[25]

The USAF has scheduled its next-generation ICBM, the Ground Based Strategic Deterrent (GBSD) weapon system, to begin replacing the Minuteman III in 2028, with full replacement by 2036.[26] Each GBSD will be able to carry up to two W87 or W87-1 MIRVs (see below)—for a maximum of 800 warheads across all GBSDs—but will probably carry only one warhead under normal circumstances. The USAF is expected to conduct its first flight test of the system in 2023.[27] The projected cost of the programme has continued to increase and the absence of competition in the bidding process for the contract may have eliminated any potential to make savings up front.[28] In May 2021 the US Congressional Budget Office (CBO) estimated that the cost of acquiring and maintaining the ICBMs would total approximately $82 billion over the 10-year period 2021–30, approximately $20 billion more than the CBO had previously estimated for the period 2019–28.[29] The cost is

[22] Cisneros, M., 'AFCEC leads bed-down efforts for B-21 Raider stealth bomber', Ellsworth Air Force Base, Press release, 22 Nov. 2021.

[23] Tirpak, J. A., 'A new bomber vision', *Air Force Magazine*, 1 June 2020.

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

[25] For further detail on the warheads and yields see Kristensen, H. M. and Korda, M., 'US 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. For further detail on the GBSD see Kristensen and Korda (note 25), p. 341.

[27] Tirpak, J., 'New GBSD will fly in 2023; no margin left for Minuteman', *Air Force Magazine*, 14 June 2021. The requirements for reaching initial operating capability are deploying 20 GBSD missiles loaded with legacy W87-0/Mk21 warheads and re-entry vehicles, upgrading 20 Minuteman III launch facilities to GBSD standards, and operationally certifying 3 GBSD launch control centres and 1 integrated command centre.

[28] Reif, K., 'New ICBM replacement cost revealed', *Arms Control Today*, vol. 47, no. 2 (Mar. 2017); and Burns, R., 'Pentagon estimates cost of new nuclear missiles at $95.8B', AP News, 20 Oct. 2020.

[29] US Congressional Budget Office, 'Projected costs of US nuclear forces, 2021 to 2030', May 2021, p. 10; and US Congressional Budget Office, 'Projected costs of US nuclear forces, 2019 to 2028', Jan. 2019, p. 9.

likely to increase further, which perhaps calls into question the decision not to extend the life of the existing Minuteman III.

The USAF is also modernizing the nuclear warheads that will be used to arm the GBSD.[30] The projected cost of the programme for the replacement warhead, known as the W87-1, is between $11.8 billion and $15 billion, but this estimate does not include costs associated with production of plutonium pits for the warhead (see below).[31] In March 2021 the NNSA completed its review of requirements for the W87-1, a key milestone that allows the programme to progress to the next stage of its development.[32]

Sea-based missiles

The US Navy operates a fleet of 14 Ohio-class SSBNs, of which 12 are normally considered to be operational and 2 are typically undergoing refuelling and overhaul at any given time. Eight of the SSBNs are based at Naval Base Kitsap in Washington state and six at Naval Submarine Base Kings Bay in Georgia.

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 deployable SSBNs can carry no more than 240 missiles.[33] Around 8 to 10 SSBNs are normally at sea, of which 4 or 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 deterrent patrols per year.[34]

The Trident II D5 SLBMs carry two basic warhead types: the 455-kt W88 and the W76, which exists in two versions, the 90-kt W76-1 and the low-yield W76-2.[35] The NNSA has begun modernizing the ageing W88 warhead, and the first production unit for the W88 Alt 370 was completed on 1 July 2021.[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, of which about 944 were deployed on missiles.[37]

[30] For further detail on the GBSD see Kristensen and Korda (note 25), pp. 341–42.

[31] US Department of Energy, National Nuclear Security Administration (NNSA), *Fiscal Year 2021 Stockpile Stewardship and Management Plan: Biennial Plan Summary*, Report to Congress (NNSA: Washington, DC, Dec. 2020), pp. 5-32, 5-33.

[32] Sirota, S., 'NNSA completes requirements review of GBSD's W87-1 warhead', Inside Defense, 22 Apr. 2021.

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

[34] 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.

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

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

[37] US Department of State, Bureau of Arms Control, Verification and Compliance, 'New START Treaty aggregate numbers of strategic offensive arms', Fact sheet, 1 Dec. 2020.

The newest warhead, the low-yield W76-2, was first deployed in late 2019 on USS *Tennessee* (SSBN-734), which patrols the Atlantic Ocean, 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 about 8 kt.[39]

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'), with the upgrade scheduled for completion in 2024.[40] In 2021 the US Navy conducted several flight tests of the D5LE SLBM, which is equipped with the new Mk6 guidance system.[41] The D5LE will arm Ohio-class SSBNs for the remainder of their service lives (up to 2042) and will be deployed on the United Kingdom's Trident submarines (see section III). A new class of SSBN, the Columbia class, will initially also be armed with the D5LE, but from 2039 these will eventually be replaced with an upgraded SLBM, the D5LE2.[42] The first Columbia-class SSBN—USS *Columbia* (SSBN-826)—is scheduled to start patrols in 2031.[43]

To arm the D5LE2, the NNSA has begun early design development of a new nuclear warhead, known as the W93, to complement the W76 and W88 warheads. This would be the first brand-new warhead 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 delivered to the British Royal Navy (see section III). Production of the W93 is scheduled to begin in the mid 2030s.[44]

Warhead production

From the end of the cold war, the USA relied on refurbishment of existing warhead types for its nuclear forces, but since around 2018 it has shifted to an expanded production capacity intended to produce new warheads. This plan depends heavily on the USA's ability to produce new plutonium pits. Whereas production capacity in 2021 was limited (to around 10 plutonium pits per year), the NNSA plans to produce up to 30 pits in 2026 and

[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 communications with the authors, 2019–20.

[40] Wolfe, J., Director of US Strategic Systems Programs, Statement before the Subcommittee on Strategic Forces, US Senate Armed Services Committee, 1 May 2019, p. 4.

[41] US Navy, 'USS Wyoming successfully tests Trident II D5LE missiles', Press release, 18 Sep. 2021.

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

[43] Wolfe (note 42), p. 3.

[44] US Department of Defense, 'W93/Mk7 Navy warhead: Developing modern capabilities to address current and future threats', White paper, May 2020, p. 2. Part of this document is available online. For further detail on this warhead programme see Kristensen and Korda (note 25), p. 343.

at least 80 pits per year by 2030 to meet the demands of the US nuclear modernization programmes.[45] In order to fulfil these objectives, the NNSA is modernizing its plutonium facility (PF-4) at Los Alamos National Laboratory in New Mexico and creating a new plutonium processing facility at Savannah River in South Carolina.[46]

In June 2021 the acting administrator of the NNSA announced to the US Congress what outside experts had long predicted—that the NNSA's goal of producing up to 80 pits per year by 2030 would not be possible.[47] This indicates that some of the aforementioned nuclear weapon programmes will probably face delays or that new delivery systems could be initially deployed with legacy warheads.[48]

Non-strategic nuclear forces

US non-strategic (tactical) nuclear forces include nuclear bombs delivered by several types of short-range fighter-bomber aircraft, as well as potentially a future nuclear-armed SLCM.

Air force weapons

The USA, as of January 2022, 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.[49] An estimated 200 tactical B61 bombs remained in the stockpile.

SIPRI estimates that the USAF has deployed approximately 100 of the B61 bombs for potential use by fighter-bomber aircraft at six air bases in five other member states of the North Atlantic Treaty Organization (NATO): Kleine Brogel in Belgium; Büchel in Germany; Aviano and Ghedi in Italy; Volkel in the Netherlands; and İncirlik in Turkey.[50] The remaining (*c*. 100) B61 bombs

[45] US Department of Energy, 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.

[46] US Department of Energy (note 45).

[47] Demarest, C., 'Plutonium pit production in SC might happen in 2035. The target was 2030', *Aiken Standard*, 12 June 2021. See also e.g. US Government Accountability Office (note 45), p. 5; and Hunter, D. E. et al., 'Independent assessment of the two-site pit production decision: Executive summary', Institute for Defense Analyses document no. NS D-10711, May 2019, p. 4.

[48] US Air Force (USAF), *Report on Development of Ground-Based Strategic Deterrent Weapon*, Report to eight congressional committees (USAF: [Arlington, VA,] May 2020), p. 4. The USAF is already anticipating that the W87-1 will not be completed on time and is therefore planning for the GBSD to reach initial operational capability with legacy warheads.

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

[50] For a detailed overview of the dual-capable aircraft programmes of the USA and its NATO allies see Kristensen (note 11), pp. 299–300; and Andreasen, S. et al., *Building a Safe, Secure, and Credible NATO Nuclear Posture* (Nuclear Threat Initiative: Washington, DC, Jan. 2018).

are thought to be stored at Kirtland AFB in New Mexico for potential use by US aircraft in support of allies outside Europe, including in East Asia.[51] USA-based fighter wings for this mission include the 366th Fighter Wing at Mountain Home AFB in Idaho.[52]

The USA has completed development of the new B61-12 guided nuclear bomb, which will replace all existing versions of the B61 (both strategic and non-strategic). Delivery was scheduled to start in 2020 but production problems in 2019 caused delays; the first production unit was completed in November 2021, and full-scale production is scheduled for May 2022.[53] Certification training by the air forces of the countries where the bombs will be based is likely to begin in 2023. The new version is equipped with a guided tail-kit that enables it to hit targets more accurately, meaning that it can use lower yields against targets and thus generate less radioactive fallout.[54]

Operations to integrate the incoming B61-12 on existing USAF and NATO aircraft continued in 2021. The USAF plans to integrate the B61-12 on seven types of aircraft operated by the USA or its NATO allies: 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).[55] The Tornado's age prevents it from using the B61-12's new guided tail-kit function, and the aircraft will instead deliver the B61-12 as a 'dumb' bomb akin to the older B61-3s and B61-4s.

Germany plans to retire its Tornado aircraft by 2030, and would require a new dual-capable aircraft if it intended to remain part of NATO's nuclear-sharing mission. In November 2021 the incoming coalition government confirmed that its intention was for Germany to remain part of the mission.[56]

Navy weapons

As noted above, the 2018 NPR established a requirement for a new nuclear-armed SLCM—the SLCM-N.[57] In 2019 the US Navy began an 'analysis of alternatives' study for the new weapon, which was reportedly completed in 2021.[58]

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

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

[53] Mehta, A., 'How a $5 part used to modernize nuclear warheads could cost $850 million to fix', *Defense News*, 25 Sep. 2019; and US Department of Energy, National Nuclear Security Administration (NNSA), 'NNSA completes first production unit of B61-12 life extension program', 2 Dec. 2021.

[54] 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.

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

[56] Siebold, S. and Wacket, M., 'Germany to remain part of NATO's nuclear sharing under new government', Reuters, 24 Nov. 2021.

[57] US Department of Defense (note 8), pp. 54–55.

[58] Wolfe (note 42).

The USA eliminated all non-strategic naval nuclear weapons after the end of the cold war. Completion of the SLCM-N would therefore mark a significant change in US Navy strategy.[59] In a leaked memorandum from June 2021, the acting Secretary of the Navy recommended that the SLCM-N be defunded, noting that 'the Navy cannot afford to simultaneously develop the next generation of air, surface, and subsurface platforms and must prioritize these programs balancing the cost of developing next generation capabilities against maintaining current capabilities'.[60] If the Biden administration decides to continue with the programme and the US Congress agrees to fund it, then the new missile could be deployed on attack submarines by the end of the 2020s. This could potentially result in the first significant increase in the size of the US nuclear weapon stockpile since 1996.

[59] Kristensen, H. M., 'Declassified: US nuclear weapons at sea', FAS Strategic Security Blog, Federation of American Scientists, 3 Feb. 2016.

[60] Shelbourne, M. and LaGrone, S., 'SECNAV memo: New destroyer, fighter or sub: You can only pick one; cut nuclear cruise missile', USNI News, 8 June 2021.

II. Russian nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2022, Russia maintained a military stockpile of approximately 4477 nuclear warheads, around 20 fewer than the estimate for January 2021. About 2565 of these were offensive strategic warheads, of which roughly 1588 were deployed on land- and sea-based ballistic missiles and at bomber bases. Russia also possessed approximately 1912 non-strategic (tactical) nuclear warheads. All of the non-strategic warheads are thought to be at central storage sites.[1] An estimated additional 1500 retired warheads were awaiting dismantlement (260 fewer than the estimate for 2021), giving a total inventory of approximately 5977 warheads (see table 10.3).

These estimates are based on publicly available information about the Russian nuclear arsenal and the authors' estimates. Because of a lack of transparency, estimates and analysis of Russia's nuclear weapon developments come with considerable uncertainty, particularly with regard to Russia'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 interviews with military officials.[2]

In September 2021 Russia declared 1458 deployed warheads attributed to 527 strategic launchers, thus remaining in compliance with the final warhead limits prescribed by the 2010 Russian–United States Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START).[3] This treaty places a cap on the numbers of Russian and US deployed strategic nuclear forces. The numbers of deployed warheads presented here differ from the numbers reported under New START because the treaty attributes one weapon to each deployed bomber, even though bombers do not carry weapons under normal circumstances. Additionally, the treaty does not count weapons in storage 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.

[1] For an overview of Russia's nuclear weapon storage facilities see Podvig, P. and Serrat, J., *Lock Them Up: Zero-deployed Non-strategic Nuclear Weapons in Europe* (United Nations Institute for Disarmament Research: Geneva, 2017).

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

[3] US Department of State, Bureau of Arms Control, Verification and Compliance, 'New START Treaty aggregate numbers of strategic offensive arms', Fact sheet, 1 Sep. 2021. For a summary and other details of New START see annex A, section III. On the negotiation of the renewal of New START see chapter 11, section I, in this volume.

Table 10.3. Russian nuclear forces, January 2022

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	**516**				**2 565**[c]
Aircraft (bombers)	*68*[d]				*580*[e]
Tu-95MS6/16/M (Bear-H)[f]	55	1984/ 2015	6 500– 10 500	6–16 x 200 kt AS-15A or AS-23B ALCMs	448
Tu-160/M/M2 (Blackjack)	13	1987/ 2021	10 500– 13 200	12 x 200 kt AS-15A or AS-23B ALCMs, bombs	132
Land-based missiles (ICBMs)	*306*				*1 185*[g]
RS-20V Voevoda (SS-18 Satan)	40	1988	11 000– 15 000	10 x 500–800 kt	400[h]
RS-18 (SS-19 Stiletto)	0	1980	10 000	6 x 400 kt	0[i]
Avangard (SS-19 Mod 4)[j]	6	2019	10 000	1 x HGV	6
RS-12M Topol (SS-25 Sickle)	9[k]	1988	10 500	1 x 800 kt	9
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)	153	2010	10 500	[4 x 250 kt]	612[l]
RS-24 Yars (SS-27 Mod 2/silo)	20	2014	10 500	4 x [250 kt]	80
RS-28 Sarmat (SS-X-29)	. .	[2022]	>10 000	[10 x 500 kt]	–
Sea-based missiles (SLBMs)	*10/160*[m]				*800*[n]
RSM-50 Volna (SS-N-18 M1 Stingray)	0/0	1978	6 500	3 x 50 kt	0[o]
RSM-54 Sineva/Layner (SS-N-23 M2/3)	5/80	2007/ 2014	9 000	4 x 100 kt[p]	320[q]
RSM-56 Bulava (SS-N-32)	5/80	2012	>8 050	[6 x 100 kt]	480[r]
Non-strategic nuclear forces					**1 912**[s]
Navy weapons	. .				*935*
Submarines/surface ships/naval aircraft	. .	Land-attack cruise missiles, sea-launched cruise missiles, anti-submarine weapons, surface-to-air missiles, depth bombs, torpedoes[t]			935
Air force weapons	*260*				*500*
Tu-22M3 (Backfire-C)	60	1974	. .	3 x ASMs, bombs	300
Su-24M/M2 (Fencer-D)	70	1974	. .	2 x bombs	70[u]
Su-34 (Fullback)	120	2006	. .	2 x bombs	120[u]
Su-57 (Felon)	–	[2024]	. .	[bombs, ASMs]	. .
MiG-31K (Foxhound)	10	2018	. .	1 x ALBM	10

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	*886*				*387*
53T6 (SH-08, Gazelle)	68	1986	30	1 x 10 kt	68
S-300/400 (SA-20/21)	750[v]	1992/ 2007	. .	1 x low kt	290
3M55/P-800 Oniks (SS-N-26 Strobile), 3K55/K300-P Bastion (SSC-5 Stooge)	60	2015	>400	1 x [10–100 kt]	25
SPU-35V Redut (SSC-1B Sepal)	8[w]	1973	500	1 x 350 kt	4
Army weapons	*164*				*90*
9K720 Iskander-M (SS-26 Stone), 9M728 Iskander-K (SSC-7 Southpaw)	144	2005	350	1 x [10–100 kt]	70[x]
9M729 (SSC-8)	20	2016	2 350	1 x [10–100 kt]	20[y]
Total stockpile					**4 477**
Deployed warheads					1 588
Reserve warheads					2 889
Retired warheads awaiting dismantlement					**1 500**
Total inventory					**5 977**

. . = data 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 air bases.

[c] Approximately 1588 of these strategic warheads 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 one 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 about 50 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 more than 800 nuclear weapons but, given that only some of the bombers are fully operational, SIPRI estimates that only about 580 weapons have been assigned to the long-range bomber force, of which approximately 200 might be deployed and stored at the two strategic bomber bases. The remaining weapons are thought to be in central storage facilities.

[f] There are two types of Tu-95MS aircraft: the Tu-95MS6, which can carry 6 AS-15A missiles internally; and the Tu-95MS16, which can carry an additional 10 AS-15A missiles externally, for a total of 16 missiles. Both types were being modernized in 2021. The modernized aircraft (Tu-95MSM) can carry 8 AS-23B missiles externally and possibly 6 internally, for a total of 14 missiles.

[g] These ICBMs can carry a total of 1185 warheads, but SIPRI estimates that they have had their warhead load reduced to approximately 812 warheads, with the remaining warheads in storage.

[h] It is possible that, as of Jan. 2022, the RS-20Vs carried only five warheads each to meet the New START limit for deployed strategic warheads. It is also possible that one of the four RS-20V regiments started an upgrade in late 2021 to convert to the Avangard.

[i] It is possible 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] It is possible that one regiment at Barnaul, Altai krai, has not yet completed upgrade to RS-24. In 2021 one additional regiment at Yurya, Kirov oblast, had nine RS-12M launchers and was expected to upgrade to the RS-24 in 2022; however, the regiment served a back-up launch transmission function and was not nuclear-armed. Therefore, it is not included in this table.

[l] Two more road-mobile regiments were being upgraded from RS-12M to RS-24. It is possible that, as of Jan. 2022, the RS-24s carried only three warheads each to meet the New START limit on deployed strategic warheads.

[m] 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 10 operational SSBNs in 2021, 1 or 2 were in overhaul at any given time and did not carry their assigned nuclear missiles and warheads (see note n).

[n] 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, one or two SSBNs were in overhaul and did not carry nuclear weapons. Therefore, it is estimated here that only around 576 of the 800 SLBM warheads have been deployed.

[o] The last remaining Delta III-class SSBN was converted to an attack submarine in mid 2021. Therefore, it no longer carries the RSM-50.

[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. In 2006 US intelligence estimated that the 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.

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

[r] It is possible that, as of Jan. 2022, Bulava SLBMs carried only four warheads each for Russia to meet the New START limit on deployed strategic warheads.

[s] 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.

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

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

[v] As of Jan. 2022, 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.

[w] 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. 2022.

[x] 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'.

[y] This figure assumes that there are five 9M729 battalions, each with four launchers, for a total of 80 missiles. Each launcher is assumed to have at least one 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 about 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), *Nuclear Posture Review 2018* (DOD: Arlington, VA, Feb. 2018); DOD, *2019 Missile Defense Review* (DOD: Arlington, VA, 2019); US Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020* (DOD: Arlington, VA, 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 role of nuclear weapons in Russian military doctrine

Russia's 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'.[4] This formulation is largely consistent with previous public iterations of Russian nuclear policy, despite US allegations of a shift towards greater reliance on potential first use of nuclear weapons (see section I).[5]

Strategic nuclear forces

As of January 2022, Russia had an estimated 2565 warheads assigned for potential use by strategic launchers: long-range bombers, land-based intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs). This is a decrease of approximately 20 warheads compared with January 2021, due to fluctuations in the arsenal caused by the gradual replacement of some heavy ICBMs with newer ICBMs that carry fewer warheads, as well as the dismantlement of two SSBNs.

[4] 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.

[5] US Department of Defense (DOD), *Nuclear Posture Review 2018* (DOD: Arlington, VA, Feb. 2018), p. 30.

