10. World nuclear forces

Overview

At the start of 2021, 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 13 080 nuclear weapons, of which 3825 were deployed with operational forces (see table 10.1). Approximately 2000 of these are 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. North Korea's military nuclear programme remains central to its national security strategy, although in 2020 it did not conduct any tests of nuclear weapons or long-range ballistic missile delivery systems.

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 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 (HEU) or separated plutonium. China, France, Russia, the UK and the USA have produced both HEU and plutonium for use in their nuclear weapons; India and Israel have produced mainly plutonium; and Pakistan has produced mainly HEU but is increasing its ability to produce plutonium.

Table 10.1. World nuclear forces, January 2021

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]	Other warheads	Total inventory
United States	1945	1 800[c]	2 000[d]	1 750[e]	5 550
Russia	1949	1 625[f]	2 870[g]	1 760[e]	6 255
United Kingdom	1952	120	105	–	225[h]
France	1960	280	10[i]	. .	290
China	1964	–	350	–	350
India	1974	–	156	. .	156
Pakistan	1998	–	165	. .	165
Israel	. .	–	90	. .	90
North Korea	2006	–	. .	[40–50]	[40–50][j]
Total[k]		**3 825**	**5 745**	**3 510**	**13 080**

. . = not applicable or not available; – = nil or a negligible value; [ ] = uncertain figure.

Note: SIPRI revises its world nuclear forces data each year based on new information and updates to earlier assessments. The data for Jan. 2021 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 become fully operationally available.

[c] This figure includes approximately 1400 warheads deployed on ballistic missiles and nearly 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.

[d] This figure includes *c.* 130 non-strategic nuclear bombs stored in the USA.

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

[f] This figure includes approximately 1425 strategic warheads on ballistic missiles and about 200 deployed at heavy bomber bases.

[g] This figure includes *c.* 960 strategic and *c.* 1910 non-strategic warheads in central storage.

[h] 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. 2021. A planned reduction to an inventory of 180 warheads by the mid 2020s was ended by a government review undertaken in 2020 and published in early 2021. The review introduced a new ceiling of 260 warheads.

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

[j] This estimate lists the number of warheads North Korea could potentially build with the amount of fissile material it has produced. There is no publicly available evidence that North Korea has produced an operational nuclear warhead for delivery by an intercontinental-range ballistic missile, but it might have a small number of warheads for medium-range ballistic missiles.

[k] These totals do not include figures for North Korea and are rounded to the nearest 5 warheads.

North Korea has produced plutonium for use in nuclear weapons but may have produced HEU as well. All states with a civilian nuclear industry are capable of producing fissile materials (see section X).

HANS M. KRISTENSEN AND MATT KORDA

I. United States nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2021, the United States maintained a military stockpile of approximately 3800 nuclear warheads, roughly the same number as in January 2020. Approximately 1800 of these—consisting of about 1700 strategic and 100 non-strategic (or tactical) warheads—were deployed on aircraft, ballistic missiles and submarines. In addition, about 2000 warheads were held in reserve and around 1750 retired warheads were awaiting dismantlement (250 fewer than the estimate for 2020), giving a total inventory of approximately 5550 nuclear warheads (see table 10.2).

These estimates are based on publicly available information regarding the US nuclear arsenal. In 2010 the USA for the first time declassified the entire history of its nuclear weapon stockpile size, but since 2019 there has been a shift towards a lower level of transparency.[1] This was evidenced by the fact that in 2020, as had been the case in 2019, the US administration of President Donald J. Trump declined to declassify the number of nuclear weapons in the stockpile and the number of retired warheads that had been dismantled over the year.[2] The refusal, which was not explained, provided political cover for other nuclear-armed states to be less transparent and made an accurate independent assessment of the US nuclear arsenal significantly harder.

In 2020 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.[3] The numbers of deployed warheads presented below 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—and does not count warheads stored at bomber bases.

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

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

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

[3] 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 2021

All figures are approximate and some are based on assessments by the authors. Totals for strategic and non-strategic forces are rounded to the nearest 5 warheads.