Aircraft and air-delivered weapons

As of January 2022, Russia's Long-Range Aviation command operated a fleet of approximately 68 operational heavy bombers, comprising 13 Tu-160 (Blackjack) and 55 Tu-95MS (Bear) bombers.[6] Not all of these counted as deployed under New START and some were undergoing various upgrades. The maximum possible payload on the bombers is more than 800 nuclear weapons but, since only some 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.[7]

Modernization of the bombers—which includes upgrades to their avionics suites, engines and long-range nuclear and conventional cruise missiles—continued but remained subject to delays.[8] The upgraded Tu-95MS is known as the Tu-95MSM and the upgraded Tu-160 is known as the Tu-160M. The upgraded bombers are capable of carrying the new Kh-102 (AS-23B) nuclear air-launched cruise missile. In his end-of-year defence report, President Vladimir Putin indicated that four Tu-95MS aircraft were upgraded in 2021 and delivery of two Tu-160Ms was scheduled for 2022.[9] It seems likely that all of the Tu-160s and most of the Tu-95s will eventually be upgraded to maintain a bomber force of perhaps 50–60 operational aircraft. Russia has also resumed production of the Tu-160M airframes to produce at least 10 brand-new Tu-160M2 bombers with new engines and advanced communications suites.[10] The maiden flight of the first Tu-160M2 was initially expected in late 2021, but was delayed until January 2022.[11]

The modernized Tu-95MSM, Tu-160M and Tu-160M2 bombers are intended to be only a temporary bridge to Russia's next-generation bomber: the PAK-DA. This is a subsonic aircraft whose flying-wing design may look similar to that of the USA's B-2 bomber. Construction of the first PAK-DA's cockpit reportedly began in May 2020, with final assembly of the first aircraft postponed from 2021 to 2023, and serial production expected to begin in

[6] 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).

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

[8] President of Russia, 'Meeting with workers of Gorbunov Kazan aviation factory and Tu-160M pilots', 25 Jan. 2018.

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

[10] 'Tu-160M2, Tu-22M3M bombers to get communications suite from latest Su-57 fighter', TASS, 12 Aug. 2020.

[11] 'First newly-built Tu-160M to make maiden flight in 4th quarter of 2021', TASS, 30 Dec. 2020; and United Aircraft Corporation (@UAC_Russia_eng), 'Today, the first newly manufactured strategic missile carrier Tu-160M performed its maiden flight from the airfield of the Kazan Aviation Plant. The flight took place at an altitude of 600 meters and lasted about 30 minutes', Twitter, 12 Jan. 2022.

2028 or 2029.[12] The PAK-DA will eventually replace all Tu-95s and Tu-160s as well as the Tu-22s deployed with non-strategic forces (see below).[13]

Land-based missiles

As of January 2022, Russia's Strategic Rocket Forces (SRF)—the branch of the armed forces that controls land-based ICBMs—consisted of 12 missile divisions grouped into 3 armies, deploying an estimated 306 ICBMs of different types and variations (see table 10.3).[14] These ICBMs can carry a maximum of about 1185 warheads, but SIPRI estimates that they have had their warhead load reduced to around 812 warheads, to keep Russia below the New START limit for deployed strategic warheads. These ICBMs carry approximately half of Russia's estimated 1588 deployed strategic warheads.

At the end of 2021, Russia's ICBM force was most of the way through a significant modernization programme to replace all Soviet-era missiles with new types. The missiles will not be replaced on a one-for-one basis, meaning that Russia will probably have fewer missiles after the modernization is completed. The programme also involves substantial reconstruction of silos, launch control centres, garrisons and support facilities.[15] The modernization programme, which began in the late 1990s, appears to be progressing more slowly than previously envisioned. In December 2021 Colonel General Sergey Karakaev, commander of the SRF, stated that around 83 per cent of the ICBM force had been modernized, which is significantly lower than the goal announced in 2014 of 97 per cent of modernization completed by the end of 2020.[16] In November 2020 the chief designer of the RS-24 Yars (SS-27 Mod 2) missile suggested that the last Soviet-era ICBM would be phased out by 2024.[17] However, this seems unlikely based on SIPRI's assessment of the probable time frame for replacing the RS-20V (SS-18) (see below).

The bulk of the modernization programme has focused on the RS-24 Yars, a version of the RS-12M1/2 Topol-M (SS-27 Mod 1) deployed with multiple independently targetable re-entry vehicles (MIRVs). In December 2020

[12] '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; and Lavrov, A., Kretsul, R. and Ramm, A., [PAKage agreement: The latest bomber assigned a deadline for production], *Izvestia*, 14 Jan. 2020 (in Russian).

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

[14] One of these ICBM divisions, the 40th missile regiment at Yurya, Kirov oblast, was being modernized alongside the rest of the ICBM force; however, the regiment's ICBMs are believed to serve as back-up launch code transmitters and therefore have not been armed with nuclear weapons.

[15] See e.g. Kristensen, H. M., 'Russian ICBM upgrade at Kozelsk', FAS Strategic Security Blog, Federation of American Scientists, 5 Sep. 2018.

[16] [Russia's indisputable argument], Interview with Karakaev, S. V. (Col. Gen.), *Krasnaya Zvezda*, 17 Dec. 2021 (in Russian); and 'Russian TV show announces new ICBM to enter service soon', TRK Petersburg Channel 5, 21 Apr. 2014, Translation from Russian, BBC Monitoring.

[17] 'Russia to complete rearming Strategic Missile Force with advanced Yars ICBMs by 2024', TASS, 2 Nov. 2020.

the Russian Ministry of Defence's television channel declared that approximately 150 mobile and silo-based RS-24 ICBMs had been deployed.[18] SIPRI estimates that, as of January 2022, this number had grown to approximately 173 mobile- and silo-based RS-24 missiles, including four completed mobile divisions (Irkutsk, Nizhniy Tagil, Novosibirsk and Yoshkar-Ola), with two more in progress (Barnaul and Vypolzovo—sometimes referred to as Bologovsky).[19] The upgrade to the Barnaul division was scheduled for completion by April 2022, and 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.[20] In addition, one completed mobile division at Teykovo, Ivanovo oblast, was equipped with both the single-warhead RS-12M1 Topol-M (SS-27 Mod 1) and MIRV-equipped RS-24 ICBMs. The first silo-based RS-24s have been installed at Kozelsk, Kaluga oblast; one regiment of 10 silos was completed in 2018, and the second regiment was completed in 2020.[21] In December 2021 Colonel General Karakaev announced that the third regiment at Kozelsk had begun combat duty with new RS-24 ICBMs; however, commercial satellite imagery indicated that the necessary infrastructure upgrades had only been completed at a couple of the regiment's silos.[22] Given how long it took to upgrade the previous two regiments, it is unlikely that the third regiment will be completed by the 2024 target date. 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 its first regiment of six RS-18 (SS-19 Mod 4) missiles equipped with the Avangard hypersonic glide vehicle (HGV) system.[23] The missiles were installed in former RS-20V silos at Dombarovsky, Orenburg oblast. Russia has been installing Avangard-equipped missiles at a rate of two per year in upgraded complexes with new facilities, fences and Dym-2 perimeter defence systems.[24] Russia plans to install the first two missiles in the second Avangard regiment at Dombarovsky in 2022 or 2023 (construction was already well under way in

[18] Levin, E., [Strategic Rocket Forces commander names the number of Yars complexes entering combat duty], *Krasnaya Zvezda*, 8 Dec. 2020 (in Russian).

[19] Tikhonov, A., [You won't catch them by surprise], *Krasnaya Zvezda*, 28 May 2018 (in Russian); and [The commander of the Strategic Missile Forces announced the completion of the rearmament of the Tagil division], RIA Novosti, 29 Mar. 2018 (in Russian).

[20] [The Barnaul division of the Strategic Missile Forces will be completely re-equipped with the Yars complex in 2022], TASS, 20 Jan. 2022 (in Russian); and authors' estimates.

[21] [Two regiments of the Strategic Rocket Forces will be re-equipped with 'Yars' missile systems in 2021], TASS, 21 Dec. 2020 (in Russian); and authors' assessment based on observation of satellite imagery.

[22] [Russia's indisputable argument] (note 16); and authors' assessment based on observation of satellite imagery.

[23] President of Russia (note 9).

[24] Russia Insight, 'BREAKING! Russia's new top secret "toy" revealed: "Dym" small arms system protects RS-24 Yars ICBMs', YouTube, 21 Dec. 2018.

2021), with the entire regiment's rearmament scheduled for completion by the end of 2027.[25]

Russia has also been developing a new 'heavy' liquid-fuelled, silo-based ICBM, known as the RS-28 Sarmat (SS-X-29), as a replacement for the RS-20V. Like its predecessor, the RS-28 is expected to carry a large number of MIRVs (possibly as many as 10), but some might be equipped with one or more Avangard HGVs. After manufacturing-related delays, full-scale flight testing of the RS-28 was scheduled to begin in early 2022 at the new proving ground at Severo-Yeniseysky, Krasnoyarsk krai, with serial production expected to begin in mid 2022—although this would depend on a successful flight-test programme.[26] In December 2021 Colonel General Karakaev announced that the first RS-28 ICBMs would assume combat duty at the ICBM complex at Uzhur, Krasnoyarsk krai, sometime in 2022.[27] Satellite imagery indicates that, as of January 2022, the regiment's older RS-20Vs had already been removed to prepare for the incoming RS-28 ICBMs.[28]

In December 2021 Karakaev also declared the development of 'a new mobile ground-based missile system'. This could be a reference to the development programme for the future Osina-RV ICBM, which is reportedly derived from the RS-24.[29] It is also possible that Karakaev was referring to Russia's 'Kedr' project, which reportedly includes research and development on next-generation missile systems.[30] The Kedr ICBM will probably be fielded sometime around 2030.

Russia conducted several small- and larger-scale exercises with road-mobile and silo-based ICBMs during 2021. These included combat patrols for road-mobile regiments, simulated launch exercises for silo-based regiments, and participation in command staff exercises.[31]

Sea-based missiles

As of January 2022, the Russian Navy had a fleet of 10 operational nuclear-armed SSBNs. The fleet included five Soviet-era Delfin-class or Project 667BDRM (Delta IV) SSBNs and five (of a planned total of 10) Borei-class or Project 955 (Dolgorukiy) SSBNs. The number of SSBNs is lower

[25] [Russia's indisputable argument] (note 16); and 'Russia's 1st regiment of Avangard hypersonic missiles to go on combat alert by yearend', TASS, 10 Aug. 2021.

[26] President of Russia (note 9); Safronov, I. and Nikolsky, A., [Tests of the latest Russian nuclear missile start at the beginning of the year], *Vedomosti*, 29 Oct. 2019 (in Russian); and Военно-болтовой (@warbolts), [This is not the first time in the course of litigation details are revealed about the progress of the ROC on the creation of advanced weapons. . .], Telegram, 4 Jan. 2022 (in Russian).

[27] [Russia's indisputable argument] (note 16).

[28] Authors' assessment based on observation of satellite imagery.

[29] [Russia's indisputable argument] (note 16); and Военно-болтовой (@warbolts), [The missile system with the index '15P182' is being created by JSC 'Corporation' MIT], Telegram, 15 June 2021 (in Russian).

[30] 'Russia develops new-generation Kedr strategic missiles system', TASS, 1 Mar. 2021.

[31] See e.g. 'Yars ICBM launchers embark on combat patrols in Siberia drills', TASS, 26 July 2021.

than the previous year's estimate because in 2021 Russia's last Kalmar-class or Project 667BDR (Delta III) SSBN was reclassified as a multi-purpose submarine, and one Delfin-class SSBN was withdrawn from the navy to prepare for its disposal in 2022.[32]

The two newest Borei submarines 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.[33] The second Borei-A was delivered to the navy in December 2021, following a test launch of a Bulava SLBM from the vessel in October.[34] The third Borei-A was launched in December 2021, meaning that it is not expected to be delivered to the navy before December 2022.[35] The next four Borei-A SSBNs are scheduled for delivery in the mid to late 2020s; the first two keels were laid in 2015 and 2016, while the last two keels were laid in August 2021.[36] Eventually, five Borei SSBNs will be assigned to the Northern Fleet (in the Arctic Ocean) and five will be assigned to the Pacific Fleet, replacing all remaining Delfin-class SSBNs.[37]

Each of the 10 operational SSBNs can be equipped with 16 ballistic missiles and the Russian SSBN fleet can carry a total of 800 warheads.[38] However, one or two SSBNs are normally undergoing repairs and maintenance at any given time and are 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 576 of the 800 warheads have been deployed.

In 2021 the Russian Navy continued to develop the Poseidon or Status-6 (Kanyon), a long-range, strategic nuclear-powered torpedo intended for future deployment on two new types of special-purpose submarine: (*a*) the K-329 Belgorod or Project 09852—a converted Antei-class or Project 949A (Oscar-II) guided-missile submarine (SSGN)—and (*b*) the Khabarovsk-class

[32] [Guarantor of stability in the Asia-Pacific region], Interview with Dmitriev, V. (Vice Admiral), *Krasnaya Zvezda*, 19 Mar. 2021 (in Russian); and 'Russian Navy to decommission Delta IV-class strategic nuclear-powered submarine in 2022', TASS, 28 Apr. 2021.

[33] Russian Ministry of Defence, [On Russia Day, the newest Borei-A class strategic missile submarine 'Prince Vladimir' was inaugurated into the Navy], 12 June 2020 (in Russian).

[34] Sevmash, [The ceremony of handing over to the Navy of two nuclear submarines 'Prince Oleg' and 'Novosibirsk' took place at Sevmash], 21 Dec. 2021 (in Russian); and Lindemann, I., [Missile submarine 'Prince Oleg' launched 'Bulava' from the White Sea], TV Zvezda, 21 Oct. 2021 (in Russian).

[35] Sevmash, [The ceremony of pulling out of the boathouse of the nuclear submarine 'Generalissimo Suvorov' took place at Sevmash], 25 Dec. 2021 (in Russian).

[36] Sevmash, [Nuclear-powered submarine cruisers 'Dmitry Donskoy' and 'Prince Potemkin' laid down at Sevmash], 23 Aug. 2021 (in Russian).

[37] [Source: Two more 'Borei-A' strategic submarines will be built at 'Sevmash' by 2028], TASS, 30 Nov. 2020 (in Russian).

[38] The Delfin-class or Project 667BDRM (Delta IV) SSBNs carry RSM-54 Sineva/Layner (SS-N-23 M2/3) SLBMs, while the Borei(-A)-class or Project 955(A) SSBNs carry RSM-56 Bulava (SS-N-32) SLBMs. Each RSM-54 can carry up to four warheads, while each RSM-56 can carry up to six warheads. It is assumed that each RSM-56 has had its warhead load reduced to four warheads, to meet New START limits.

or Project 09851 submarine, based on the Borei-class SSBN hull.[39] The Belgorod was originally scheduled for delivery to the navy by the end of 2020 but returned to dry dock in October 2021 following delayed sea trials.[40] The official transfer of the Belgorod to the Pacific Fleet was expected to take place in July 2022.[41] The Belgorod and the Khabarovsk submarines will each be capable of carrying up to six Poseidon torpedoes.[42]

The Russian Navy conducted military exercises with its ballistic missile submarines throughout 2021. Notably, in March 2021 three SSBNs—two Delfin-class vessels and possibly a Borei-class vessel—simultaneously surfaced alongside each other near the North Pole during Russia's Umka-2021 major Arctic exercise.[43]

Non-strategic nuclear forces

There is no universally accepted definition of 'tactical', 'non-strategic' or 'theatre' nuclear weapons. Generally speaking, these terms refer to shorter-range weapons that are not covered by arms control agreements regulating long-range strategic forces.

Different agencies within the US intelligence community have offered varying estimates of Russian non-strategic nuclear weapons. The 2018 US Nuclear Posture Review stated that Russia had 'up to 2000' non-strategic nuclear weapons, while the US Defense Intelligence Agency in 2021 suggested a lower range of '1000 to 2000'.[44] These examples reflect both the degree of uncertainty associated with estimating Russian non-strategic nuclear forces, and the variations in estimates between different US governmental agencies.

SIPRI estimates that, as of January 2022, Russia had approximately 1912 warheads assigned for potential use by non-strategic forces—an unchanged estimate from the previous year. Russia's non-strategic nuclear weapons—most of which are dual-capable, meaning that they can also be

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

[40] ['Poseidon' drone carrier submarine 'Belgorod' to be handed over to the fleet in 2021], TASS, 24 Dec. 2020 (in Russian); and Sutton, H. I., 'The submarine which came in from the cold: Belgorod under cover', Covert Shores, 6 Oct. 2021.

[41] 'Russian Navy to receive special-purpose sub with nuclear-armed drones in summer: Sources', TASS, 26 Jan. 2022.

[42] [Second 'Poseidon' carrier submarine planned to be launched in spring–summer 2021], TASS, 6 Nov. 2020 (in Russian).

[43] Russian Ministry of Defence, [Integrated arctic expedition of the Russian Navy and the Russian Geographical Society 'Umka-21'], YouTube, 26 Mar. 2021 (in Russian).

[44] US Department of Defense (note 5), p. 53; and Berrier, S., Director, US Defense Intelligence Agency, 'Worldwide threat assessment', Statement for the record, US Senate Armed Services Committee, 26 Apr. 2021.

armed with conventional warheads—are intended for use by ships and submarines, aircraft, air- and missile-defence systems, and army missiles.

Russia's non-strategic nuclear weapons chiefly serve to compensate for perceived weaknesses in its conventional forces, to provide regional attack options, and to maintain overall parity with the total US nuclear force level. There has been considerable debate about the role that non-strategic nuclear weapons have in Russian nuclear strategy, including potential first use.[45]

Navy weapons

The Russian military service that is thought to be assigned the highest number of non-strategic nuclear weapons is the navy, with an estimated 935 warheads for use by land-attack cruise missiles, anti-ship cruise missiles, anti-submarine rockets, depth bombs, and torpedoes delivered by ships, submarines and naval aviation.

The nuclear version of the long-range, land-attack Kalibr submarine-launched cruise missile (SLCM), also known as the 3M-14 (SS-N-30A), is a significant new addition to the navy's stock of weapons.[46] It has been integrated on numerous types of surface ship and attack submarine, including the new Yasen/-M or Project 885/M (Severodvinsk) SSGN.[47] The second boat of this class completed its sea trials in late 2020, hitting a target over 1000 kilometres away with a Kalibr cruise missile, and became operational with the Northern Fleet in 2021.[48] The next Yasen-M SSGN was delivered to the Pacific Fleet in December 2021, indicating that it will probably become operational in 2022.[49]

Other notable navy weapons include the 3M-55 (SS-N-26) SLCM and the future 3M-22 Tsirkon (SS-NX-33) hypersonic anti-ship missile (although

[45] On this debate see e.g. US Department of Defense (note 5), 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*, vol. 97, no. 6 (Nov./Dec. 2018); Stowe-Thurston, A., Korda, M. and Kristensen, H. M., 'Putin deepens confusion about Russian nuclear policy', Russia Matters, 25 Oct. 2018; Tertrais, B., 'Russia's nuclear policy: Worrying for the wrong reasons', *Survival*, vol. 60, no. 2 (Apr. 2018); and Ven Bruusgaard, K., 'The myth of Russia's lowered nuclear threshold', War on the Rocks, 22 Sep. 2017.

[46] 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.

[47] 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.

[48] 'Newest Russian submarine hits target 1000 km away with Kalibr cruise missile', TASS, 23 Nov. 2020; and 'Defense ministry announces Kazan missile-carrying submarine joins Russian Navy', TASS, 7 May 2021.

[49] Manaranche, M., 'Yasen-M class SSGN "Novosibirsk" begins its sea trials', Naval News, 2 July 2021; and Sevmash (note 34).

it is unclear whether the Tsirkon is dual-capable), which will begin serial production and delivery to the navy in 2022.[50]

Air force weapons

The second largest stock of non-strategic nuclear weapons is assigned to the Russian Air Force, which is estimated to have approximately 500 nuclear warheads for use by Tu-22M3 (Backfire-C) intermediate-range bombers, Su-24M (Fencer-D) fighter-bombers, Su-34 (Fullback) fighter-bombers and MiG-31K (Foxhound) attack aircraft.[51] The new Su-57 (Felon) combat aircraft, also known as PAK-FA, is dual-capable, and the first serial production units were delivered in 2020 and 2021.[52]

The MiG-31K is equipped with the new 9A-7760 Kinzhal air-launched ballistic missile, which in 2021 was operational with the Southern Military District and Northern Fleet, and will eventually be integrated into the Western and Central Military Districts by 2024.[53] Russia has also begun introducing the nuclear-capable Kh-32 air-to-surface missile, an upgrade of the Kh-22N (AS-4) used on the Tu-22M3.[54]

Air-, coastal- and missile-defence weapons

The third largest stock of non-strategic nuclear weapons is assigned to Russian air-, coastal- and missile-defence forces, which are estimated to have around 387 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. Russia has also been developing the S-500 air-defence system, which might potentially be dual-capable, but there is no publicly available authoritative information confirming a nuclear role.[55] It is likely that the stock of warheads associated with Russia's air-, coastal- and missile-defence forces will eventually decrease due to the improving capabilities of conventional air-defence interceptors—including

[50] 'Russia's Tsirkon sea-launched hypersonic missile enters final stage of trials: Top brass', TASS, 20 Jan. 2022.

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

[52] D'Urso, S., 'First serial production Su-57 Felon delivered to the Russian Aerospace Forces', *The Aviationist*, 30 Dec. 2020; and Rob Lee (@RALee85), 'Two new "serial" Su-57 fighters (bort red 02 and 52, including RF-81775) photographed in Novosibirsk', Twitter, 3 Feb. 2022.

[53] President of Russia (note 9); 'Russia's upgraded MiG-31 fighters to provide security for Northern Sea Route', TASS, 26 Nov. 2021; and [Add hypersonic: Another military district will be armed with 'Daggers'], *Izvestia*, 7 June 2021 (in Russian).

[54] US Department of Defense (note 5), p. 8.

[55] Podvig, P., 'Missile defense in Russia', Working paper, Federation of American Scientists (FAS), Project on Nuclear Dynamics in a Multipolar Strategic BMD World, May 2017.

the Nudol and Aerostat systems under development in 2021—and the retirement of legacy warheads.

Army weapons

The Russian Army has the smallest stock of non-strategic nuclear weapons, 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 2022, the dual-capable Iskander-M had completely replaced the Tochka (SS-21) SRBM in 12 missile brigades.[56] The 9M728 Iskander-K (SSC-7) GLCM might also be dual-capable.

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.[57] SIPRI estimates that four or five 9M729 battalions have so far been co-deployed with four or five of the Iskander-M brigades. Following President Putin's October 2020 declaration of willingness to impose a moratorium on future 9M729 deployments in European territory, subject to conditions, the Russian foreign ministry in December 2021 published a draft security agreement that included a ban on deployment of Russian and US missiles with ranges previously covered by the now defunct INF Treaty in areas where they could reach the other side's territory.[58]

There have been suggestions that the Russian Army may also have stocks of nuclear artillery shells and landmines, but the publicly available evidence is conflicting.[59]

[56] Authors' assessment based on observation of satellite imagery.

[57] 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*.

[58] 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, Unofficial translation, 17 Dec. 2021. See also Kristensen, H. M. and Korda, M., 'Russian nuclear forces', *SIPRI Yearbook 2020*, p. 356.

[59] E.g. the 2018 US Nuclear Posture Review did not list nuclear artillery shells or landmines, but a statement by former US Department of Defense official Ellen M. Lord before a US Senate subcommittee in May 2019 did mention them. US Department of Defense (note 5); and Lord, E. M., Under Secretary for Acquisition and Sustainment, Statement before the Subcommittee on Strategic Forces, US Senate Armed Services Committee, 1 May 2019, p. 3.

III. British nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2022, the United Kingdom's nuclear weapon inventory consisted of approximately 225 warheads (see table 10.4)—an unchanged estimate from the previous year. This estimate is based on publicly available information on the British nuclear arsenal and conversations with British officials. The authors consider the British government to have generally been more transparent about its nuclear activities than many other nuclear-armed states—for example, by having declared the size of its nuclear weapon inventory in 2010 and the number of warheads it intends to keep in the future. However, the UK has never declassified the history of its inventory or the actual number of warheads it possesses, and in 2021 declared that it will no longer publicly disclose figures for the country's operational stockpile, deployed warheads or deployed missile numbers.[1]

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 . . . NATO [North Atlantic Treaty Organization] Allies'.[3]

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 nuclear-powered ballistic missile submarines (SSBNs) that carry Trident II D5 submarine-launched ballistic missiles (SLBMs).[4] 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.[5] While the second and third SSBNs

[1] British Government, *Global Britain in a Competitive Age: Integrated Review of Security, Defence, Development and Foreign Policy*, CP 403 (HM 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 Topical Backgrounder, 14 June 2021.

[2] British Government, *National Report of the United Kingdom of Great Britain and Northern Ireland, pursuant to Actions 5, 20 and 21 of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) Review Conference 2010 for the 10th NPT Review Conference* (British Ministry of Defence: London, Nov. 2021), p. 9.

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

[4] Mills, C., *Replacing the UK's Strategic Nuclear Deterrent: Progress of the Dreadnought Class*, Briefing Paper no. CBP-8010 (House of Commons Library: London, 2 Mar. 2021), p. 7.

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

Table 10.4. British nuclear forces, January 2022

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 inventory					**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 four SSBNs, one is in overhaul at any given time.

[b] The three 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, approximately 40 are deployed on the single SSBN that is at sea at any given time.

[f] This figure includes *c.* 45 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 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 inventory appears to have remained at approximately 225 warheads throughout the decade 2010–20. The integrated review of security, defence, development and foreign policy undertaken in 2020 and published in early 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.

remain in port and could be put to sea in a crisis, the fourth would probably be unable to deploy because it would be in the midst of extensive overhaul and maintenance.

The UK operates its submarines at a 'reduced alert' level with detargeted missiles, meaning that it could take days—rather than minutes—to fire nuclear missiles in a crisis.[6] This distinguishes British nuclear policy from that of countries such as Russia or the United States, which are postured to launch nuclear missiles at a moment's notice and could be prompted to launch without first receiving a wholly accurate confirmation of an adversarial

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

first strike. In order to command its submarines in the event of a degraded command and control environment, the British government uses a system of pre-written 'letters of last resort' to issue possible retaliatory orders: on a prime minister's first day in office, after being briefed on the precise damage that a Trident missile could cause, the prime minister is expected to offer preplanned instructions regarding the UK's response in the event of a nuclear crisis.[7]

Revisions to British nuclear policy

For approximately 15 years, the British government had been in the process of reducing the number of operationally available warheads and the size of its overall nuclear stockpile, until a sudden policy shift occurred in 2021.

In 2006 the British Ministry of Defence (MOD) announced that the country would be 'reducing the number of operationally available warheads from fewer than 200 to fewer than 160'.[8] By May 2010, the MOD had also reduced the country's overall nuclear stockpile from approximately 240 to 245 warheads in 2006 to no more than 225 warheads.[9]

In October 2010 the British government's strategic defence and security review (SDSR) announced additional plans for reductions: the number of warheads carried by each submarine would be reduced from 48 to 40 and the number of operational missiles on each submarine would also be reduced; the number of operationally available nuclear warheads would be reduced from fewer than 160 to no more than 120; and the overall nuclear stockpile would be reduced from no more than 225 warheads to no more than 180.[10] The 2015 SDSR reaffirmed these planned reductions and announced that the number of operationally available nuclear warheads had already been reduced from fewer than 160 to no more than 120, and that all Vanguard-class SSBNs 'now carr[ied] 40 nuclear warheads and no more than eight operational missiles' (see below).[11]

Despite these reductions and the government's stated intentions about gradually further reducing the overall nuclear stockpile, from 2010 until 2021 the size of the UK's stockpile remained constant at approximately

[7] Norton-Taylor, R., 'Theresa May's first job: Decide on UK's nuclear response', *The Guardian*, 12 July 2016.

[8] British Ministry of Defence, *The Future of the United Kingdom's Nuclear Deterrent*, White Paper, CM 6994 (HM Stationery Office: London, Dec. 2006), p. 8.

[9] British Ministry of Defence, 'Response to Freedom of Information Act request made by Rob Edwards: Ref. 25-03-2013-173601-014', 25 July 2013.

[10] British Government, *Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review*, Cm 7948 (HM Stationery Office: London, 2010), p. 38.

[11] Fallon, M., British secretary of state for defence, 'Statement on nuclear deterrent', *Hansard*, 20 Jan. 2015, column 4WS; and British Government, *National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom*, Cm 9161, (HM Stationery Office: London, 2015), p. 34.

225 warheads. While warheads removed from operationally available service throughout this period were placed into storage, they were not dismantled, contrary to what many analysts believed at the time.[12]

In its integrated review of security, defence, development and foreign policy, published in March 2021, the British government revealed a marked shift in policy by announcing a significant increase to the upper limit of its nuclear stockpile, to up to no more than 260 warheads.[13] British officials clarified that the target of 180 warheads stated in the 2010 and 2015 SDSRs 'was indeed a goal, but it was never reached, and it has never been our cap'.[14] In addition, in its 2021 national report in advance of the planned 2022 10th Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, the British government stated that the 260 number 'is a ceiling, not a target, and it is not our current stockpile number'.[15]

It is unclear what exactly has prompted the UK to reverse decades of gradual disarmament policy. British government officials have offered differing and somewhat vague explanations for the increase in the UK's overall nuclear stockpile, but following the integrated review's publication, Ben Wallace, the British secretary of state for defence, explicitly pointed to improvements in Russia's ballistic missile defence capabilities as one driving factor.[16] It is also possible that raising the limit on its nuclear stockpile could enable the UK to deploy its SSBNs with a full load of Trident missiles and warheads. If the UK intends to increase the size of its nuclear stockpile, this would position the UK with China and Russia as the three members out of the five permanent members of the United Nations Security Council that are increasing the sizes of their nuclear stockpiles.

Nuclear weapon modernization

The UK's lead SSBN, HMS *Vanguard*, entered service in December 1994, while the last submarine in the class, HMS *Vengeance*, entered service in February 2001 with an expected service life of 25 years.[17] The 2015 SDSR stated the government's intention to replace the Vanguard-class submarines with four new SSBNs, known as the Dreadnought class.[18]

[12] British officials, Interviews with the authors, May 2021.

[13] British Government (note 1) p. 76.

[14] Aidan Liddle (@AidanLiddle), the UK's permanent representative to the Conference on Disarmament, 'That cap was maintained in 2015. 180 was indeed a goal, but it was never reached, and it has never been our cap. And by the way, we're talking about ceilings, not targets, or indeed our actual numbers', Twitter, 16 Mar. 2021. This information was also later confirmed by other officials. British officials, Interviews with the authors, May 2021.

[15] British Government (note 2), p. 11.

[16] BBC Politics (@BBCPolitics) '#Marr: Do we need 80 new nuclear weapons? Defence Secretary Ben Wallace: "We need a credible nuclear deterrent"', Twitter, 21 Mar. 2021.

[17] Mills (note 4).

[18] British Government (note 11), para. 4.73.

The new Dreadnought-class submarines were originally expected to begin entering into 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 approximately 37 to 38 years.[19] The UK is participating in 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 D5LE and D5LE2, respectively; the D5LE will function until the early 2060s and the D5LE2 until the mid 2080s.[20]

The warhead carried on the Trident II D5 is called the Holbrook, which is currently being upgraded to accommodate the USA-produced Mk4A re-entry body, in a collaboration between the British MOD's Atomic Weapons Establishment and US nuclear laboratories. British defence officials have suggested that 'the Mk4A programme will not increase the destructive power of the warhead'.[21] However, the Mk4A is equipped with a new fuze system incorporating new technology that significantly increases the system's ability to conduct nuclear strike missions against hardened targets.[22] British defence officials have acknowledged the enhanced capability.[23] According to Nukewatch, a UK-based disarmament group that tracks warhead convoys across the country, it is possible that sufficient Mk4A-upgraded warheads had been produced by the end of 2021 to arm the UK's Vanguard-class SSBNs.[24]

The British government in 2020 announced its intention to replace the Holbrook with a new warhead, which will use the Mk7 aeroshell to be developed for the new US W93 warhead.[25] Although the administration of US President Joe Biden is expected to continue the W93 programme started under the previous administration, British defence officials stated in 2021 that the UK's warhead replacement programme would move forward regardless of the status of the USA's W93 programme.[26]

[19] Mills (note 4).

[20] Mills (note 4).

[21] British Ministry of Defence, 'Defence in the media: 8 June 2016', Defence in the Media blog, 8 June 2016.

[22] Kristensen, H. M., McKinzie, M. and Postol, T., 'How US nuclear force modernization is undermining strategic stability: The burst-height compensating super-fuze', *Bulletin of the Atomic Scientists*, 1 Mar. 2017.

[23] Norton-Taylor, R., 'Trident more effective with US arming device, tests suggest', *The Guardian*, 6 Apr. 2011.

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

[25] Wallace, B., British secretary of state for defence, 'Nuclear deterrent', Written Statement HCWS125, British Parliament, 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 Subcommittee on Strategic Forces, US Senate Armed Forces Committee, 12 May 2021, pp. 6–7. For further detail see Kristensen, H. M. and Korda, M., 'British nuclear forces', *SIPRI Yearbook 2021*.

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

The new Dreadnought-class submarines will have 12 launch tubes—a reduction from the 16 carried by the Vanguard-class (see below). Delivery of the first batch of missile tubes, which are produced in the USA, was initially delayed, but, as of January 2022, all 12 of the tubes required for the first SSBN in the class (HMS *Dreadnought*) had been delivered and were in the process of being integrated into the SSBN's pressure hull.[27] The Dreadnought-class is expected to be significantly stealthier than its predecessor, as a result of its hull design and electric-drive propulsion.[28]

The cost of the Dreadnought programme has been a source of concern and controversy since its inception.[29] In its annual update to the parliament in December 2021, the MOD reported that a total of £10.4 billion ($14.3 billion) had been spent on the programme's concept, assessment and delivery phases as of 31 March 2021—of which £1.9 billion ($2.6 billion) was spent in financial year 2020/21.[30]

Sea-based missiles

The current Vanguard-class SSBNs can each be armed with up to 16 Trident II D5 SLBMs. The UK does not own the missiles, but has purchased the right to 58 Trident SLBMs from a pool shared with the US Navy at the US Strategic Weapons Facility in Kings Bay, Georgia.[31] Previously, under limits set out in the 2010 SDSR and reaffirmed by the 2015 SDSR, when on patrol, the submarines would be armed with no more than 8 operational missiles with a total of 40 nuclear warheads.[32] However, after the 2021 integrated review's policy changes, it is possible that these limits are no longer applicable and that the number of deployed missiles and warheads on each submarine could therefore increase.

[27] British Ministry of Defence, 'The United Kingdom's future nuclear deterrent: The 2021 update to Parliament', 16 Dec. 2021.

[28] Sutton, H. I., 'First submarine to use new stealth technology', Naval News, 3 Nov. 2021; O'Rourke, R., *Navy Columbia (SSBN-826) Class Ballistic Missile Submarine Program: Background and Issues for Congress*, Congressional Research Service (CRS) Report R41129 (US Congress, CRS: Washington, DC, 19 Oct. 2021), p. 41; and O'Rourke, R., *Electric-drive Propulsion for US Navy Ships: Background and Issues for Congress*, Congressional Research Service (CRS) Report RL30622 (US Congress, CRS: Washington, DC, 31 July 2000), pp. 11–12.

[29] Mills (note 4). See also Kristensen and Korda (note 25), p. 361.

[30] British Ministry of Defence (note 27).

[31] Allison, G., 'No, America doesn't control Britain's nuclear weapons', UK Defence Journal, 20 July 2019.

[32] Fallon (note 11); and British Government (note 11), p. 34.

IV. French nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2022, France's nuclear weapon stockpile consisted of about 290 warheads, the same number as in January 2021. 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 10.5). 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]

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, and President Emmanuel Macron has implied that these 'vital interests' could increasingly take on a European dimension.[4] No changes to French military doctrine were announced in 2021.

Nuclear weapon modernization

President Macron has reaffirmed the French government's commitment to the long-term modernization of France's air- and sea-based nuclear deterrent forces.[5] Current plans include the modernization of France's nuclear-powered ballistic missile submarines (SSBNs, or *sous-marins nucléaires lanceurs d'engins*, SNLEs), SLBMs, aircraft and ALCMs (see below). The 2018 Law on Military Planning (Loi de Programmation Militaire, LPM) for

[1] For additional information see Kristensen, H. M. and Korda, M., 'Estimating world nuclear forces: An overview and assessment of sources', SIPRI Topical Backgrounder, 14 June 2021.

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

[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] Macron, E., French President, Speech on the challenges and priorities of defence policy (in French), Toulon, 19 Jan. 2018.

Table 10.5. French nuclear forces, January 2022

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*
M51.2[f]	48[g]	2017	>9 000[h]	4–6 x 100 kt TNO	240
M51.3[i]	–	[2025]	>[9 000]	[up to 6] x [100 kt] TNO	–
Total stockpile					**290**[j]

[ ] = uncertain SIPRI estimate; – = nil or a negligible value; 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 ASMP-A (*air–sol moyenne portée–améliorée*) air-launched cruise missile (ALCM). Most sources report that the ASMP-A has a range of 500–600 kilometres, although some suggest that it might be over 600 km.

[c] The TN81 warhead for the original ASMP had an estimated yield of 300 kt, but the new TNA warhead has a so-called medium energy yield.

[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 four SSBNs, one is in overhaul at any given time.

[f] The last M51.1 missiles were offloaded from *Le Terrible* in late 2020 in preparation for a one-year refuelling overhaul and upgrade to the more advanced M51.2 missile.

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

[h] The M51.2 has a 'much greater range' than 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., Speech, ArianeGroup, Les Mureaux, 14 Dec. 2017; Hollande, F., Speech on nuclear deterrence, Istres Air Base, 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; 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.

2019–25 allocated €37 billion ($43.7 billion) for maintenance and modernization of France's nuclear forces and infrastructure.[6] This is a significant nominal increase on the €23 billion ($30.5 billion) allocated to nuclear forces and associated infrastructure by the LPM for 2014–19.[7]

The 2022 budget of the Ministry of the Armed Forces (France's defence ministry) allocated €5.3 billion ($6.3 billion) to nuclear weapon-related activity, which is €0.3 billion more than in the 2021 budget.[8] France intends to spend a total of €25 billion ($29.5 billion) on nuclear modernization between 2019 and 2023.[9]

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 Air Base 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.[10]

The Rafale aircraft are equipped with medium-range air-to-surface cruise missiles (*air–sol moyenne portée–améliorée*, ASMPA), which are currently being refurbished, with delivery expected in 2022 or 2023.[11] The ASMPA missiles are equipped with a new warhead, the *tête nucléaire aéroportée*

[6] Agence-France Presse, 'Macron promulgue la loi de programmation militaire 2019–2025' [Macron signs the Law on Military Planning for 2019–2025], *Le Figaro*, 13 July 2018; Loi relative à la programmation militaire pour les années 2019 à 2025 [Law on Military Planning for the Years 2019 to 2025], French Law no. 2018-607 of 13 July 2018, *Journal Officiel de la République Française*, 14 July 2018; and Agence-France Presse, 'France to spend 37 bn euros on upgrading nuclear arsenal', France 24, 8 Feb. 2018. The total defence budget approved for the seven-year period was €295 billion ($348 billion). On France's military expenditure see chapter 8, sections I and II, in this volume.

[7] Loi relative à la programmation militaire pour les années 2014 à 2019 [Law on Military Planning for the Years 2014 to 2019], French Law no. 2013-1168 of 18 Dec. 2013, *Journal Officiel de la République Française*, 19 Dec. 2013.

[8] French Ministry of the Armed Forces (MAF), *Projet de loi de finances: Année 2022* [Finance bill: Year 2022] (MAF: Paris, Sep. 2021), p. 43; and Rose, M., 'Amid arms race, Macron offers Europe French nuclear wargames insight', Reuters, 7 Feb. 2020.

[9] 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.

[10] 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 of the French Senate no. 560, 23 May 2017.

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

(TNA), 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.[14] France's Rafale aircraft are also being modernized, and flight trials for the latest F4 configuration with new radars and targeting capabilities began in May 2021.[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 is capable of carrying 16 SLBMs. However, at any given time one SSBN is out of service for overhaul and maintenance work, and is not armed. France has 48 SLBMs in service—enough to equip the three operational SSBNs.

The French Navy (Marine nationale) maintains a continuous at-sea deterrence posture with one SSBN on patrol at all times. It has conducted more than 500 such patrols since 1972.[16]

France's SLBM, the M51, is being upgraded. The first version, the M51.1, was capable of carrying up to six TN-75 warheads in multiple independently targetable re-entry vehicles (MIRVs), each with an explosive yield of 100 kilotons. Over the past several years, the M51.1 has been gradually replaced by the M51.2, an upgraded version with greater range and improved accuracy. With the deployment of the M51.2 on *Le Téméraire* in mid 2020, the only SSBN left to receive this upgrade, *Le Terrible*, began its major refit in late 2020.[17] Thus, the M51.1 had been officially removed from service by early 2021.

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

[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.

[16] French Ministry of the Armed Forces, '500e patrouille d'un sous-marin nucléaire lanceur d'engins' [500th patrol of a nuclear-powered ballistic missile submarine], 12 Oct. 2018.

[17] French Ministry of the Armed Forces and Naval Group, 'Le SNLE *Le Terrible* transféré de l'Île Longue à la base navale de Brest pour son grand carénage' [The SSBN *Le Terrible* transferred from Île Longue to the Brest naval base for its major refit], Press release, 8 Jan. 2021.

The M51.2 is designed to carry a new, stealthier nuclear warhead, the *tête nucléaire océanique* (TNO), which has a reported yield of up to 100 kt.[18] To allow for targeting flexibility, some of the missiles have fewer warheads than others.[19] France has also commenced design work on another upgrade, the M51.3, which will have improved accuracy. The first M51.3 missiles are scheduled to replace their M51.2 predecessors and become operational in 2025.[20]

In April 2021 France conducted a successful test launch of the M51 from the missile testing site near Biscarosse in south-west France; however, the impact area referenced in the notice to mariners was significantly offset from a regular ballistic trajectory.[21] This could potentially indicate that the launch included a test of a manoeuvrable re-entry vehicle or a post-boost capability. This was the 10th test of the M51.