Type	Designation	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads[b]
Strategic nuclear forces						**3 570**
Aircraft (bombers)		*107/66*[c]				*848*[d]
B-52H	Stratofortress	87/46	1961	16 000	20 x ALCMs 5–150 kt[e]	528[f]
B-2A	Spirit	20/20	1994	11 000	16 x B61-7,-11, B83-1 bombs[g]	320
Land-based missiles (ICBMs)		*400*				*800*[h]
LGM-30G	Minuteman III					
	Mk12A	200	1979	13 000	1–3 x W78 335 kt	600[i]
	Mk21 SERV	200	2006	13 000	1 x W87 300 kt	200[j]
Sea-based missiles (SLBMs)		*14/280*[k]				*1 920*[l]
UGM-133A	Trident II (D5/D5LE)					
	Mk4	. .	1992	>12 000	1–8 x W76-0 100 kt	–[m]
	Mk4A	. .	2008	>12 000	1–8 x W76-1 90 kt	1 511
	Mk4A	. .	2019	>12 000	1 x W76-2 8 kt	25[n]
	Mk5	. .	1990	>12 000	1–8 x W88 455 kt	384
Non-strategic nuclear forces						230[o]
F-15E	Strike Eagle	. .	1988	3 840	5 x B61-3, -4[p]	80
F-16C/D	Falcon	. .	1987	3 200[q]	2 x B61-3, -4	70
F-16MLU	Falcon (NATO)	. .	1985	3 200	2 x B61-3, -4	40
PA-200	Tornado (NATO)	. .	1983	2 400	2 x B61-3, -4	40
Total stockpile						**3 800**[r]
Deployed warheads						1 800[s]
Reserve warheads						2 000
Retired warheads awaiting dismantlement[t]						**1 750**
Total inventory						**5 550**[u]

. . = 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.

Note: The table lists the total number of warheads estimated to be available for the delivery systems. Only some of these are deployed and the strategic warheads do not necessarily correspond to the data-counting rules of the 2010 Russian–US Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START).

[a] For aircraft, the listed range refers to the maximum unrefuelled range. All nuclear-equipped aircraft can be refuelled in the air. Actual mission range will vary according to flight profile, weapon loading and in-flight refuelling.

[b] These numbers show the total number of warheads estimated to be assigned to nuclear-capable delivery systems. Only some of these warheads are deployed on missiles and at air bases.

[c] The first figure is the total number of bombers in the inventory; the second is the number equipped for nuclear weapons. The USA has declared that it will deploy no more than 60 nuclear bombers at any time but normally only about 50 nuclear bombers are deployed, with the remaining aircraft in overhaul.

[d] Of the *c*. 848 bomber weapons, *c*. 300 (200 ALCMs and 100 bombs) are deployed at the bomber bases; all the rest are in central storage. Many of the gravity bombs are no longer fully active and are slated for retirement after the B61-12 is fielded in the early 2020s.

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

[f] In 2006 the Department of Defense decided to reduce the future ALCM fleet to 528 missiles. It is possible the inventory has been reduced slightly since then. Burg., R. (Maj. Gen.), 'ICBMs, helicopters, cruise missiles, bombers and warheads', Statement, US Senate, Armed Services Committee, Strategic Forces Subcommittee, 28. Mar. 2007, p. 7.

[g] Strategic gravity bombs are only assigned to B-2A bombers. 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. The administration of President Barack Obama decided that the B83-1 would be retired once the B61-12 is deployed, but the 2018 Nuclear Posture Review indicates that the B83-1 might be retained for a longer period.

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

[i] Only 200 of these W78 warheads are deployed; all the rest are in central storage.

[j] 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.

[k] 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. As of Sep. 2020, the New START aggregate data listed 11 SSBNs deployed with 220 SLBMs.

[l] Of the 1920 SLBM warheads, just over 1000 are deployed on submarines; all the rest are 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 downloaded 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.

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

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

[o] Approximately 100 of the 230 tactical bombs are thought to be deployed across 6 NATO airbases outside the USA. The remaining bombs are in central storage in the USA. Older B61 versions will be dismantled once the B61-12 is deployed.

[p] 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 km, but Lockheed Martin, which produces the F-16, lists 3200 km.