In the LPM for 2019–25, the French government announced that it would produce a third-generation SSBN, designated the SNLE 3G.[22] The programme was officially launched in early 2021.[23] The SNLE 3G will eventually be equipped with a further modification of the M51 SLBM, the M51.4.[24] 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.[25] In 2021 France dismantled its second of five retired SSBNs and plans to complete the deconstruction programme by 2026.[26]

[18] Groizeleau (note 9); 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.

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

[20] 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.

[21] French Ministry of the Armed Forces, 'Succès d'un tir d'essai de missile M51 sans charge militaire', 28 Apr. 2021; and Dr Marco Langbroek (@Marco_Langbroek), 'Navigational Warnings suggest that France will be test-firing an #ICBM from DGA Essais de Missiles near Biscarosse towards Bermuda between Apr 28–May 21. Target area does not fit a simple ballistic trajectory', Twitter, 25 Apr. 2021.

[22] French Ministry of the Armed Forces, 'Projet de loi de programmation militaire, 2019–2025' [Military Planning Bill, 2019–2025], Press kit, Feb. 2018, p. 38.

[23] 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.

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

[25] French Ministry of the Armed Forces (note 23); Groizeleau (note 9); and Mackenzie (note 23).

[26] Naval Group, 'Naval Group starts the deconstruction of a third French nuclear-powered ballistic missile submarine in Cherbourg', News release, 15 Sep. 2021.

V. Chinese nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2022, China maintained an estimated total stockpile of about 350 nuclear warheads. This estimate is higher than the 'low-200' warheads reported in the United States Department of Defense (US DOD) 2020 report to the US Congress; however, the DOD's estimate only referred to 'operational' nuclear warheads and therefore presumably excluded warheads assigned to the newer launchers that were in the process of being fielded.[1] As a result, even though SIPRI's estimate of China's total inventory is the same as for January 2021, the ratio of stockpiled and other stored warheads has changed because additional and new launchers became operational during 2021. These warheads have been assigned to China's operational land- and sea-based ballistic missiles and to nuclear-configured aircraft (see table 10.6). Although it is expected to increase significantly in the next decade, China's nuclear stockpile as at January 2022 remained much smaller than that of either Russia or the USA.

SIPRI's estimate of 350 warheads relies on publicly available information on the Chinese nuclear arsenal.[2] China itself has never declared the size of its nuclear arsenal. Occasionally, Chinese officials reference open-source estimates as a means of discussing China's nuclear weapon programme publicly or in diplomatic negotiations.[3] As a result, many of the assessments here rely on data from the US DOD and must therefore be treated with a degree of caution. For example, in 2021 the US DOD estimated that China 'likely intends to have at least 1000 warheads by 2030'; however, this claim relies on several assumptions about China's future force posture and plutonium production that have not yet been fully realized.[4]

The role of nuclear weapons in Chinese military doctrine

The Chinese government's declared aim is to maintain its nuclear capabilities at the minimum level required for safeguarding national security. The goal is 'deterring other countries from using or threatening to use nuclear

[1] 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: Arlington, VA, 1 Sep. 2020), p. 85.

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

[3] See e.g. Chinese Ministry of National Defense, 'China reiterates it will not join so-called China–US–Russia arms control negotiations', 9 July 2020.

[4] US Department of Defense, *Military and Security Developments Involving the People's Republic of China 2021*, Annual Report to Congress (Office of the Secretary of Defense: Arlington, VA, 3 Nov. 2021), p. 90; 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).

weapons against China'.[5] For decades, China did so with an arsenal of mainly liquid-fuelled land-based ballistic missiles and a few sea-based ballistic missiles, with a small stockpile of gravity bombs available for bombers as a semi-dormant back-up capacity. Since around 2017, China has started to put in place a triad of nuclear forces—solid-fuelled mobile and siloed land-based missiles, nuclear-powered ballistic missile submarines (SSBNs), and bombers with a full, re-established nuclear mission—in order to strengthen its nuclear deterrence and counterstrike capabilities in response to what it sees as a growing threat from other countries.[6]

Despite the continuing growth in the sophistication and size of its nuclear arsenal, there is no official public evidence that the Chinese government has deviated from its long-standing core nuclear policies, including its no-first-use (NFU) policy.[7] Although US officials have publicly and increasingly questioned China's NFU policy in recent years, the US DOD's 2021 report to the US Congress on China's military power acknowledged that 'there has also been no indication that national leaders are willing to publicly attach such additions, nuances, or caveats [to the NFU policy]'.[8]

In April 2021 the commander of US Strategic Command stated before the US Congress that 'increasing evidence suggests China has moved a portion of its nuclear force to a Launch on Warning (LOW) posture and . . . [is] adopting a limited "high alert duty" strategy'.[9] Additionally, in July 2021 an official from the US Department of State noted that 'Since 2017 PLA [the People's Liberation Army] has also conducted exercises involving launch-on-warning, and now has deployed at least one satellite into orbit for its [LOW] posture'.[10]

The Chinese posture has always involved procedures for loading warheads onto launchers in a crisis, but with warheads kept in central storage, separate from their delivery vehicles, during peacetime.[11] The US DOD's 2021 report

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

[6] Fabey, M., 'China on faster pace to develop nuclear triad, according to Pentagon, analysts', Jane's, 3 May 2019; and 'Chinese military paper urges increase in nuclear deterrence capabilities', Reuters, 30 Jan. 2018.

[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] Zhou, L., 'China should "fine-tune" nuclear weapons policy amid US pressure, ex-diplomat says', *South China Morning Post*, 22 Sep. 2021; and US Department of Defense (note 4), pp. 90–91.

[9] Richard, C. A., Commander, United States Strategic Command, Statement before the US Senate Armed Services Committee, 20 Apr. 2021.

[10] Shashank Joshi (@shashj), '. . . PRC is building nuclear reactors and [ENR] facilities, while seeking to portray them as having only civilian purposes. Since 2017 PLA has also conducted exercises involving launch-on-warning, and now has deployed at least one satellite into orbit for its [LoW] posture', Twitter, 29 July 2021.

[11] 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 4), p. 91.

Table 10.6. Chinese nuclear forces, January 2022

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)	20	2009	3 100	1 x bomb	20
H-6N (B-6N)	–	2021	. .	1 x ALBM	–
H-20 (B-20)	–	[2025]	. .	. .	–
Land-based missiles[e]	*398*				*258*
DF-4 (CSS-3)	6[f]	1980	5 500	1 x 3 300 kt	6
DF-5A (CSS-4 Mod 2)	10	1981	12 000	1 x 4 000–5 000 kt	10
DF-5B (CSS-4 Mod 3)	10	2015	13 000	5 x 200–300 kt	50
DF-5C (CSS-4 Mod 4)	. .	[2020s]	13 000	[MIRV]	. .
DF-15 (CSS-6)	. .	1990	600	1 x . .[g]	. .
DF-17 (CSS-22)	36[h]	2020	>1 800	1 x HGV[i]	. .
DF-21A/E (CSS-5 Mod 2/6)	40[j]	2000/2016	>2 100[k]	1 x 200–300 kt	40[l]
DF-26 (CSS-18)	200	2016	4 000	1 x 200–300 kt	20[m]
DF-31 (CSS-10 Mod 1)	6	2006	7 200	1 x 200–300 kt	6
DF-31A/AG (CSS-10 Mod 2)[n]	72	2007/2018	11 200	1 x 200–300 kt	72
DF-41 (mobile version) (CSS-20)	18[o]	2020	12 000	3 x 200–300 kt	54
Sea-based missiles (SLBMs)	*6/72*[p]				*72*
JL-2 (CSS-N-14)	72	2016	>7 000	1 x 200–300 kt	72
JL-3 (CSS-N-X-. .)	. .	[2020s][q]	>10 000	[MIRV]	. .
Total stockpile	**490**				**350**[r]

. . = 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; 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 one warhead per nuclear-capable launcher, except for the MIRV-capable DF-5B, which can carry up to five warheads, and the MIRV-capable DF-41, which is estimated to carry three 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 (one 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 (US DOD) reported in 2018 that the People's Liberation Army Air Force was reassigned a nuclear mission.

[e] China defines missile ranges as short-range, <1000 kilometres; medium-range, 1000–3000 km; long-range, 3000–8000 km; and intercontinental range, >8000 km.

[f] The US DOD's 2021 report to the US Congress still listed the old liquid-fuelled DF-4 as an element of China's fixed intercontinental ballistic missile (ICBM) force, but the DF-4 is generally believed to be in the process of being retired.

[g] 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.

[h] This number is based on the assumption that two DF-17 brigades were operational and up to two more were under preparation as of Jan. 2022.

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

[j] In 2017 the US Air Force's (USAF) National Air and Space Intelligence Center reported that China had 'fewer than 50' Mod 2 launchers. The Mod 6 is thought to be a replacement for the Mod 2.

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

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

[m] The DF-26 is a dual-capable launcher. It is thought that its mission is primarily conventional and that only a few launchers are assigned nuclear warheads. Only one 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.

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

[o] This number assumes two brigades were operational as of Jan. 2022. It is possible that the number of launchers is closer to 24.

[p] 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. Two additional Jin-class (Type 094) SSBNs joined the fleet in 2021 to give a total of six SSBNs.

[q] US officials have suggested that the JL-3 might have already become operational; however, it is thought that the system is intended to arm the future Type 096 SSBN, which will not be ready for several years.

[r] The US DOD's 2021 report to the US Congress stated that the 'operational' stockpile was in the low 200s and increasing. Since then, the DF-41 and two additional submarines have become operational (see notes o and p). Consequently, SIPRI estimates that the total stockpile is larger and includes approximately 350 warheads.

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.

reaffirmed that China 'almost certainly keeps the majority of its nuclear force on a peacetime status—with separated launchers, missiles, and warheads'.[12] A transition to a LOW posture, where space-based sensors could detect an incoming attack before impact, does not necessarily require China to keep

[12] US Department of Defense (note 4), pp. 90–91.

warheads on delivery vehicles under normal circumstances, and doing so would constitute a significant change to the country's long-held nuclear custodial practices. But missile brigades need training to be ready to load the warheads. The US DOD's 2021 report stated that the PLA Rocket Force (PLARF) brigades 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'.[13]

Aircraft and air-delivered weapons

Chinese medium-range bombers have long had a capability of delivering nuclear weapons and were used to conduct more than 12 atmospheric nuclear tests in the 1960s and 1970s. Until 2018, the capability was not fully operational and was probably a back-up contingency mission. As a result, until 2018, SIPRI continued to assess that China maintained a small inventory of gravity bombs for secondary contingency use by Hong-6, or H-6 (B-6) bombers.[14]

In 2018, however, the US DOD reported that the PLA Air Force (PLAAF) was 'newly re-assigned a nuclear mission'.[15] In its 2021 report, the US DOD concluded that China in 2019 had 'signaled the return of the airborne leg of its nuclear triad after the PLAAF publicly revealed the H-6N (B-6N) as its first nuclear-capable air-to-air refuelable bomber', and noted that as of 2020, the H-6N had been operationally fielded.[16] Legacy H-6 bombers did not include an air-to-air refuelling probe, which significantly limited their long-range targeting capability.

Since at least 2015, 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] This missile, which can be carried by the H-6N bomber and is designated as CH-AS-X-13 by the USA, may be a variant of the Dong Feng-21, or DF-21 (CSS-5), medium-range ballistic missile (MRBM), or

[13] US Department of Defense (note 4), pp. 90–91.

[14] 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.

[15] 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: Arlington, VA, 16 May 2018), p. 75.

[16] US Department of Defense (note 4), pp. 55–56.

[17] US Department of Defense (note 4), 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. 37; and Stewart, V. R., Director, US Defense Intelligence Agency, 'Worldwide threat assessment', Statement for the record, US Senate Armed Services Committee, 9 Feb. 2016.

possibly the DF-15.[18] The first base to be equipped with this capability might be Neixiang, Henan province, where an H-6N bomber was observed flying with the possible new ALBM in October 2020.[19] In its 2021 report, the US DOD stated that 'The PRC has possibly already established a nascent "nuclear triad" with the development of a nuclear-capable air-launched ballistic missile . . . and improvement of its ground and sea-based nuclear capabilities', potentially indicating that it assessed the ALBM to be operational.[20] Even so, the 'viability' of the triad would depend on the survivability and capability of each leg.

In addition to the intermediate-range H-6 bomber, the PLAAF has been developing its first long-range strategic bomber, known as the H-20 (B-20), with an anticipated range of at least 8500 kilometres and a stealthy design.[21] The aircraft might be in production within 10 years, according to the US DOD.[22] The US DOD has also suggested that the H-20 will be dual-capable—that is, able to deliver both conventional and nuclear weapons.[23]

Land-based missiles

China's nuclear-capable land-based ballistic missile arsenal has been undergoing significant modernization as China replaces its ageing silo-based, liquid-fuelled missiles with large numbers of new mobile and silo-based, solid-fuelled models.

Intercontinental ballistic missiles

In 2021 commercial satellite imagery revealed that China had started construction of what appeared to be more than 300 new missile silos across at least three distinct fields in northern China.[24] On several separate occasions, different elements of the US government appeared to validate the open-

[18] Wright, T., 'Chinese PLAAF H-6N pictured carrying large missile', International Institute for Strategic Studies, 23 Oct. 2020; and Panda, A., 'Revealed: China's nuclear-capable air-launched ballistic missile', The Diplomat, 10 Apr. 2018.

[19] Lee, R., 'China's Air Force might be back in the nuclear business', The Diplomat, 9 Sep. 2020; and Rod Lee (@roderick_s_lee), 'The video footage of an H-6N with a possible air-launched ballistic missile appears to be taken at this location just outside Neixiang Afld. This corroborates my theory that the 106th bde operates H-6N's and, per the CMPR suggesting nuclear-capable ALBMs, is a nuclear unit', Twitter, 17 Oct. 2020.

[20] US Department of Defense (note 4), p. 90.

[21] US Department of Defense (note 4), p. 85.

[22] US Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020* (US Department of Defense: Arlington, VA, Mar. 2020), figure 1.1, p. 3.

[23] US Department of Defense (note 4), p. 85.

[24] 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.

source assessment that the construction sites were associated with China's missile programme.[25] If China eventually fills each suspected silo site with a single-warhead missile, the number of warheads attributed to China's intercontinental ballistic missile (ICBM) force, estimated at January 2022 as around 190 warheads, could more than double to approximately 450 warheads. If each suspected silo were filled with a missile equipped with three multiple independently targetable re-entry vehicles (MIRVs), this number could rise to approximately 1000 warheads. However, as of January 2022 it was unclear how China 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]

Notably, China's new silo fields are located deeper inside China than any other known ICBM base and are beyond the reach of US conventional cruise missiles. This, combined with the large number of silos, could suggest that one of the main drivers of the construction effort is to reduce the vulnerability of China's nuclear arsenal from long-range conventional strikes.

In its 2021 report to the US Congress, the US DOD estimated that China's operational arsenal included 100 ICBMs, and that the number of warheads on Chinese ICBMs capable of reaching the USA was expected to grow to 200 by 2025.[27] Additionally, the report noted that China appeared to be doubling the number of launchers in some ICBM brigades, although this could be the result of redistributing existing launchers.[28]

The silo-based, liquid-fuelled, two-stage DF-5 (CSS-4) family of missiles—which first entered into service in the early 1980s—were believed to be China's longest-range ICBMs as at the end of 2021. Along with the road-mobile, solid-fuelled, three-stage DF-31A/AG (CSS-10 Mod 2) ICBM and the new solid-fuelled, three-stage DF-41 (CSS-20) ICBM, DF-5s are capable of targeting all of continental USA and Europe.

China is believed to have deployed at least two mobile DF-41 brigades—totalling around 18 launchers—and appeared to be preparing for the

[25] US Strategic Command (@US_Stratcom), 'This is the second time in two months the public has discovered what we have been saying all along about the growing threat the world faces and the veil of secrecy that surrounds it', Twitter, 27 July 2021; Shashank Joshi (@shashj), 'State Dept. told me: "This build-up is deeply concerning, raises questions about the PRC's intent, and reinforces the importance of pursuing practical measures to reduce nuclear risks"', Twitter, 29 July 2021; and US Department of Defense (note 4), pp. 60–62.

[26] Roderick Lee of the United States Air Force's China Aerospace Studies Institute—who disclosed the third Chinese silo complex at Hanggin Banner in Aug. 2021—suggests that circumstantial evidence could indicate that China might consider using some of its new ICBM silos in a conventional strike role. Lee, R., 'A case for China's pursuit of conventionally armed ICBMs', The Diplomat, 17 Nov. 2021.

[27] US Department of Defense (note 4), pp. 60–62.

[28] US Department of Defense (note 4), p. 61; and Decker Eveleth (@dex_eve), 'Ok, this is a bit of an overstatement: TEL garages have doubled at 644, the DF-41 OT&E brigade, possibly indicating ~24 launchers. At other new ICBM units, number of garages has actually gone down, from 12 to 8. Possible the PLARF is redistributing existing DF-31AG launchers', Twitter, 3 Nov. 2021.

integration of additional DF-41 brigades.[29] The US DOD assessed in 2020 and 2021 that China might ultimately plan to deploy the DF-41 in both 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.[30] However, the new silo fields were still only in the early stages of construction in late 2021.[31]

The US DOD's 2021 report states that China has also begun developing a new missile called the DF-27, which could have a range of 5000–8000 km.[32] However, public information about this new missile is scarce and rife with unsubstantiated rumours.

After many years of research and development, China has modified a small number of ICBMs to deliver nuclear MIRVs, apparently to improve the penetration capabilities of its warheads in response to advances in US and, to a lesser extent, Russian and future Indian missile defences. The DF-5B (CSS-4 Mod 3) is a MIRV-capable variant of the DF-5 that can carry up to five warheads, two more than previously assumed.[33] A second variant under development, the DF-5C (CSS-4 Mod 4), can reportedly also deliver multiple warheads. Some US media reports have suggested that it might be capable of carrying up to 10 warheads, but it seems more likely that it will carry a number similar to that of the DF-5B version.[34] There has been speculation that the DF-41 is able to carry 6–10 warheads, but there is significant uncertainty about the actual capability, and it is likely to carry fewer than its maximum capacity in order to maximize range. SIPRI cautiously estimates that the DF-41 carried 3 warheads as at January 2022.

China reportedly conducted two tests of what appeared to be a hypersonic boost-glide system in July and August 2021.[35] According to the US Office of the Director of National Intelligence, at least one test 'flew completely around the world', indicating that the test might have been of an orbital bombardment system.[36] Additionally, the US DOD noted that at least one test fired a missile mid-flight over the South China Sea.[37] Other credible details

[29] US Department of Defense (note 4), p. 62; and Rod Lee (@roderick_s_lee), 'More evidence that 651 Bde has DF-41s: An officer assigned to 651 Bde inspecting a probable 41 TEL in garrison. Known 651 Bde personalities state that in the past few years, the brigade has been swapping out for a new missile that was featured in the 2019 parade', Twitter, 28 Dec. 2021.

[30] US Department of Defense (note 4), p. 62; and US Department of Defense (note 1), p. 56.

[31] Gertz, B., 'Exclusive: China building third missile field for hundreds of new ICBMs', *Washington Times*, 12 Aug. 2021.

[32] US Department of Defense (note 4), p. 62.

[33] US Department of Defense (note 4), p. 61; 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.

[34] Gertz, B., 'China tests missile with 10 warheads', Washington Free Beacon, 31 Jan. 2017.

[35] Sevastopulo, D., 'China conducted two hypersonic weapons tests this summer', *Financial Times*, 20 Oct. 2021. See also chapter 13, section VI, in this volume.

[36] US Office of the Director of National Intelligence (ODNI), *Annual Threat Assessment of the US Intelligence Community* (ODNI: McLean, VA, 7 Feb. 2022), p. 7.

[37] Sevastopulo (note 35).

about this new system are scarce; however, if the initial reporting is accurate, then the system may be intended to counter advances in US missile defences.

Intermediate- and medium-range ballistic missiles

In 2016 the PLARF began the deployment of the dual-capable DF-26 (CSS-18) intermediate-range ballistic missile (IRBM). This missile has an estimated maximum range exceeding 4000 km and can therefore reach targets in India, the South China Sea, and the western Pacific Ocean, including the US strategic base on Guam.[38] The missile is equipped with a manoeuvrable re-entry vehicle (MaRV) that can be swapped with another warhead at a rapid pace, thus theoretically allowing 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—at the last minute.[39] The majority of the DF-26s are thought to serve a conventional mission with a smaller number assigned a nuclear role. In its 2021 report, the US DOD noted that: 'The DF-26 is the PRC's first nuclear-capable missile system that can conduct precision strikes, and therefore, is the most likely weapon system to field a lower-yield warhead in the near-term.'[40] It remains unclear, however, whether low-yield options have been produced for China's nuclear forces.