[r] Of these 3800 weapons, approximately 1800 are deployed on ballistic missiles, at bomber bases in the USA and at 6 NATO airbases outside the USA; all the rest are in central storage.

[s] The deployed warhead number in this table differs from the number declared under New START because the treaty attributes 1 warhead per deployed bomber—even though bombers do not carry warheads under normal circumstances—and does not count warheads stored at bomber bases.

[t] 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. Based on previous performance and the completion of the W76-1 life-extension programme, SIPRI estimates that roughly 250 (but possibly more) retired warheads were dismantled during 2020.

[u] In addition to these intact warheads, more than 20 000 plutonium pits are stored at the Pantex Plant, Texas, and perhaps 4000 uranium secondaries are 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; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and author's estimates.

partners.'[4] The NPR further clarifies that the USA reserves the right to use nuclear weapons first 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'.[5]

The USA continued to implement the 2018 NPR throughout 2020. This included a 25 per cent increase in funding in financial year 2021 for the US National Nuclear Security Administration (NNSA), which, among other things, oversees nuclear warhead research, development and acquisition programmes.[6] The Trump administration continued to implement several large-scale nuclear weapon programmes initiated under the administration of President Barack Obama, including modernization programmes for all three legs of the nuclear triad. The Trump administration also continued to implement several of its own newer non-strategic nuclear weapon programmes. For example, in 2020 the USA completed the deployment of low-yield W76-2 nuclear warheads on its fleet of nuclear-powered ballistic missile submarines (SSBNs) in the Atlantic and Pacific oceans, and it made progress in its plans to field a new nuclear-armed sea-launched cruise missile (SLCM-N; see below).

The 2018 NPR's justification for the deployment of low-yield warheads and the development of the SLCM-N reflected important doctrinal changes in US nuclear 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 escalating to first use of non-strategic nuclear weapons, in the event that Russia perceived it was about to lose a conventional war.[7] However, there is little publicly available evidence of such a shift in Russia's nuclear doc-

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

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

[6] Woolf, A. F., *Energy and Water Development Appropriations: Nuclear Weapons Activities*, Congressional Research Service (CRS) Report for Congress R44442 (US Congress, CRS: Washington, DC, 22 Dec. 2020), p. i. The US financial year starts on 1 Oct. of the year before the named year and ends on 30 Sep. On US military expenditure see chapter 8, section I, in this volume.

[7] US Department of Defense (note 4), pp. 8, 53–55.

trine.[8] Both the W76-2 and SLCM-N are explicitly intended to restrengthen US non-strategic nuclear weapon operations, which had seemingly reduced in importance for the US military since the end of the cold war. Notably, a 2020 paper by the US Department of Defense (DOD) suggests that the SLCM-N will 'provid[e] additional limited employment capabilities that an adversary will have to consider if contemplating the coercive use of nuclear weapons', and the NPR states that the weapons 'expand the range of credible US options for responding to nuclear or non-nuclear strategic attack'.[9] However, a nuclear attack in response to non-nuclear strategic attacks would constitute first use of nuclear weapons—the very act that the NPR criticizes Russia for including in its presumed doctrine.

Based on the more aggressive nuclear posture set out by the NPR, at the end of 2020 the Trump administration disclosed plans to develop an entirely new nuclear warhead, known as the W93 (see below).[10] This would be the first brand-new warhead developed by the USA since the end of the cold war. The W93 was part of a much broader nuclear weapon modernization plan presented in the NNSA's Nuclear Weapons Stockpile and Management Plan, which doubled the number of new nuclear warhead programmes compared with the previous plan published in 2019.[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 2020. SIPRI estimates that a total of 3570 nuclear warheads are assigned to the triad, of which an estimated 1700 warheads are deployed on missiles and at bomber bases.

[8] Bruusgaard, K. V., '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), May 2016.

[9] US Office of the Under Secretary of Defense for Policy, *Strengthening Deterrence and Reducing Nuclear Risks*, part II, *The Sea-Launched Cruise Missile-Nuclear (SLCM-N)* (US Department of State, Office of the Under Secretary of State for Arms Control and International Security: Washington, DC, 23 July 2020), p. 3; and US Department of Defense (note 4), p. xiii. For a summary and other details of the Nuclear Posture Review see Kristensen, H. M., 'US nuclear forces', *SIPRI Yearbook 2019*, pp. 289–94.