China appears to be producing the DF-26 in significant numbers, and in 2021 the US DOD estimated that China might have up to 200 launchers and 300 missiles in its inventory, although SIPRI estimates that only a small number of those have a nuclear role.[41] The launcher number might also be on the higher end of an estimated range and could also include launchers in production as of January 2022. There were sightings of the missile at several PLARF brigade bases during 2021, and PLARF brigades conducted several exercises that featured multiple waves of missile strikes, reloads and relocations.[42]

The US DOD's 2021 report indicated a sizable increase in China's MRBM force, from 150 launchers and 150-plus missiles in 2020 to 250 launchers and 600 missiles in 2021.[43] Most of these are conventional versions, and the numbers are probably on the higher end of an estimated range and could also include launchers and missiles in production. SIPRI estimates that, as of January 2022, around 40 of the PLARF's MRBMs were nuclear

[38] US Department of Defense (note 4), p. 61.

[39] 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 4), p. 61.

[40] US Department of Defense (note 4), p. 93.

[41] US Department of Defense (note 4), p. 163.

[42] Liu, X., 'PLA Rocket Force practices night DF-26 missile launch', *South China Morning Post*, 9 June 2021.

[43] US Department of Defense (note 4), p. 163; and US Department of Defense (note 1), p. 166.

DF-21s (CSS-5). The DF-21 is a two-stage, solid-fuelled mobile missile. The original DF-21 (CSS-5 Mod 1), which was first deployed in 1991, has been retired. An upgraded variant, the DF-21A (CSS-5 Mod 2), was first deployed in 1996 and an enhanced version, possibly known as the DF-21E (CSS-5 Mod 6), was fielded in 2017.[44] Two other versions of the DF-21 (DF-21C and DF-21D) are armed with conventional warheads.

The PLARF has also begun fielding the new DF-17 (CSS-22) MRBM equipped with a hypersonic glide vehicle (HGV).[45] The US DOD's 2021 report noted that the DF-17 is 'primarily a conventional platform', but that it could 'be equipped with nuclear warheads'.[46] As of January 2022, the DF-17 was operational in at least two brigades, with integration under way in several additional brigades.[47]

Sea-based missiles

In 2021 China continued to pursue its long-standing strategic goal from the early 1980s of developing and deploying a sea-based nuclear deterrent. According to the US DOD's 2021 report, the PLA Navy (PLAN) has constructed six Type 094 SSBNs.[48] The two newest boats—Type 094A, believed to be variants of the original design—were handed over to the PLAN in April 2020 and one of them formally entered service in April 2021.[49] The US DOD's 2021 report assessed that these six operational Type 094 SSBNs constitute China's 'first credible, sea-based nuclear deterrent'.[50]

China's four original Type 094 submarines can each carry up to 12 three-stage, solid-fuelled Julang-2, or JL-2 (CSS-N-14), submarine-launched ballistic missiles (SLBMs). The JL-2 is a sea-based variant of the DF-31 ICBM. It has an estimated maximum range in excess of 7000 km and is believed to carry a single nuclear warhead.[51]

There has been considerable speculation about whether the missiles on China's SSBNs are mated with warheads under normal circumstances; there appear to be no credible public reports that China has commenced

[44] O'Halloran, J. C. (ed.), *IHS Jane's Weapons: Strategic, 2015–16* (IHS Jane's: Coulsdon, 2015), pp. 21–22; and US Department of Defense (note 4), p. 93.

[45] US Department of Defense (note 4), p. 61.

[46] US Department of Defense (note 4), p. 61.

[47] Rod Lee (@roderick_s_lee), 'The PLA appears to be fielding the (likely hypersonic) DF-17 at an operational unit, suggesting the DF-17 has achieved at least initial operational capability. PRC television footage from 29 December shows a probable DF-17 TEL at the PLARF's 627 Brigade in Jieyang', Twitter, 30 Dec. 2020; Chan, M., 'Chinese military beefs up coastal forces as it prepares for possible invasion of Taiwan', *South China Morning Post*, 18 Oct. 2020; and authors' estimates.

[48] US Department of Defense (note 4), p. 49.

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

[50] US Department of Defense (note 4), p. 49.

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

nuclear-armed patrols. The routine deployment of nuclear weapons on China's SSBNs would constitute a significant change to the country's long-held practice of keeping nuclear warheads in central storage in peacetime and would pose operational challenges for its nuclear command-and-control arrangements. During a war, geographic choke points and advanced US anti-submarine warfare capabilities could force China to deploy its nuclear submarines in a protective bastion within the South China Sea, rather than sail them past Japan and out into the Pacific Ocean. These constraints significantly limit Chinese SSBNs from targeting continental USA.

The US DOD's 2021 report indicates that the PLAN has begun construction of its next-generation SSBN, Type 096, and a potential hull section was visible in commercial satellite imagery from February 2021.[52] Reports vary widely on the design parameters, but the new submarine is expected to be larger and quieter than the Type 094 and could possibly 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. In 2021 the US DOD assessed that China could have up to eight SSBNs by 2030.[53]

The Type 096 SSBN will be armed with a successor to the JL-2: the JL-3 SLBM, which is thought to use technologies from the land-based DF-41 ICBM and have a longer range than the JL-2. The US Air Force's National Air and Space Intelligence Center has assessed that the JL-3 will be capable of carrying multiple warheads and have a range of more than 10 000 km.[54] According to the US DOD, the JL-3's longer range could enable the PLAN to deploy its SSBNs in bastions in the South China Sea and the Bohai Gulf, to enhance their survivability.[55]

[52] US Department of Defense (note 4), p. 49; and Sutton, H. I., 'First image of China's new nuclear submarine under construction', Naval News, 1 Feb. 2021.

[53] US Department of Defense (note 4), p. 49.

[54] US Air Force (note 17), p. 37.

[55] US Department of Defense (note 4), p. 91.

VI. Indian nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2022, India was estimated to have a growing stockpile of about 160 nuclear weapons—a small increase from the previous year (see table 10.7). These weapons were assigned to a maturing nuclear triad of aircraft, land-based missiles and ballistic missile submarines. The warhead estimate is based on calculations of India's inventory of weapon-grade plutonium, 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 itself has not provided much public information about the size of its nuclear forces, other than conducting occasional parade displays and making announcements about missile flight tests. India has continued to expand the size and capability of its nuclear weapon inventory as well as its infrastructure for producing nuclear warheads.

The role of nuclear weapons in Indian military doctrine

Until the early 2010s, the limited ranges of India's initial nuclear systems meant that 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, it appears that India has placed increased emphasis on China in recent years. It remains to be seen how this development, as well as recent border clashes with China and Pakistan, will affect India's nuclear arsenal and strategy.[2] While India has adhered to a nuclear no-first-use policy since 1999, this pledge was qualified by a 2003 caveat that India could use nuclear forces to retaliate against attacks by non-nuclear weapons of mass destruction (WMD).[3] This 2003 statement was reaffirmed as recently as 2018, and could still be in place as official policy.[4] Doubts about India's commitment to the no-first-use policy have increased, and although India is believed to store its warheads separate from its delivery systems, there has been increasing evidence of some parts of India's nuclear arsenal

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

[2] On the border tensions in 2021 between China and India and between India and Pakistan see chapter 4, section III, in this volume.

[3] Indian Ministry of External Affairs, 'The Cabinet Committee on Security reviews [o]perationalization of India's nuclear doctrine', Press release, 4 Jan. 2003; and Indian Embassy in Washington, DC, 'Draft report of National Security Advisory Board on Indian nuclear doctrine', 17 Aug. 1999.

[4] Indian Prime Minister's Office, 'Prime Minister felicitates crew of INS Arihant on completion of nuclear triad', Press release, 5 Nov. 2018.

Table 10.7. Indian nuclear forces, January 2022

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]	*48*				*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	–	[2022]	2 000	–	–
Land-based missiles	*64*				*64*
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	8	2018	>3 200	1 x 10–40 kt	8
Agni-IV	–	[2022]	>3 500	1 x 10–40 kt	–
Agni-V	–	[2022]	>5 000	1 x 10–40 kt	–
Agni-VI	–	[2025]	>6 000	1 x 10–40 kt	–
Agni-P	–	[2025]	1 000–2 000	[2 x 10–40 kt MIRV]	–
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]					*32*
Total stockpile	**126**				**160**[k]

– = 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 two-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 one nuclear warhead per launcher. All estimates are approximate.

[d] 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—two ships and one nuclear-powered ballistic missile submarine (SSBN); the second is the maximum number of missiles that they can carry. India has launched two SSBNs, but only one—INS *Arihant*—was believed to be operational as of Jan. 2022, and was believed to have only a limited operational capability. The other SSBN—INS *Arighat*—was being fitted out and might become operational during or after 2022.

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

[h] 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 SSBN 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. SIPRI estimates that around 12 additional K-15 missiles and warheads have been produced for deployment on INS *Arighat* and might become operational during or after 2022 (see notes f and k).

j Each missile tube will be able to carry one K-4 SLBM once it becomes operational.

k In addition to the approximately 128 warheads estimated to be assigned to operational forces, SIPRI estimates that around 32 warheads might have been produced to arm Agni-IV and Agni-V missiles (*c.* 20 warheads) and K-15 missiles (*c.* 12 warheads for INS *Arighat*), for a total estimated stockpile of around 160 warheads. India's 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, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat*, various years; Indian news media reports; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

being kept at a much higher state of readiness.[5] This growing emphasis on increased readiness and quicker ability to launch has prompted some analysts to consider the possibility that India could be transitioning towards a counterforce nuclear posture with the goal of targeting an adversary's nuclear weapons early in a crisis, before they could be used.[6] However, other analysts have challenged those claims, citing a lack of evidence and pointing to other ways in which declaratory policy has remained consistent.[7]

Aircraft and air-delivered weapons

Aircraft are the most mature component of India's nuclear strike capabilities. India has several types of combat aircraft with performance characteristics that make them suitable as nuclear delivery platforms, including the Mirage 2000H, Jaguar IS and Rafale. However, with the exception of the Mirage 2000H, for which there is at least one detailed source that describes how the aircraft was converted for a nuclear strike role in the 1990s, there are no official sources that confirm their nuclear-capable roles. Given this significant uncertainty, SIPRI estimates that approximately 48 nuclear bombs have been assigned to Indian aircraft.

The Indian Air Force (IAF) has reportedly certified its Mirage 2000H combat aircraft for delivery of nuclear gravity bombs.[8] The IAF has begun upgrading 51 of these aircraft with new mission computers, radar, navigation, avionics, and communications systems, as well as a life-extension programme intended to keep the aircraft in service until the 2040s.[9] It has also been

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

[6] Clary, C. and Narang, V., 'India's counterforce temptations: Strategic dilemmas, doctrine, and capabilities', *International Security*, vol. 43, no. 3 (2019); and Kaushal, S. et al., 'India's nuclear doctrine: The Agni-P and the stability–instability paradox', Royal United Services Institute (RUSI), 8 July 2021.

[7] Rajagopalan, R., *India and Counterforce: A Question of Evidence*, ORF Occasional Paper no. 247 (Observer Research Foundation: New Delhi, May 2020).

[8] 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.

[9] Philip, S. A., 'Why India is set to miss 2021 deadline to upgrade Mirage 2000 fighters', The Print, 7 Oct. 2021.

widely reported in Indian media sources that the IAF's Jaguar IS combat aircraft might also be certified to deliver nuclear gravity bombs.[10]

In addition to the Mirage 2000H, India has acquired 36 Rafale combat aircraft from France, scheduled for full delivery by early 2022.[11] According to the Indian Ministry of Defence (MOD), the 'Rafale will provide IAF the strategic deterrence and requisite capability cum technological edge'.[12] It is unclear whether this language indicates a future nuclear role for the Rafales, and there have been other instances where the Indian MOD used similar language to describe non-nuclear systems.[13] However, at the time of the sale, Indian defence officials reportedly told the media that the decision to purchase the Rafales was based on its ability to be converted for a nuclear strike role.[14]

Land-based missiles

The Indian Army's Strategic Forces Command operates four types of mobile nuclear-capable ballistic missile: the short-range Prithvi-II (250 kilometres) and Agni-I (700 km); the medium-range Agni-II (>2000 km); and the intermediate-range Agni-III (>3200 km).[15] As of January 2022, three new land-based ballistic missiles were in development: the Agni-P (1000–2000 km), the Agni-IV (>3500 km) and the Agni-V (>5000 km); while a variant with an even longer range, the Agni-VI (6000 km), was in the design stage of development.[16]

The Agni-P and Agni-V missiles achieved significant milestones in 2021, with test launches, respectively, in June and December, and in October.[17] The

[10] See e.g. Cohen, S. and Dasgupta, S., *Arming Without Aiming: India's Military Modernization* (Brookings Institution Press: Washington, DC, 2010), pp. 77–78; and Shukla, A., 'Jaguar fighter gets 20-year lease of life with DARIN-III avionics', *Business Standard*, 24 Nov. 2016.

[11] Gupta, S., '36th Rafale to have all India specific enhancements, arrives Jan 2022', *Hindustan Times*, 10 Sep. 2021; and NDTV, '3 of 4 remaining Rafale jets will arrive on time in February: Air Force chief', 18 Dec. 2021.

[12] Indian Ministry of Defence (MOD), *Annual Report 2018–19* (MOD: New Delhi, 2019), p. 43.

[13] See e.g. Tiwary, A. K., 'IAF: The strategic force of choice', *Indian Defence Review*, vol. 22, no. 3 (July–Sep. 2007); and Major, F. H., 'Indian Air Force in the 21st century: Challenges and opportunities', *Journal of Defence Studies*, vol. 2, no. 1 (summer 2008).

[14] Singh, S., 'Behind Rafale deal: Their "strategic" role in delivery of nuclear weapons', *Indian Express*, 18 Sep. 2016; and Malhotra, J., 'India favoured Rafale also because of its "nuclear advantage"', The Print, 15 Feb. 2019.

[15] The Prithvi-II's range is often reported as 350 km. However, the range is set at 250 km in information provided by the United States. See e.g. 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. 17.

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

[17] Indian Ministry of Defence (MOD), 'DRDO successfully flight tests new generation Agni P ballistic missile', Press release, 28 June 2021; Indian MOD, 'Surface to surface ballistic missile, Agni-5, successfully launched from APJ Abdul Kalam Island', Press release, 27 Oct. 2021; and Indian MOD, 'New generation ballistic missile "Agni P" successfully test-fired by DRDO', Press release, 18 Dec. 2021.

medium-range Agni-P (described by the Indian MOD as a next-generation nuclear-capable ballistic missile) reportedly incorporates technology developed specifically for the Agni-V programme, including advanced navigation and new mobile canisterized launch systems, which will reduce the time required to place the missiles on alert in a crisis.[18] The solid-fuelled Agni-P can reportedly manoeuver upon re-entry, which could allow the missile to evade regional missile defences.[19] It is expected that the Agni-P will eventually replace India's first-generation Agni-I missile, and possibly the Prithvi-II and Agni-II missiles, once the system becomes operational. The three-stage, solid-fuelled Agni-V was test launched for the eighth time in October 2021.[20] Notably, this was the first user trial for the system, meaning that its integration into the Indian armed forces is likely to take place in 2022 or 2023.[21]

India has also begun developing a land-based, short-range version (750 km) of the K-15 submarine-launched ballistic missile (SLBM), known as the Shaurya. Because the K-15 is nuclear-capable, media reports have also widely attributed nuclear capability to the Shaurya.[22] No official government statement has confirmed this, however, and with only three or four flight tests, reports about imminent deployment seem premature.[23] The United States Air Force's National Air and Space Intelligence Center (NASIC) did not mention the Shaurya in its ballistic and cruise missile reports of 2020 and 2017.[24] Because of the high level of uncertainty about the status of the Shaurya, it is not included in SIPRI's estimate for January 2022.

India seems to have been pursuing a technology development programme for multiple independently targetable re-entry vehicles (MIRVs). Notably, the June 2021 Agni-P test appeared to use two decoys to simulate a MIRV-equipped payload, with defence sources suggesting that a functional MIRV capability would take another two years to develop and flight test; however, given the inherent technological barriers to developing an operational MIRV

[18] 'DRDO successfully flight tests new generation Agni P ballistic missile' (note 17); and Rout, H. K., 'India test fires new generation nuclear capable Agni-Prime missile off Odisha coast', *New Indian Express*, 28 June 2021.

[19] Philip, S. A., 'Agni Prime is the new missile in India's nuclear arsenal. This is why it's special', The Print, 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.

[20] 'Surface to surface ballistic missile, Agni-5, successfully launched from APJ Abdul Kalam Island' (note 17).

[21] Gupta, S., 'Strategic Forces Command conducts Agni V trial, hits target 5,000 km away', *Hindustan Times*, 28 Oct. 2021.

[22] 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.

[23] Subramanian, T. S. and Mallikarjun, Y., 'India successfully test-fires Shourya missile', *The Hindu*, 24 Sep. 2011; and Press Trust of India, '"Shaurya" successfully test fired', *The Hindu*, 3 Oct. 2020.

[24] United States Air Force (note 15), p. 17; and US Air Force, NASIC, *Ballistic and Cruise Missile Threat 2017* (NASIC: Wright-Patterson Air Force Base, OH, June 2017).

capability, it could take much longer.[25] It is also possible that the Agni-V, and eventually the intercontinental Agni-VI, could be equipped with MIRVs.[26]

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 build a fleet of four to six nuclear-powered ballistic missile submarines (SSBNs).[27] The first SSBN, INS *Arihant*, was launched in 2009, formally commissioned in 2016 and completed its first 'deterrence patrol' in 2018, although it is doubtful that the submarine's missiles carried nuclear warheads during the patrol; it is unlikely that India's submarines will carry a nuclear payload during peacetime.[28] SIPRI estimates that 12 nuclear warheads were delivered for potential deployment by INS *Arihant* and another 12 produced for a second SSBN, INS *Arighat*. INS *Arihant* appears to have only a limited operational capability relative to its successors, given its less powerful reactor and fewer missile tubes.

INS *Arighat* was launched in November 2017 and was undergoing advanced sea trials in 2021 ahead of its expected commissioning into the Indian Navy in 2022.[29] A third submarine, known as S4, was reportedly launched in November 2021, and a fourth was expected to be launched in 2023.[30]

Photographs indicate that INS *Arihant* and INS *Arighat* have each been equipped with a four-tube vertical-launch system and could carry up to 12 two-stage, 700-km-range K-15 (which may have been renamed to the B-05) SLBMs.[31] India's third and fourth submarines are expected to be larger than its first two. They will reportedly have eight launch tubes to hold up to 24 K-15 missiles or 8 K-4 missiles, which are in development.[32]

[25] Pandit, R., 'Key trial of 5,000-km ICBM Agni-V in October', *Times of India*, 24 Sep. 2021.

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

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

[28] Dinakar, P., 'Now, India has a nuclear triad', *The Hindu*, 18 Oct. 2016; Indian Prime Minister's Office (note 4); Davenport (note 27); and Joshi, Y., 'Angels and dangles: Arihant and the dilemma of India's undersea nuclear weapons', War on the Rocks, 14 Jan. 2019.

[29] Bhattacharjee, S., 'Third Arihant class submarine quietly launched in November', *The Hindu*, 4 Jan. 2022. Until its launch, the submarine was assumed to be named INS *Aridhaman*.

[30] Chris Biggers (@CSBiggers), 'India quietly launched S4 in November 2021 at SBC . . .', Twitter, 28 Dec. 2021; and Unnithan, S., 'A peek into India's top secret and costliest defence project, nuclear submarines', *India Today*, 10 Dec. 2017.

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

[32] Bhattacharjee (note 29); and Hans Kristensen (@nukestrat), 'New submarine cover (17°42'23"N, 83°16'23"E) constructed at Vizag is 40m longer than first one. India's third SSBN will be longer with more missile tubes than the 4 on first two boats. Current missile compartment is ~15m with tubes in row instead of pairs as other navies have', Twitter, 12 Mar. 2021.

The K-4 is a two-stage, 3500-km-range SLBM being developed by the Indian Defence Research and Development Organisation (DRDO). The K-4 will eventually replace the K-15, although with only four or eight missiles per submarine, depending on the number of launch tubes.[33] The DRDO has also started to develop extended-range versions: the K-5, which will reportedly have a range in excess of 5000 km, and the K-6, which will have an even longer range.[34] With only two successful launches, which took place in January 2020 after two previous attempts failed, and none from a submarine, as of January 2022, the K-4 still seemed to be several years from operational capability.[35]

India's first naval nuclear weapon, the Dhanush missile, is a version of the dual-capable Prithvi-II that can be launched from two Sukanya-class offshore patrol vessels often seen at the Mumbai and Karwar naval bases on India's west coast.[36] Although NASIC has listed the Dhanush system as deployed, its usefulness in combat is highly questionable, given the slow speed and high degree of vulnerability of the Sukanya-class vessels.[37] Therefore, the system will probably be retired when the SSBN programme with longer-range missiles matures.

Cruise missiles

There have been numerous claims in news articles and on private websites 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.[38] However, no official or authoritative source has attributed nuclear capability to India's cruise missiles. Therefore, they are not included in SIPRI's estimate for January 2022.

[33] Jha, S., 'India's undersea deterrent', The Diplomat, 30 Mar. 2016; and United States Air Force (note 15), p. 30.

[34] Unnithan (note 30).

[35] Peri, D., 'India successfully test-fires 3,500-km range submarine-launched ballistic missile K-4', *The Hindu*, 19 Jan. 2020; and Pandit, R., 'DRDO: Arihant's N-capable missile "ready to roll"', *Times of India*, 25 Jan. 2020.

[36] 'Nuke-capable Dhanush and Prithvi-II launched', *New Indian Express*, 12 Mar. 2011; and Indian Ministry of Defence (note 12), p. 100.

[37] US Air Force (note 24).

[38] 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.

VII. Pakistani nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

According to SIPRI estimates, Pakistan possessed approximately 165 nuclear warheads as of January 2022, around the same number as the previous year (see table 10.8). The Pakistani government has never publicly disclosed the size of its nuclear arsenal. Limited official public data and widespread 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.[1] 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. The development of several new delivery systems and growing accumulation of fissile materials suggests that Pakistan's nuclear weapon arsenal and fissile material stockpile are likely to continue to expand over the next decade, although projections vary considerably.[2]

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] According to Pakistan, its full spectrum nuclear weapon posture includes long-range missiles and aircraft as well as several short-range, lower-yield nuclear-capable weapon systems.[4] Pakistan's emphasis on non-strategic (tactical) nuclear weapons is specifically intended to be a reaction to India's 'Cold Start' doctrine, which revolves around maintaining the capability to launch large-scale conventional strikes or incursions against Pakistani territory at a level below the threshold at which Pakistan would

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

[2] 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*; International Panel on Fissile Materials, 'Pakistan', 31 Aug. 2021; and section X of this chapter.

[3] Kidwai, K., Keynote address and discussion session, South Asian Strategic Stability: Deterrence, Nuclear Weapons and Arms Control (Workshop), 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.

retaliate with nuclear weapons.[5] In 2015 a retired member of Pakistan's National Command Authority suggested that 'by introducing the variety of tactical nuclear weapons in Pakistan's inventory', Pakistan has 'blocked the avenues for serious military operations by the other side'.[6] In June 2021 Pakistani Prime Minister Imran Khan stated in an interview, 'I'm not sure whether we're growing [the nuclear arsenal] or not because as far as I know . . . the only one purpose [of Pakistan's nuclear weapons]—it's not an offensive thing', further noting that 'Pakistan's nuclear arsenal is simply as a deterrent, to protect ourselves'.[7]

Aircraft and air-delivered weapons

At the end of December 2021, Pakistan had a small stockpile of 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 Pakistan Air Force (PAF) with a nuclear-capable standoff capability at ranges of 350–600 kilometres.[8] There is no publicly available evidence to suggest that either version of the Ra'ad ALCM had been operationally deployed as of January 2022.

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 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.[9] The nuclear capability of Pakistan's F-16 fighter-bombers is uncertain. Many analysts continue to assign a potential nuclear role to these aircraft based on reports in the late 1980s that

[5] Kidwai (note 3); and Saalman, L. and Topychkanov, P., *South Asia's Nuclear Challenges*, SIPRI Report (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. 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 with *India Today* in 2017. Unnithan, S., '"We will cross again"', *India Today*, 4 Jan. 2017.

[6] Kidwai, K., Conversation transcript, Carnegie Endowment for International Peace, 23 Mar. 2015, p. 5.

[7] Laskar, R. H., 'Pakistan PM Imran Khan again seeks US intervention on Kashmir', *Hindustan Times*, 21 June 2021.

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

[9] 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.

Table 10.8. Pakistani nuclear forces, January 2022

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	*118*[g]				*118*
Abdali (Hatf-2)	10	2015	200	1 x 5–12 kt	10
Ghaznavi (Hatf-3)	16	2004	300	1 x 5–12 kt	16
Shaheen-I (Hatf-4)	16	2003	750	1 x 5–12 kt	16
Shaheen-IA[h]	–	. .	900	1 x 5–12 kt	–
Shaheen-II (Hatf-6)	16	2014	2 000	1 x 10–40 kt	16
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]					*11*
Total stockpile	**154**				**165**[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 higher yields. There is no open-source evidence that Pakistan has developed two-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 one missile. This estimate counts an average of one 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 therefore it is 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 one or more missile reloads.

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

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

[j] The Pakistani military in 2017 claimed 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 enable engagement against both land and sea targets. The original Babur's range is listed as 350 km by the US Air Force's National Air and Space Intelligence Center, while Pakistan claims that the improved Babur-1A's range is 450 km.

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

[m] In addition to the approximately 154 warheads estimated to be assigned to operational forces, SIPRI estimates that around 11 warheads have been produced to arm future Shaheen-III and cruise missiles, for a total estimated stockpile of about 165 warheads. Pakistan's warhead stockpile is expected to continue to increase.

Sources: Pakistani Ministry of Defence, various documents; US Air Force, 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.

Pakistan was modifying them to deliver nuclear weapons.[10] At the end of 2021, Pakistan was also operating more than 100 JF-17 aircraft, and intended to acquire around another 188 JF-17s to replace the ageing Mirage III and Mirage V aircraft.[11] 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 onto the JF-17.[12] However, in the light of these considerable uncertainties, it is not possible for SIPRI to make an assessment as to whether Pakistan's F-16s and JF-17s have a dedicated nuclear weapon-delivery role and therefore they are omitted from table 10.8.

Land-based missiles

As of January 2022, Pakistan's nuclear-capable ballistic missile arsenal comprised short- and medium-range systems.

Pakistan has deployed four types of solid-fuelled, road-mobile short-range ballistic missiles: Abdali (also designated Hatf-2), Ghaznavi (Hatf-3), Shaheen-I (Hatf-4) and Nasr (Hatf-9). The dual-capable Ghaznavi was test

[10] For further detail on the role of the F-16s see Kristensen, H. M. and Kile, S. N., 'Pakistani nuclear forces', *SIPRI Yearbook 2020*, p. 370.

[11] International Institute for Strategic Studies (IISS), *The Military Balance 2019* (Routledge: London, 2019), pp. 298–99; Warnes, A., 'PAC Kamra rolls out final 14 JF-17B fighters for Pakistan Air Force', Janes, 31 Dec. 2020; Khan, B., 'Why is the Pakistan Air Force procuring 26 JF-17B fighters?', Quwa, 19 Jan. 2020; and 'Pakistan aeronautical complex delivers new JF-17B batch', Quwa, 2 Jan. 2021.

[12] Fisher, R., 'JF-17 Block II advances with new refuelling probe', *Jane's Defence Weekly*, 27 Jan. 2016; 'Ra'ad ALCM: The custodian of Pakistan's airborne nuclear deterrence', PakDefense, 6 Dec. 2020; and 'Update on Pakistan: "JF-17 Thunder's integration with RA'AD II ALCM"', Pakistan Strategic Forum, 8 July 2020.

launched twice in 2021, after which the PAF listed its range as 290 km.[13] The Shaheen-IA, an extended-range version of the Shaheen-I that was still in development, was test launched twice in 2021—once to a range of 900 km.[14] With the exception of the Abdali, Pakistan displayed all its nuclear-capable short-range missiles at the Pakistan Day Parade in March 2021.[15]

The arsenal also included two types of medium-range ballistic missile: the liquid-fuelled, road-mobile Ghauri (Hatf-5), with a range of 1250 km; and the two-stage, solid-fuelled, road-mobile Shaheen-II (Hatf-6), with a range of 2000 km.[16] The Shaheen-II has been test launched seven times since 2004, with the most recent launch taking place in 2019.[17] A longer-range variant in development, the Shaheen-III, has been test launched only twice—in 2015 and early 2021—and had not yet been deployed as of January 2022.[18] This missile has a claimed range of 2750 km, making it the longest-range system that Pakistan has tested to date. Notably, the Shaheen-III, but not the Shaheen-II, was displayed at the Pakistan Day Parade in March 2021.[19] The Pakistani government claimed in 2017 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 has not conducted any subsequent test launches of the missile.[20]

In addition to expanding its arsenal of land-based ballistic missiles, Pakistan continued in 2021 to develop the nuclear-capable Babur (Hatf-7) ground-launched cruise missile. The United States Air Force's National Air and Space Intelligence Center has claimed that the Babur has a range of

[13] 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 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.

[14] 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 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.

[15] Pakistani Inter Services Public Relations (ISPR), DG ISPR (@OfficialDGISPR), 'Pakistan Day Parade: March 2021', Twitter, 24 Mar. 2021.

[16] 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.

[17] 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; and Jamal, S., 'Pakistan tests nuclear-capable Shaheen-III ballistic missile', *Gulf News*, 20 Jan. 2021.

[19] Pakistani Inter Services Public Relations (note 15).

[20] 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 (NASIC) also describes the 2017 test as involving 'the MIRV version of the Ababeel'. US Air Force (note 16), p. 25. On the Ababeel see also Kile and Kristensen (note 2), p. 335.

350 km.[21] Pakistan has test launched the Babur approximately a dozen times since 2005 and has used it in army field training since 2011, which indicates that the system is probably operational. Pakistan has been upgrading the Babur's avionics and navigation systems to enable target engagement both on land and at sea; the upgraded version is known as the Babur-1A. Following the system's most recent test in February 2021, the Pakistani military stated that the Babur-1A's range was 450 km.[22] An extended-range version known as the Babur-2 (sometimes referred to as the Babur-1B) has a claimed range of 900 km—double that of the Babur-1A. Pakistan test launched the Babur-2 in 2016, 2018, 2020 (which resulted in a failure) and most recently in December 2021.[23]

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.[24] Pakistan test launched the Babur-3 first in 2017 and again in 2018.[25]

China was still expected to deliver the first of eight air-independent propulsion-powered Hangor-class submarines to Pakistan in 2022, possibly for a nuclear role with the Babur-3 SLCM.[26] If Pakistan does intend to deploy both nuclear and conventional missiles on its attack submarines, this could ultimately create issues around entanglement of nuclear and non-nuclear capabilities, with the potential risk of unintended escalation.[27]

[21] 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.

[22] Pakistani Inter Services Public Relations (ISPR), ISPR Official, 'Press release no. PR24/2021, Pak conducted successful launch of Babur cruise missile -11 Feb 2021(ISPR)', YouTube, 11 Feb. 2021.

[23] 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 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.

[24] 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.

[25] 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.

[26] Khan, B., 'Profile: Pakistan's new Hangor submarine', Quwa, 11 Nov. 2019.

[27] For further discussion on entanglement in the South Asian context see Saalman and Topychkanov (note 5).

VIII. Israeli nuclear forces

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As of January 2022, Israel was estimated to have a stockpile of around 90 nuclear warheads (see table 10.9), the same number as in January 2021. This estimate is on the lower end of a possible range that other analysts have estimated could reach as high as 300 nuclear weapons; however, SIPRI assesses that these larger estimates are probably too high.[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 there is significant uncertainty about the size of Israel's nuclear arsenal and the yields and characteristics attributed to its weapons.[3] The estimate here is largely based on calculations of Israel's inventory of weapon-grade plutonium 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.

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'.[4] However, to accommodate the apparent fact that Israel possesses a significant nuclear arsenal, Israeli policymakers have previously interpreted 'introducing nuclear weapons' as testing, publicly declaring or actually using nuclear capability, which, according to available open-access sources, Israel has not yet done.[5] Another caveat may be that the warheads are not fully assembled under normal circumstances (i.e. the nuclear cores would be stored and managed separately from their delivery systems). It is unclear what

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

[2] For further detail on Israel's 'strategic ambiguity' policy see Cohen, A., 'Israel', eds H. Born, B. Gill and H. Hänggi, *Governing the Bomb: Civilian Control and Democratic Accountability of Nuclear Weapons* (SIPRI and Oxford University Press: Oxford, 2010), pp. 152–68.

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

[4] This formulation was first expressed during Israel's negotiations with the United States over the purchase of 50 F-4 Phantom aircraft in the late 1960s. During these negotiations, it was made explicitly clear that both sides had very different opinions about what 'introducing nuclear weapons' meant; however, these competing interpretations allowed the two sides to look the other way, thus satisfying both their security interests and alliance relationships while 'agreeing to disagree' over their interpretations of what 'introducing nuclear weapons' actually meant. The most recent public iteration of this policy by an Israeli head of state was made by Benjamin Netanyahu in 2011. Prime Minister's Office, 'PM Netanyahu's interview with Piers Morgan of CNN', 17 Mar. 2011.

[5] Cohen, A. and Burr, W., 'Israel crosses the threshold', Electronic Briefing Book no. 189, National Security Archive, 28 Apr. 2006; and Cohen, A. and Burr, W., 'The US discovery of Israel's secret nuclear project', Electronic Briefing Book no. 510, National Security Archive, 15 Apr. 2015.

circumstances would prompt Israel to 'introduce' nuclear weapons into the region under its own narrow definition. It is believed that one such scenario would involve a crisis that poses an existential threat to the State of Israel, such as a full-scale conventional attack.

In 2021 Israeli Prime Minister Naftali Bennett and United States President Joe Biden met to reaffirm that the USA would not pressure Israel to disarm or join the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT), and that any arms control agreement would not negatively impact Israel's nuclear arsenal.[6] This has reportedly been a ritual performed with every US president since the administration of President Bill Clinton.

Military fissile material production

Declassified US government documents indicate that Israel may have assembled its first nuclear weapons in the late 1960s, using plutonium produced by the Israel Research Reactor 2 (IRR-2) at the Negev Nuclear Research Center near Dimona, in southern Israel.[7] This heavy water reactor, which was commissioned in 1963, 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).[8]

The International Panel on Fissile Materials (IPFM) estimates that, as of the beginning of 2020, Israel may have a stockpile of 850–1120 kilograms of plutonium.[9] Another analyst estimates a lower amount, approximately 530 kg, depending on assumptions about the reactor efficiency.[10] Assuming that its warhead arsenal is likely to consist of single-stage, boosted fission weapons, Israel could potentially use the larger number estimated by the IPFM to build anywhere between 170 and 278 nuclear weapons. 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

[6] Ravid, B., 'Biden and Israeli PM renewed agreement on covert nuclear program', Axios, 1 Sep. 2021; and Entous, A., 'How Trump and three other US presidents protected Israel's worst-kept secret: Its nuclear arsenal', *New Yorker*, 18 June 2018.

[7] 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.

[8] 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.

[9] International Panel on Fissile Materials, 'Countries: Israel', 31 Aug. 2021.

[10] Jones, G. S., 'Estimating Israel's stocks of plutonium, tritium and heu', Proliferation Matters, 18 Sep. 2018, p. 6.

Table 10.9. Israeli nuclear forces, January 2022

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.

[c] The United States Air Force's F-15E Strike Eagle has been given a nuclear role. It is not known whether the Israeli Air Force has added nuclear capability to this aircraft, but when Israel sent half a dozen F-15s from Tel Nof Air Base to the United Kingdom in Sep. 2019, a US official privately commented that Israel had sent its nuclear squadron.

[d] Commercial satellite images show what appear to be 23 caves or bunkers for mobile Jericho launchers at Sdot Micha Air Base. High-resolution satellite imagery that became available in 2021 indicates that each cave appears to have two 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 of the Jericho ballistic missile 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 six standard 533 millimetre torpedo tubes, Israel's submarines are reportedly equipped with four additional, specially designed 650 mm tubes that could potentially be used to launch 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. and Burr, W., 'Israel crosses the threshold', *Bulletin of the Atomic Scientists*, vol. 62, no. 3 (May/June 2006); Cohen, A., *Israel and the Bomb* (Columbia University Press: New York, 1998); US National Security Archive, various document collections related to Israel's nuclear weapon programme and declassified US government documents relating to Israel's nuclear weapon capability; Albright, D., Berkhout, F. and Walker, W., SIPRI, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997); 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.

number of weapons Israel could build. As a result, SIPRI estimates that Israel has approximately 90 warheads, rather than several hundred.

Having produced enough plutonium for Israel to produce some weapons, IRR-2 may now be operated primarily to produce the tritium needed to boost those weapons.[11] Shutdown of the ageing reactor was scheduled for 2003 but has been postponed until at least 2023. The Israel Atomic Energy Commission is reportedly examining ways to extend its service life until the 2040s.[12] Satellite imagery indicates that significant construction started at the Negev Nuclear Research Center in late 2018 or early 2019 and continued throughout 2021, with a large dig several storeys deep located near the reactor.[13] It is unclear whether the construction is related to life-extension operations at Dimona.

Aircraft and air-delivered weapons

Approximately 30 of Israel's nuclear weapons are estimated to be gravity bombs for delivery by F-16I aircraft. It is possible that some F-15 aircraft could also play a nuclear role.[14] When Israel sent half a dozen F-15s from Tel Nof Air Base to the United Kingdom for an exercise in September 2019, a US official privately commented that Israel had sent its nuclear squadron.[15]

Nuclear gravity bombs without nuclear cores would probably be stored at protected facilities near one or two air force bases. It is possible that Tel Nof Air Base in central Israel and Hatzerim Air Base in the Negev desert might have nuclear missions. Israel is also acquiring 50 F-35s from the USA, which are particularly suitable for deep strike operations, although it is unclear whether Israel would use them for that role.[16]

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.[17] The missiles are believed to be located, along with their mobile transporter-erector-launchers (TELs), in

[11] Kelley, R. and Dewey, K., 'Assessing replacement options for Israel's ageing Dimona reactor', *Jane's Intelligence Review*, 20 Nov. 2018; and International Panel on Fissile Materials (note 9).

[12] Bob, Y. J., 'Experts agree Dimona nuke reactor can exceed original life expectancy', *Jerusalem Post*, 12 July 2019.

[13] Gambrell, J., 'Secretive Israeli nuclear facility undergoes major project', AP News, 25 Feb. 2021.

[14] Israeli Air Force, 'The F-15I as the IAF's Strategic Aircraft', 19 Jan. 2016; and Israeli Air Force, '19 years of "Ra'am"', 19 Jan. 2017.

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

[16] Lockheed Martin, 'Israel's 5th generation fighter', [n.d.].

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

caves or bunkers at Sdot Micha Air Base near Zekharia, about 25 kilometres west of Jerusalem. High-resolution satellite imagery that became available in 2021 showed that an upgrade of the bunkers is ongoing, and indicated that each suspected Jericho missile bunker might be capable of storing two launchers. Given that there are 23 caves or bunkers visible in satellite imagery, this lends support to the estimate of approximately 50 mobile missile launchers. Each cluster of bunkers also appears to be coupled with a covered high-bay drive-through facility, 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.

Israel is upgrading its arsenal of missiles from the solid-fuelled, two-stage Jericho II medium-range ballistic missile to the Jericho III intermediate-range ballistic missile. The newer and more capable Jericho III is a three-stage missile with a longer range, exceeding 4000 km. It first became operational in 2011 and might now have replaced the Jericho II.[18] In recent years—including 2015, 2017, 2019, 2020 and possibly 2021—Israel has conducted several test launches of what it calls 'rocket propulsion systems', although it is possible that some of these tests could be related to the development of Israeli space-launch vehicles, which use solid rocket motors.[19] In April 2021 video footage captured a blast at Sdot Micha Air Base that external analysts suggested was likely to be another rocket engine test; however—unlike its previous rocket propulsion tests—the Israeli Ministry of Defence did not confirm it as such.[20]

Sea-based missiles

Israel operates five German-built Dolphin-class (Dolphin-I and Dolphin-II) diesel–electric submarines, and plans to take delivery of at least four more submarines.[21] It is possible that the newer enlarged Dolphin-II submarines could be equipped with a vertical launch system that could carry new types of missile.[22] In early 2022 Israel signed a deal with Germany to procure three submarines, which will be known as the Dakar class, to replace the three

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

[19] Agence France-Presse, 'Israel tests rocket propulsion system', *Defense News*, 5 May 2015; Israeli Ministry of Defense (@Israel_MOD), 'A few moments ago, Israel conducted a test launch of a rocket propulsion system around central Israel', Twitter, 29 May 2017; Kubovich, Y., 'Israel carries out test launch for rocket propulsion system', *Haaretz*, 6 Dec. 2017; and Israeli Ministry of Defense (@Israel_MOD), 'The Israel Ministry of Defense has completed a test of a rocket propulsion system from a military base in central Israel. The test launch was scheduled in advance and carried out as planned', Twitter, 31 Jan. 2020.

[20] Lewis, J., 'Israeli rocket motor test', Arms Control Wonk, 23 Apr. 2021.

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

[22] Sutton, H. I., 'Israel's submarine secret: New dolphin-IIs could have VLS', Naval News, 19 Jan. 2022.

oldest Dolphin-class boats.[23] In addition to six standard 533 millimetre torpedo tubes, Israel's submarines are equipped with four additional, specially designed 650 mm tubes.[24] Both the German and Israeli governments have stated that these tubes are 'for the transfer of special forces and the pressure-free stowage of their equipment'; however, the unusual diameter has led many to speculate that Israel has modified some or all of the submarines to carry indigenously produced nuclear-armed sea-launched cruise missiles (SLCMs), giving it a sea-based nuclear strike capability.[25] Additionally, a 2012 media report—which remains one of the most significant exposés on the topic—quoted several former German defence ministry officials stating that they had always assumed that Israel would use the submarines for nuclear weapons.[26] If this is true, the naval arsenal might include about 10 cruise missile warheads for the submarines. Israel's submarines have their home port at Haifa on the Mediterranean coast. In recent years—including in 2021—they have occasionally sailed through the Suez Canal, as a possible deterrence signal to Iran.[27]

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

[24] Sutton, H. I., 'History of Israeli subs', Covert Shores, 20 May 2017; and Bergman, R. et al., 'Israel's deployment of nuclear missiles on subs from Germany', *Der Spiegel*, 4 June 2012.