[10] 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. 2–6. See also Kristensen, H. M., 'NNSA nuclear plan shows more weapons, increasing costs, less transparency', Federation of American Scientists (FAS) Strategic Security Blog, 30 Dec. 2020.

[11] US Department of Energy (note 10).

Aircraft and air-delivered weapons

The US Air Force (USAF) currently operates a fleet of 169 heavy bombers: 62 B-1Bs, 20 B-2As and 87 B-52Hs. Of these, 66 (20 B-2As and 46 B-52Hs) are nuclear-capable. 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 almost 850 warheads are assigned to strategic bombers, of which about 300 are deployed at bomber bases and ready for delivery on relatively short notice.

Both the B-2As and B-52Hs are undergoing modernization intended to improve their ability to receive and transmit secure nuclear mission data. This includes the ability to communicate with the Advanced Extreme High Frequency (AEHF) satellite network used by the US president and military leadership to transmit launch orders and manage nuclear operations.[12]

The development of the next-generation long-range strike bomber, known as the B-21 Raider, is well under way and the first two test aircraft are being constructed.[13] The B-21 will be capable of delivering two types of nuclear weapon: the B61-12 guided nuclear gravity bomb, which is nearing full-scale production and will also be deliverable from shorter-range non-strategic aircraft (see below); and the Long-Range Standoff Weapon (LRSO) ALCM, which is in development. The new bomber is scheduled to enter service in the mid 2020s.[14] The B-21 will replace the B-1B and B-2A bombers at Dyess Air Force Base (AFB) in Texas, Ellsworth AFB in South Dakota, and Whiteman AFB in Missouri.[15] The nuclear-capable B-21 will also replace non-nuclear B-1B bombers and entail 'the reintroduction of nuclear mission requirements'.[16] The number of US bomber bases with nuclear weapon storage capability is thus expected to increase from two as of January 2021 to five by the early 2030s.[17] The USAF plans to acquire at least 100 (but possibly as many as 145) B-21 bombers by the mid 2030s.[18] However, the final number will be determined by funding decisions made by the US Congress.

[12] 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.

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

[14] Gertler, J., *Air Force B-21 Raider Long-range Strike Bomber*, Congressional Research Service (CRS) Report for Congress R44463 (US Congress, CRS: Washington, DC, 13 Nov. 2019), p. 10.

[15] US Air Force, Secretary of the Air Force Public Affairs, 'Air force selects locations for B-21 aircraft', 2 May 2018.

[16] 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.

[17] Kristensen, H. M., 'USAF plans to expand nuclear bomber bases', Federation of American Scientists (FAS) Strategic Security Blog, 17 Nov. 2020.

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

Land-based missiles

As of January 2021, the USA deployed 400 Minuteman III ICBMs in 450 silos across three missile wings. The 50 empty silos are kept in a state of readiness and can be reloaded with stored missiles if necessary.[19]

Each Minuteman III ICBM is armed with one warhead: either a 335-kiloton W78 or a 300-kt W87. The W78 warhead is carried in the Mk12A re-entry vehicle and the W87 is carried in the Mk21 re-entry vehicle. 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). SIPRI estimates that there are 800 warheads assigned to the ICBM force, of which 400 are deployed on the missiles.

The USAF has begun development of a next-generation ICBM, the Ground Based Strategic Deterrent (GBSD). It is scheduled to begin replacing the Minuteman III in 2028, with full replacement by 2036.[20] On 8 December 2020 the USAF awarded a $13.3 billion engineering and manufacturing development contract to Northrop Grumman Corporation—the sole bidder for the GBSD contract. According to the USAF, the GBSD is a 'modular design' with 'evolutionary warfighting effectiveness' that will give the US ICBM force 'increased accuracy, extended range and improved reliability'.[21] It has not yet publicly provided a rationale for why these enhanced capabilities are needed for the ICBM mission.