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

[26] Bergman et al. (note 24). See also Frantz, D., 'Israel's arsenal is point of contention', *Los Angeles Times*, 12 Oct. 2003; and Sutton (note 24).

[27] See e.g. 'Iranian state media claims Israeli submarine passed through Suez into Red Sea', *Times of Israel*, 10 Aug. 2021.

IX. North Korean nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

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 2022, North Korea possessed approximately 20 nuclear weapons, but that it probably possessed sufficient fissile material for approximately 45–55 nuclear devices (see table 10.10). 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), North Korea's 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 official public data and the fact that North Korean state media sources can be subject to manipulation, misinterpretation or exaggeration. Most of the data presented here is derived from sources outside North Korea, including satellite imagery, United States government reports and statements, and expert analyses.[1]

In 2021 North Korea did not conduct any nuclear explosive tests or flight tests of long-range ballistic missiles, despite the government's announcement in January 2020 that it would no longer observe its self-imposed moratorium from 2018 on conducting either type of test.[2] However, North Korea did conduct several tests of short-range ballistic missiles (SRBMs)—including tests from new types of launcher—as well as new land-attack cruise missiles, hypersonic glide vehicles (HGVs), and submarine-launched ballistic missiles (SLBMs).

Additionally, in January 2021 North Korean leader Kim Jong Un announced at the eighth congress of the ruling Workers' Party of Korea (WPK) that, since the previous congress in 2016, North Korea had 'already accumulated nuclear technology developed to such a high degree as to miniaturize, lighten and standardize nuclear weapons and to make them tactical ones and to complete the development of a super-large hydrogen bomb'. Kim also emphasized the need to 'develop the nuclear technology to a higher level and make nuclear weapons smaller and lighter for more tactical uses'.[3] The 'super-large hydrogen bomb' might refer to a weaponized design of the large-yield device with a suspected thermonuclear yield that was tested in 2017,

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

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

[3] Korean Central News Agency, 'On report made by Supreme Leader Kim Jong Un at eighth party congress of WPK', National Committee on North Korea, 9 Jan. 2021.

while the smaller and lighter weapons might be intended for deployment on one or several of the new shorter-range missiles test launched in 2021.[4]

The role of nuclear weapons in North Korean military doctrine

The 2013 law on nuclearization—one of the most recent official documents pertaining to North Korean nuclear doctrine—states that North Korea's nuclear arsenal would only be used 'to repel invasion or attack from a hostile nuclear weapons state and make retaliatory strikes', and that 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'.[5] In a speech marking the 75th anniversary of the ruling WPK in October 2020, Kim Jong Un reiterated North Korea's pledge not to use nuclear weapons 'preemptively'.[6] 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'.[7]

As with other nuclear-armed states, it seems unlikely that North Korea would use its nuclear weapons outside of extreme circumstances where the continued existence of the state and its leadership was in question. However, in the event of such a scenario, it is possible that North Korea would use its nuclear weapons in an attempt to forestall adversarial action. Occasionally, North Korea has signalled or explicitly mentioned which targets it intends to prioritize in the event of imminent invasion. North Korea has specifically indicated that it would first target the Blue House, the executive office and official residence of the head of state of the Republic of Korea (South Korea), most likely as a response to the public acknowledgement by South Korea of its preparations to conduct 'decapitation' strikes aimed at eliminating North Korea's political and military leadership early in a conflict.[8] North Korea has stated that to forestall a conventional invasion, its second wave of targets would be US military bases in the Asia–Pacific region and continental USA.[9] Some nuclear weapons would probably be held in reserve to threaten targets

[4] For detail on North Korea's nuclear test in late 2017 see Fedchencko, V., 'Nuclear explosions, 1945–2017', *SIPRI Yearbook 2018*.

[5] Law on Consolidating the Position of Nuclear Weapons State for Self-Defence, adopted 1 Apr. 2013, Articles 4 and 5. For a translation see Korean Central News Agency, 'Law on consolidating position of nuclear weapons state adopted', Korea News Service, 1 Apr. 2013, available via GlobalSecurity.org.

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

[7] 'Kim Jong Un's October speech' (note 6).

[8] Korean Central News Agency, 'Crucial statement of KPA Supreme Command', Korea News Service, 23 Feb. 2016, available via GlobalSecurity.org; and Choe, S. H., 'South Korea plans "decapitation unit" to try to scare North's leaders', *New York Times*, 12 Sep. 2017.

[9] Ko, Y. H., 'North Korean missile proliferation', Statement before the Subcommittee on International Security, Proliferation and Federation Services, US Senate Hearing no. 105-241, 21 Oct. 1997; Korean Central News Agency (note 8); and Allard, L., Duchâtel, M. and Godement, F., 'Pre-empting defeat: In search of North Korea's nuclear doctrine', European Council on Foreign Relations, 22 Nov. 2017.

Table 10.10. North Korean forces with potential nuclear capability, January 2022

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. Some systems have been excluded because it is unlikely that they have a nuclear or operational role.

Type/ North Korean designation (US designation)[a]	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. Status unknown; may have been superseded by newer solid-fuelled SRBMs.
(KN23/KN24[b]/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 several times from wheeled, tracked and rail-based launchers since 2019. 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. Operational.
Hwasong-9 (KN04/Scud-ER)	2016	1 000	Single-stage, liquid-fuelled Scud extended-range 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.
Land-attack cruise missile	2021	1 500	Flight tested multiple times in 2021 from wheeled TEL. Under development.
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. Under development.

Type/ North Korean designation (US designation)[a]	Year first displayed	Range (km)	Description and status
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. Status unknown; may have been superseded.
Hwasong-12 (KN17)	2017	>4 500	Single-stage, liquid-fuelled MRBM launched from 8-axle wheeled TEL. Flight tested several times in 2017 with mixed success. 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.
Hwasong-15 (KN22)	2017	>12 000	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. Deployment status unknown.
Hwasong-17 (KN28)[c]	2020	14 000	Two-stage, liquid-fuelled ICBM launched from 11-axle wheeled TEL. Largest ICBM to date, possibly capable of carrying MIRVs and penetration aids. No known flight tests. Displayed at parade in Oct. 2020 and at exhibition in Oct. 2021. 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)[a]	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; probably under development.
Total warheads			**20**[d]

HGV = hypersonic glide vehicle; ICBM = intercontinental ballistic missile; IRBM = intermediate-range ballistic missile; MIRV = multiple independently targetable re-entry vehicle; MRBM = medium-range ballistic missile; NASIC = United States National Air and Space Intelligence Center; SLBM = submarine-launched ballistic missile; SRBM = short-range ballistic missile; TEL = transporter-erector-launcher.

[a] 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.

[b] 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 (Hangul) alphabet. This indicates that the KN24 is an improvement on or replacement for the original Hwasong-11 SRBM, which the US Department of Defense designates as the KN02 (Toksa).

[c] 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.

[d] SIPRI estimates that North Korea might have produced enough fissile material to build between 45 and 55 nuclear warheads; however, it is likely that it has assembled fewer warheads, perhaps around 20, 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: Arlington, VA, 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 the 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.

within the US mainland, in an attempt to 'decouple' the USA from its Asia–Pacific allies.

The North Korean announcement in 2021 to 'make nuclear weapons smaller and lighter for more tactical uses' could potentially 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.

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.[10] 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.[11] Between December 2018 and July 2021 the IAEA found no signs that North Korea's ageing 5-megawatt-electric (MW(e)) graphite-moderated research reactor had been operational; however, in August 2021 the IAEA reported that 'since early July 2021, there have been indications, including the discharge of cooling water, consistent with the operation of the reactor'.[12] Despite the intermittent discharge of cooling water throughout the latter half of 2021, there were no other indicators of reactor operations, such as steam emissions from the generator building.[13]

The Yongbyon complex's Thermal Plant—which supplies steam to the Radiochemical Laboratory used for plutonium reprocessing—operated between February 2021 and July 2021 after a multi-year hiatus.[14] The IAEA noted in August 2021 that 'this five-month timeframe is consistent with the time required to reprocess a complete core of irradiated fuel', which could indicate the possible completion of a new reprocessing campaign in 2021.[15]

[10] 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.

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

[12] 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.

[13] Pabian, Town and Liu (note 12); and Heinonen, O., Liu, J. and Pitz, S. J., 'North Korea's Yongbyon nuclear complex: 5 MWe reactor may still be operating', 38 North, 8 Oct. 2021.

[14] Makowsky, P., Pabian, F. and Liu, J., 'North Korea's Yongbyon nuclear center: Signs of activity at the radiochemical laboratory facilities', 38 North, 3 Mar. 2021; Pabian, F. et al., 'North Korea's Yongbyon nuclear center: Reprocessing status remains unclear', 38 North, 7 Apr. 2021; and Bermudez Jr, J. S. et al., 'Thermal imagery indicates activity at Yongbyon nuclear reprocessing facilities', Beyond Parallel, 15 Apr. 2021.

[15] 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.

Throughout 2021, commercial satellite imagery indicated that North Korea continued construction of a new experimental light water reactor (ELWR), which will eventually be capable of producing plutonium for nuclear weapons. The 2021 IAEA report noted that North Korea may have conducted infrastructure tests at the ELWR in March and April, but that 'it is not possible to estimate when the reactor could become operational'.[16]

In April 2021 Siegfried Hecker—the former Los Alamos National Laboratory director who was given unprecedented access to North Korean nuclear facilities over several years—estimated that North Korea's plutonium stocks were likely to be between 25 and 48 kilograms and could increase by up to 6 kg per year at full operation.[17]

Uranium enrichment capabilities

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.[18] 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. In September 2021 a report by the United Nations panel of experts assessed that North Korea continued to conduct activities at the gas centrifuge enrichment plant located at the Yongbyon complex, and noted the presence of what might have been a liquid nitrogen tank trailer at the site in April 2021—possibly indicating that the plant was operational.[19] Additionally, satellite imagery analysis indicates that North Korea is expanding this uranium enrichment plant, possibly by adding up to 1000 new centrifuges—thus potentially increasing the plant's enrichment capacity by up to 25 per cent.[20]

Using commercial satellite imagery, several non-governmental researchers have identified an additional suspected covert uranium enrichment plant located at Kangson (or Kangsong), to the south-west of Pyongyang.[21] The

[16] IAEA, GOV/2021/40-GC(65)/22 (note 15), para. 12.

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

[18] Bermudez Jr, 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, 8 Nov. 2021; and Bermudez Jr, 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, 26 Mar. 2021.

[19] United Nations, Security Council, Midterm report of the Panel of Experts submitted pursuant to resolution 2569 (2021), S/2021/777, 8 Sep. 2021, pp. 6–7.

[20] 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.

[21] 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', Institute for Science and International Security Imagery Brief, 2 Oct. 2018.

2021 IAEA report noted that 'the Kangson complex shares infrastructure characteristics with the reported centrifuge enrichment facility at Yongbyon', and that its construction matched the IAEA's understanding of the construction sequence of North Korea's uranium enrichment plant.[22] However, the 2021 UN panel of experts report cautioned that, without access to the plant, it was not possible to confirm the nature and purpose of the activities being conducted on-site.[23] A classified intelligence assessment by the USA in 2018 reportedly concluded that North Korea probably had more than one covert uranium enrichment plant and that the country was seeking to conceal the types and numbers of production facilities in its nuclear weapon programme, although a more recent open-source assessment concluded that the increased production capacity at Pyongsan indicates that North Korea does not require another uranium milling facility of comparable size.[24]

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. North Korea has demonstrated a thermonuclear capability (or a capability with suspected thermonuclear yield) once, in 2017.[25] There is no open-source evidence or state intelligence confirming North Korea's capability to deliver an operational nuclear warhead on an intercontinental ballistic missile (ICBM). Moreover, most of North Korea's nuclear tests demonstrated yields in the range of 5–15 kilotons. 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 a medium-range ballistic missile (MRBM) or possibly by an intermediate-range ballistic missile (IRBM).[26] For this reason, SIPRI estimates that North Korea could potentially produce 45–55 nuclear weapons with its inventory of fissile material as at January 2022; however, it is likely that the number of operational warheads is smaller, perhaps closer to 20.[27] This falls within the range offered by a July 2020 US Army study that stated: 'Estimates for North Korean nuclear weapons range from 20–60 bombs, with the capability

[22] IAEA, GOV/2021/40-GC(65)/22 (note 15), para. 14.

[23] United Nations, S/2021/777 (note 19), p. 7.

[24] 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; Nakashima, E. and Warrick, J., 'North Korea working to conceal key aspects of its nuclear program, US officials say', *Washington Post*, 1 July 2018; and 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), pp. 111–44.

[25] Fedchenko (note 4).

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

[27] For additional assessments see 'Estimating North Korea's nuclear stockpiles' (note 17).

to produce 6 new devices each year.'[28] Although North Korea demolished tunnels and facilities at its nuclear test site in 2018, satellite images in 2021 and early 2022 indicated that the site had not been abandoned but kept in caretaker status, potentially allowing nuclear testing to resume.[29]

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.[30] Since 2016, it has pursued development and production of several missile systems with progressively longer ranges and increasingly sophisticated delivery capabilities.[31] 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.[32]

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, while the ICBMs being developed to fulfil the nuclear role specified in North Korea's military doctrine have not yet demonstrated a reliable atmospheric re-entry vehicle or a capability for terminal-stage guidance and warhead activation.[33] As such, it remains unclear whether North Korea's missiles would be able to deliver reliably a nuclear warhead to an intercontinental-range target without further development.[34]

It must be emphasized that inclusion of a specific North Korean missile in the following overview and in table 10.10 does not necessarily indicate that it is confirmed as nuclear-capable or as having a nuclear role.

Short-range ballistic missiles

As of January 2022, North Korea had several types of SRBM, including older liquid-fuelled systems, possibly based on Soviet R-17 Scud missiles, and newer

[28] United States Army, 'North Korean tactics', Army Techniques Publication no. 7-100.2, 24 July 2020, pp. 1–11.

[29] Lee, C., 'North Korea's saber-rattling rekindles nuclear test site questions', VOA, 26 Jan. 2022.

[30] 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).

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

[32] Bermudez Jr, J. S. and Cha, V., 'Undeclared North Korea: The Yusang-ni missile operating base', Beyond Parallel, 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.

[33] Ali, I., 'US general says North Korea not demonstrated all components of ICBM', Reuters, 30 Jan. 2018; and Cohen, Z., Starr, B. and Crawford, J., 'Top general warns US may not see a North Korean attack coming', CNN, 27 Mar. 2019.

[34] Elleman, M., 'Does size matter? North Korea's newest ICBM', 38 North, 21 Oct. 2020.

solid-fuelled missiles of indigenous design. These newer missiles, known as the KN23, KN24 and KN25, have been tested more than 35 times since the beginning of 2019.[35] North Korea has also been modernizing its older SRBMs by equipping them with manoeuverable re-entry vehicles designed to evade regional (e.g. South Korean) missile-defence systems.[36] Notably, in September 2021 North Korea launched two KN23 SRBMs using a rail-mobile launcher for the first time; following the successful test, North Korea announced its intention to expand the regiment into a brigade, which could eventually consist of nine launchers with 18 KN23s.[37] Rail-mobile launchers would enable North Korea to move missiles around the country rapidly and significantly increase the survivability of its second-strike force.

While the older, less accurate SRBMs might have been developed with dual capability, there is no publicly available, authoritative information confirming a nuclear delivery role for the newer, more accurate SRBMs—although as noted above, in a May 2021 speech, Kim Jong Un hinted that North Korea's shorter-range systems might have a 'tactical' (i.e. non-strategic) nuclear role.[38] Independent assessments have suggested that a nuclear device that North Korea displayed in 2017—if, indeed, it was a functional nuclear device—might be too large to fit into these newer SRBMs.[39] However, if North Korea has miniaturized its nuclear warheads as claimed, these types of missile could be used in a dual-capable role to target US military facilities south of Seoul.

Medium- and intermediate-range ballistic missiles

Assuming that North Korea is able to produce a sufficiently compact warhead, the country's three types of MRBM—all of which were probably operational as of January 2022—are considered to be its most likely nuclear delivery systems. These three types include the single-stage, liquid-fuelled Hwasong-7 (Nodong/Rodong); the single-stage, liquid-fuelled Hwasong-9 (KN04/Scud-ER); and the two-stage, solid-fuelled Pukguksong-2 (KN15), a land-based variant of the Pukguksong-1 (KN11) SLBM.[40] All three missiles

[35] James Martin Center for Nonproliferation Studies (note 31).

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

[37] Korean Central News Agency, 'Secretary Pak Jong Chon guides launching drill of Railway Mobile Missile Regiment for inspection', KCNA Watch, 16 Sep. 2021; Xu, T., Shin, J. and Furukawa, K., 'The first DPRK missile launch from a rail-mobile launcher', Open Nuclear Network, 17 Sep. 2021; and Bermudez Jr, J. S., 'What is the significance of North Korea's rail-mobile ballistic missile launcher?', Beyond Parallel, 30 Sep. 2021.

[38] North Korean Ministry of Foreign Affairs, 'Great programme for struggle leading Korean-style socialist construction to fresh victory on report made by Supreme Leader Kim Jong Un at Eighth Congress of WPK', *Rodong Sinmun*, 9 Jan. 2021, available via KCNA Watch.

[39] Elleman, M., 'Preliminary assessment of the KN-24 missile launches', 38 North, 25 Mar. 2020.

[40] For the missiles and submarines discussed in this section, a designation in parentheses (e.g. Nodong/Rodong) following the North Korean designation (e.g. Hwasong-7) is that assigned by the US Department of Defense.

have ranges between 1000 and 1200 km, meaning that they could reach targets anywhere in South Korea or Japan.[41]

North Korea's development of the solid-fuelled Pukguksong-2 might be part of an effort to improve the survivability of its nuclear-capable ballistic missile systems. Solid-fuelled missiles can be fired more quickly than liquid-fuelled systems and require fewer support vehicles that might give away their position to overhead surveillance. In addition, the Pukguksong-2 is coupled with a tracked transporter-erector-launcher (TEL), allowing North Korea to launch it from hidden, off-road sites. Most other systems use wheeled launchers and thus require paved or relatively smooth roads—a rarity in North Korea's mountainous terrain. According to a 2021 UN panel of experts report, North Korea has also developed tracked launchers for some of its newer SRBM systems, including the KN23, KN24 and KN25.[42]

The Hwasong-10 (BM-25/Musudan) is a single-stage, liquid-fuelled missile with an estimated range exceeding 3000 km. The missile has a poor test rate and no flight tests of the Hwasong-10 are known to have been conducted since 2016–17; as such, SIPRI assesses that the Hwasong-10 programme might have been superseded by North Korea's more sophisticated missile programmes—in particular, the Hwasong-12 (KN17), a single-stage IRBM that is believed to have a new liquid-propellant booster engine that is also used for North Korea's ICBM programme.[43] The Hwasong-12 was test launched in 2017 but it is unclear whether it has been operationally deployed.[44]

In September 2021 North Korea tested a new missile called the Hwasong-8, which appeared to include an HGV carried by a modified Hwasong-12 booster. Notably, state media reported that the Hwasong-8 is the first North Korean missile to use a 'fuel ampoule', which involves placing pre-fuelled liquid-fuelled missiles in temperature-controlled canisters to facilitate faster launches.[45]

Intercontinental-range ballistic missiles

As of January 2022, North Korea was widely believed to have prioritized building and deploying an ICBM that could potentially deliver a nuclear warhead to targets in continental USA. However, as mentioned above, considerable uncertainty remained in assessments of North Korea's long-range

[41] United States Air Force (note 30).

[42] United Nations, S/2021/211 (note 32), annex 12.

[43] James Martin Center for Nonproliferation Studies (note 31).

[44] Elleman, M., 'North Korea's Hwasong-12 launch: A disturbing development', 38 North, 30 Aug. 2017.

[45] Korean Central News Agency, 'Hypersonic missile newly developed by Academy of Defence Science test-fired', KCNA Watch, 30 Sep. 2021; and Xu, T., 'Brief on the Defence Development Exhibition of the Democratic People's Republic of Korea', Open Nuclear Network, 18 Oct. 2021.

missile capabilities, and the US Air Force's most recent report, from 2020, did not list any of North Korea's ICBMs as deployed.[46]

The Hwasong-13 (KN08) had not been flight tested as of January 2022 and SIPRI assesses that it is unlikely to become an operational military system. North Korea has twice tested the Hwasong-14 (KN20), a prototype ICBM that first appeared in 2015 at a military parade in Pyongyang, but it is unclear if it was operational in 2021.[47] However, the Hwasong-14 was absent from North Korea's most recent military parade featuring ICBMs, which took place in 2020. This suggests that it may have been superseded by more sophisticated ICBM programmes.[48]

North Korea has been developing a new two-stage ICBM, the Hwasong-15 (KN22), which has a significantly larger second stage and more powerful booster engines than the Hwasong-14, as well as a new liquid-fuelled type of ICBM, the Hwasong-17.[49] The Hwasong-17 (thought to have the US designation KN28) would hypothetically be large enough to accommodate multiple warheads; however, such capabilities have not yet been demonstrated.[50]

In 2019 the US Department of Defense (DOD) indicated that North Korea had deployed one ICBM, the Taepodong-2; however, other official US sources have listed the missile as a space-launch vehicle that would need reconfiguration to be used as an ICBM and therefore it is not included in SIPRI's assessment for January 2022 of North Korean forces with potential nuclear capability.[51]

Cruise missiles

In September 2021 North Korea conducted test launches of a new land-attack cruise missile (LACM) at a claimed speed of roughly 200 metres per second to a range of 1500 km. Although North Korea has other cruise missiles in its arsenal, this is the first system that has been explicitly described as a 'strategic weapon', thus potentially implying a connection to North Korea's nuclear weapon programme.[52] The test launches followed Kim Jong Un's

[46] United States Air Force (note 30).

[47] United States Air Force (note 30), p. 27; Wright, D., 'North Korean ICBM appears able to reach major US cities', Union of Concerned Scientists, 28 July 2017; and Elleman, M., 'North Korea's Hwasong-14 ICBM: New data indicates shorter range than many thought', 38 North, 29 Nov. 2018.

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

[49] For further detail see Kristensen, H. M. and Korda, M., 'North Korean nuclear forces', *SIPRI Yearbook 2021*, p. 402.

[50] Ankit Panda (@nktpnd), 'Real good catch by @ColinZwirko: North Korea's very large road-mobile ICBM seen at the end of the October 2020 is the *Hwasong-17*, NOT Hwasong-16 (KN28 to USIC)', Twitter, 13 Oct. 2021.

[51] United States Department of Defense, *Missile Defense Review 2019* (Office of the Secretary of Defense: Arlington, VA, Jan. 2019); and United States Air Force (note 30), p. 29.

[52] Shin, H. and Smith, J., 'N.Korea tests first "strategic" cruise missile with possible nuclear capability', Reuters, 13 Sep. 2021.

January 2021 statement on pursuing 'tactical' missiles and nuclear weapons.[53] Imagery of the LACM released by North Korean state media indicates that it might include a terminal guidance system—which would improve the missile's accuracy—and that it could be launched from a TEL that carries five missiles.[54] Notably, South Korean news sources subsequently reported that neither South Korea nor the USA were aware of the LACM launch until after the announcement in North Korean state media.[55] Given that this system is designed to circumvent radars and missile-defence systems by flying at lower altitudes on manoeuvrable trajectories, it could offer North Korea a new and unique capability to attack regional targets. Kim Jong Un's statement in January 2021 that this system's 'conventional warheads are the most powerful in the world' indicates that the LACM could either be dual-capable or exclusively conventional.[56]

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.[57] During North Korea's October 2020 military parade, a new type of SLBM was unveiled—the Pukguksong-4, which the UN panel of experts estimates has a maximum range between 3500 and 5400 km for payloads of 1300 kg and 650 kg, respectively.[58] At a military parade in January 2021, North Korea unveiled its new Pukguksong-5. Both the Pukguksong-4 and Pukguksong-5 are two-stage, solid-fuelled missiles and are wider than North Korea's previous Pukguksong SLBMs.[59]

In October 2021 North Korea unveiled a 'new type' of smaller SLBM with an unknown designation at its Defence Development Exhibition.[60] The missile appears to bear similar characteristics to North Korea's newer SRBM designs.[61] The same SLBM, which North Korea described as having 'flank mobility and gliding skip mobility', was reportedly test launched one week

[53] Korean Central News Agency, 'Newly-developed long-range cruise missiles test-fired', KCNA Watch, 13 Sep. 2021; and Van Diepen, V. H., 'Initial analysis of North Korea's "new type long-range cruise missile"', 38 North, 15 Sep. 2021.

[54] Xu (note 45).

[55] See e.g. Lee, C. J., [(Exclusive) 'Both pre- and post-detection of North Korean missiles failed . . . Korea–US information disaster'], *JoongAng*, 13 Sep. 2021 (in Korean).

[56] North Korean Ministry of Foreign Affairs (note 38).

[57] For further detail on North Korea's earlier Pukguksong family of missiles see Kristensen and Korda (note 49), p. 403.

[58] NK News (note 48); and United Nations, S/2021/211 (note 32), annex 11.

[59] United Nations, S/2021/777 (note 19), annex 18-2. The larger diameter of the missiles could potentially indicate that they are designed to carry penetration aids or even multiple warheads; however, such capabilities have not yet been demonstrated.

[60] Xu (note 45).

[61] 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.

later from the port of Sinpo to an approximate range of 590 km, landing in the Sea of Japan.[62] The test's short apogee of 60 km indicates that this new SLBM is likely to have a shorter range than many of the Pukguksong SLBMs.[63] The missile was launched using North Korea's single Gorae-class (Sinpo) experimental submarine, *8.24 Yongung*.[64] This submarine can hold and launch only a single SLBM.

In November 2020 the South Korean National Intelligence Service announced that North Korea was building a new ballistic missile submarine.[65] The vessel, designated Sinpo-C by the US DOD, appears to be based on a modified Project-633 (Romeo) diesel–electric submarine and to be fitted with three missile launch canisters.[66] According to a 2019 report by North Korea's state-run Korean Central News Agency, the submarine's operational deployment was 'near at hand'.[67]

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

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

[64] Korean Central News Agency (note 62); 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 Jr, J. S. and Cha, V., 'Sinpo South shipyard update: SLBM test launch', Beyond Parallel, 21 Oct. 2021.

[65] Bermudez Jr, J. S. and Cha, V., 'Sinpo South shipyard: Construction of a new ballistic missile submarine?', Beyond Parallel, 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.

[66] Hotham, O., 'New North Korean submarine capable of carrying three SLBMs: South Korean MND', NK News, 31 July 2019; and Cha (note 65).

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

X. Global stocks and production of fissile materials, 2021

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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 2021, of HEU (table 10.11) and separated plutonium (table 10.12), including in weapons, and details of the current capacity to produce these materials (tables 10.13 and 10.14, respectively). The timeliness of the information here is constrained by the most recent annual declarations on civilian plutonium and HEU stocks to the International Atomic Energy Agency (IAEA; INFCIRC/549), which give data for 31 December 2020. The information in the tables is based on estimates prepared for the International Panel on Fissile Materials (IPFM).[1]

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). Following mining, which produces a large amount of hazardous mining waste, conversion facilities turn uranium into gaseous uranium-hexafluoride. Using the gas, the concentration of U-235 in the uranium can be increased through isotopic separation (enrichment)—now carried out typically by using gas centrifuges and previously by gaseous diffusion technology.

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 hazardous reprocessing operation that generates large amounts of long-lived radioactive waste and can expose workers to high radiation doses.

[1] For further information see International Panel on Fissile Materials, 'Fissile material stocks', 4 Sep. 2021. For further information on the history, production and use of fissile materials and options for addressing the risks these materials pose see Feiveson, H. A. et al., *Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation* (MIT Press: Cambridge, MA, 2014).

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 typically 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.

The categories for fissile materials used in this section reflect the availability of these materials for weapon purposes. Material described as ‘not directly available for weapons’ is either material produced outside of weapon programmes or weapon-related material that states pledged not to use in weapons. This material, however, is not placed under international safeguards (such as through the IAEA or Euratom) or under bilateral monitoring. Safeguarded or monitored material is listed in a separate category. Starting this year, the data accounts only for unirradiated fissile material, a category that corresponds to the IAEA definition of ‘unirradiated direct use material’.

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.

Table 10.11. Global stocks of highly enriched uranium, 2021

State	Total stock (tonnes)[a]	In weapons/ available for weapons (tonnes)	Not directly available for weapons, unsafeguarded (tonnes)	Not available for weapons, monitored/ under safeguards (tonnes)	Production status
China	14	14 ± 3	–	–	Stopped 1987–89
France[b]	29	25 ± 6	–	3.8	Stopped 1996
India[c]	4.5	–	4.5 ± 1.9	–	Continuing
Iran[d]	0.02	–	0.02	–	Continuing
Israel[e]	0.3	0.3	–	–	Unknown
Korea, North[f]	Uncertain	–	–	–	Uncertain
Pakistan[g]	4	4 ± 1.2	–	–	Continuing
Russia[h]	678	672 ± 120	6[i]	–	Continuing[j]
UK[k]	23	22	0.6[l]	–	Stopped 1962
USA[m]	495	361	134	–	Stopped 1992
Other states[n]	~4	–	–	~4	. .
Total[o]	**1 250**	**1 100**	**145**	**10**	

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

[a] The numbers in the table are for unirradiated highly enriched uranium (HEU). Most of this material is 90–93% enriched uranium-235 (U-235), which is typically considered weapon-grade. The estimates are for the start of 2021. Important exceptions are noted.

[b] A 2014 analysis offers grounds for a significantly lower estimate of the 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 weapon-grade HEU production capacity than previously assumed.

[c] 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%.

[d] The data for Iran is the International Atomic Energy Agency's (IAEA) estimate as of 5 Nov. 2021. Iran started enriching uranium up to 20% on 4 Jan. 2021 and started enriching HEU up to 60% enrichment level on 17 Apr. 2021.

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

[f] North Korea (the Democratic People's Republic of Korea, DPRK) 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 2021 suggest a potential accumulated HEU stockpile in the range 230–1180 kg.

[g] This estimate for Pakistan assumes total HEU production of 4.1 tonnes, of which *c*. 100 kg was used in nuclear weapon tests.

[h] 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 j).

[i] This material is believed to be in use in various civilian as well as military-related research facilities.

[j] 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.

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

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

[m] The amount of HEU held by the United States 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 about 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 2020, the amount available for use had been reduced to *c.* 472.1 tonnes, which is estimated to include 96 tonnes of HEU in naval reserve and 15.2 tonnes reserved for research reactors. Between the end of the US financial year (FY) 2013 (30 Sep. 2013) and the end of FY 2020 (30 Sep. 2020), the amount of material to be downblended was reduced from 41.6 tonnes to 23 tonnes.

[n] The IAEA's 2020 annual report lists 156 significant quantities of HEU under comprehensive safeguards in non-nuclear weapon states as of the end of 2020. Assuming a significant quantity to be 25 kg of HEU, the total mass is estimated to be 4 tonnes. In INFCIRC/912 (from 2017) more than 20 states committed to reducing civilian HEU stocks and providing regular reports. So far, only 2 states 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.

[o] Totals are rounded to the nearest 5 tonnes.

Sources: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, 2015). *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.5/25, 21 Sep. 2021; and Philippe, S. and Glaser, A., 'Nuclear archaeology for gaseous diffusion enrichment plants', *Science & Global Security*, vol. 22, no. 1 (2014), pp. 27–49. *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 by the Director General, GOV/2021/51, 17 Nov. 2021. *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), pp. 721–49. *Russia*: Podvig, P. (ed.), *The Use of Highly-Enriched Uranium as Fuel in Russia* (IPFM: Washington, DC, 2017). *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, 13 Oct. 2021. *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). *Non-nuclear weapon states*: IAEA, *IAEA Annual Report 2020* (IAEA: Vienna, 2020), Annex, Table A4, p. 139; 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 10.12. Global stocks of separated plutonium, 2021

State	Total stock (tonnes)[a]	In weapons/ available for weapons (tonnes)	Not directly available for weapons, unsafeguarded (tonnes)	Not available for weapons, monitored/ under safeguards (tonnes)	Military production status
China	2.9	2.9 ± 0.6	0.04[b]	–	Stopped in 1991
France	85.4	6 ± 1.0	–	79.4[c]	Stopped in 1992
India	9.2	0.71 ± 0.14	8.1 ± 4.3[d]	0.4	Continuing
Israel[e]	0.8	0.83 ± 0.1	–	–	Continuing
Japan	46.1	–	–	46.1[c]	–
Korea, North[f]	0.04	0.04	–	–	Continuing
Pakistan[g]	0.5	0.46 ± 0.16	–	–	Continuing
Russia	191	88 ± 8	88.3[h]	15[i]	Stopped in 2010
UK	119.3	3.2	116.1[c]	–	Stopped in 1995
USA[j]	87.8	38.4	46.4	3[k]	Stopped in 1988
Total[l]	**545**	**140**	**260**	**145**	

– = nil or a negligible value.

[a] Estimates are for the start of 2021. Important exceptions are noted.

[b] These numbers are based on China's INFCIRC/549 declaration to the International Atomic Energy Agency (IAEA) for the end of 2016. As of May 2022, this is the most recent declaration.

[c] The data for France, Japan and the United Kingdom is for the end of 2020, reflecting their most recent respective INFCIRC/549 declarations to the IAEA. Some states with civilian plutonium stocks do not submit an INFCIRC/549 declaration. Of these states, the Netherlands, Spain and Sweden store their plutonium abroad, but the total amounts are too small to be noted in the table.

[d] This 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.

[e] 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 end of 2020. Without tritium production, the stockpile could be as high as 1070 kg.

[f] North Korea (the Democratic People's Republic of Korea, DPRK) reportedly declared a plutonium stock of 37 kg in June 2008. It is believed that it subsequently unloaded its 5 megawatt electric reactor three additional times, in 2009, 2016 and 2018. The stockpile estimate has been reduced to account for North Korea's six nuclear tests. North Korea's reprocessing facility operated again in 2021 for five months.

[g] As of the end of 2020, Pakistan was operating four plutonium production reactors at its Khushab site. This estimate assumes that Pakistan is separating plutonium from all four reactors.

[h] This material includes 63.3 tonnes of separated plutonium declared in Russia's 2021 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.

[i] This material is weapon-grade plutonium produced between 1 Jan. 1995 and 15 Apr. 2010, when the last plutonium production reactor was shut down. It cannot be used for weapon purposes under the terms of a 1997 Russian–United States agreement on plutonium production reactors. The material is currently stored at Zheleznogorsk and is subject to monitoring by US inspectors.

[j] In 2012 the USA declared a government-owned plutonium inventory of 95.4 tonnes as of 30 Sep. 2009. In its 2021 INFCIRC/549 declaration, the most recent submitted, the USA declared 49.4 tonnes of unirradiated plutonium (both separated and in mixed oxide, MOX) as part of the stock identified as excess for military purposes (declaration for 31 Dec. 2020).

[k] The USA has placed about 3 tonnes of its excess plutonium, stored at the K-Area Material Storage Facility at the Savannah River Plant, under IAEA safeguards.

[l] Totals are rounded to the nearest 5 tonnes.

Sources: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, 2015). *Civilian stocks (except for India)*: declarations by countries to the International Atomic Energy Agency (IAEA) under INFCIRC/549. *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), pp. 721–49; 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–United States 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 10.13. Significant uranium enrichment facilities and capacity worldwide, 2021

State	Facility name or location	Type	Status	Enrichment process[a]	Capacity (thousands SWU/yr)[b]
Argentina[c]	Pilcaniyeu	Civilian	Uncertain	GD	20
Brazil	Resende	Civilian	Expanding capacity	GC	45
China[d]	Lanzhou	Civilian	Operational	GC	2 600
	Hanzhong (Shaanxi)	Civilian	Operational	GC	2 000
	Emeishan	Civilian	Operational	GC	1 050
	Heping	Dual-use	Operational	GD	230
France	Georges Besse II	Civilian	Operational	GC	7 500
Germany	Urenco Gronau	Civilian	Operational	GC	3 800
India	Rattehalli	Military	Operational	GC	15–30
Iran[e]	Natanz	Civilian	Limited operation	GC	3.5–10
	Qom (Fordow)	Civilian	Limited operation	GC	0.7–2
Japan	Rokkasho[f]	Civilian	Resuming operation	GC	75
Korea, North	Yongbyon[g]	Uncertain	Operational	GC	8
Netherlands	Urenco Almelo	Civilian	Operational	GC	5 200
Pakistan	Gadwal	Military	Operational	GC	. .
	Kahuta	Military	Operational	GC	15–45
Russia	Angarsk	Civilian	Operational	GC	4 000
	Novouralsk	Civilian	Operational	GC	13 300
	Seversk	Civilian	Operational	GC	3 800
	Zelenogorsk[h]	Civilian	Operational	GC	7 900
UK	Urenco Capenhurst	Civilian	Operational	GC	4 500
USA	Urenco Eunice	Civilian	Operational	GC	4 900

. . = not available or not applicable.

[a] The gas centrifuge (GC) is the main isotope-separation technology used to enrich uranium in uranium-235 (U-235), but a few facilities continue to use gaseous diffusion (GD).

[b] 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.

[c] In Dec. 2015 Argentina announced the reopening of its Pilcaniyeu GD uranium enrichment plant, which was shut down in the 1990s. There is no evidence of actual production.

[d] 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.

[e] In July 2015 Iran agreed the Joint Comprehensive Plan of Action (JCPOA), which ended uranium enrichment at Fordow but kept centrifuges operating and limited the enrichment capacity at Natanz to 5060 IR-1 centrifuges (equivalent to 3500–5000 SWU/yr) for 10 years. Since the withdrawal of the United States from the JCPOA in 2018, Iran has increased enrichment capacities at its facilities. As of 17 Nov. 2021, the International Atomic Energy Agency (IAEA) had verified 5229 IR-1 centrifuges (31 cascades), 1044 IR-2m centrifuges (6 cascades) and 348 IR-4 centrifuges (2 cascades) installed at the Natanz Fuel Enrichment Plant. Highly enriched uranium (HEU) production takes place at the Pilot Fuel Enrichment Plant at Natanz, with a capacity of up to 2000 SWU. At the Fordow Fuel Enrichment Plant, there were 1044 IR-1 and 189 IR-6 centrifuges as of Nov. 2021.

[f] 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.

[g] North Korea (the Democratic People's Republic of Korea, DPRK) revealed its Yongbyon enrichment facility in 2010. It appeared to be operational in 2021. It is believed that North Korea is operating at least one other enrichment facility.

[h] Zelenogorsk operates a centrifuge cascade for HEU production for fast reactor and research reactor fuel.

Sources: Indo-Asian News Service (IANS), 'Argentina president inaugurates enriched uranium plant', *Business Standard*, 1 Dec. 2015; 'Brazil's INB launches new centrifuge cascade', *Nuclear Engineering International*, 25 Nov. 2021; Zhang, H., 'China's uranium enrichment complex', *Science & Global Security*, vol. 23, no. 3 (2015), pp. 171–90; Zhang, H., *China's Fissile Material Production and Stockpile* (International Panel on Fissile Materials, IPFM: Princeton, NJ, 2017); Hecker, S. S., Carlin, R. L. and Serbin, E. A., 'A comprehensive history of North Korea's nuclear program', Stanford University, Center for International Security and Cooperation (CISAC), 2018 update; 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/2021/51, 17 Nov. 2021; and 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/2022/4, 3 Mar. 2022. Enrichment capacity data is based on IAEA, Integrated Nuclear Fuel Cycle Information Systems (iNFCIS); Urenco, 'Global operations', [n.d.]; and IPFM, *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, 2015).

Table 10.14. Significant reprocessing facilities worldwide, 2021

All facilities process light water reactor (LWR) fuel, except where indicated.

State	Facility name or location	Type	Status	Design capacity (tHM/yr)[a]
China[b]	Jiuquan pilot plant	Civilian	Operational	50
France	La Hague UP2	Civilian	Operational	1 000
	La Hague UP3	Civilian	Operational	1 000
India[c]	Kalpakkam (HWR fuel)	Dual-use	Operational	100
	Tarapur (HWR fuel)	Dual-use	Operational	100
	Tarapur-II (HWR fuel)	Dual-use	Operational	100
	Trombay (HWR fuel)	Military	Operational	50
Israel	Dimona (HWR fuel)	Military	Operational	40–100
Japan	JNC Tokai	Civilian	Reprocessing shut down[d]	(was 200)
	Rokkasho	Civilian	Start planned for 2022	800
Korea, North	Yongbyon (GCR fuel)	Military	Operational	100–150
Pakistan	Chashma (HWR fuel)	Military	Starting up	50–100
	Nilore (HWR fuel)	Military	Operational	20–40
Russia[e]	Mayak RT-1, Ozersk	Civilian	Operational	400
	EDC, Zheleznogorsk	Civilian	Starting up	250
UK	Sellafield B205 (Magnox fuel)	Civilian	To be shut down in 2022	1 500
	Sellafield Thorp	Civilian	Shut down in 2018	(was 1 200)
USA	H-canyon, Savannah River Site	Civilian	Operational	15

HWR = heavy water reactor; GCR = gas cooled 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, and heavy water- and graphite-moderated reactor fuels 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–United States 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 a 250 tHM/yr pilot experimental centre 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; and RIA Novosti, [Rosatom is ready to start 'green' processing of spent nuclear fuel], 29 May 2018 (in Russian). 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 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, 2015).