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. The total projected cost rose from $62.5 billion in 2015 to $95.8 billion in 2020.[22] For the 10-year period 2019–28 alone, the US Congressional Budget Office (CBO) in 2019 projected that the cost would be $61 billion, $18 billion higher than the 2017 estimate for 2017–26.[23] The cost is 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. Initially, some of these will also be used to arm the current Minuteman III for the remainder of its service life. The W87/Mk21 is being

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

[20] Richard, C. A., Commander, US Strategic Command, Statement, US Senate, Armed Services Committee, 13 Feb. 2020, p. 9.

[21] US Air Force, Secretary of the Air Force Public Affairs, 'Department of the Air Force awards contract for new ICBM that enhances, strengthens US triad', 8 Sep. 2020.

[22] 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', Associated Press, 20 Oct. 2020.

[23] Bennett, M., 'Projected costs of US nuclear forces, 2019 to 2028', US Congressional Budget Office, Jan. 2019, p. 9.

upgraded with a new arming, fusing and firing unit, and the W78/Mk12A will be replaced entirely. The replacement warhead was formerly known as the Interoperable Warhead 1 (IW1), but in 2018 it was given the designation W87-1 to reflect the fact that it will use a plutonium pit similar to that of the W87, with insensitive high explosives (IHE) instead of the conventional high explosives (CHE) used in the W78.[24] The projected cost of the W87-1 programme is between $11.8 billion and $15 billion, but this estimate does not include costs associated with production of plutonium pits for the W87-1.[25]

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.[26] 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 Trident II D5 SLBMs carry two basic warhead types. These are the 455-kt W88 and the W76, which exists in two versions: the 90-kt W76-1 and the low-yield W76-2.[27] The W88 warhead is carried in the Mk5 re-entry body (aeroshell); the W76-1 and W76-2 warheads each use the Mk4A re-entry body. The Mk4A is equipped with a new fuse that improves its damage effectiveness.[28] Each SLBM can carry up to eight warheads but normally carries an average of four to five. SIPRI estimates that around 1920 warheads are assigned to the SSBN fleet, of which about 1000 are currently deployed on missiles.[29]

[24] Padilla, M., 'Sandia on target for first Mk21 Fuze flight test in 2018', *Sandia LabNews*, vol. 70, no. 6 (16 Mar. 2018); and US Department of Energy, National Nuclear Security Administration (NNSA), *W78 Replacement Program (W87-1): Cost Estimates and Use of Insensitive High Explosives*, Report to Congress (NNSA: Washington, DC, Dec. 2018), pp. III, 7.

[25] US Department of Energy (note 10), pp. 5–32, 5–33.

[26] US Navy Office of Information, 'Fleet ballistic missile submarines—SSBN', America's Navy, 29 Jan. 2019.

[27] The older W76-0 version has been, or remains in the process of being, retired.

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

[29] 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 onboard the USS *Tennessee* (SSBN-734) in the Atlantic Ocean and is now deployed on SSBNs in both the Atlantic and the Pacific.[30] It is a modification of the W76-1 and is estimated to have an explosive yield of about 8 kt.[31] As noted above, the 2018 NPR claims that the warhead is needed to deter Russia from the first use of low-yield non-strategic nuclear weapons, even though the USA already has an estimated 1050 air-delivered weapons with low-yield options in its inventory.[32]

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'). The upgrade is scheduled to be completed in 2024.[33] The D5LE is equipped with the new Mk6 guidance system. 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 these will eventually be replaced with an upgraded SLBM, the D5LE2, starting in 2039.[34] The first Columbia-class SSBN—the USS *Columbia* (SSBN-826)—is scheduled to start patrols in 2031.

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. The W93 warhead will be housed in a new Mk7 re-entry body (aeroshell) that will also be delivered to the British Royal Navy. According to the DOD, the W93/Mk7 will be lighter than existing SLBM warheads, even though it will use IHE instead of CHE to increase safety. It will 'allow for more efficient targeting by expanding the footprint of targets the warhead can hit, thereby increasing targeting flexibility and efficiency', which will 'improve the SSBN force's ability to hold all targets in current plans at risk'.[35] Production is scheduled to begin in the mid 2030s.[36]

[30] Arkin, W. M. and Kristensen, H. M., 'US deploys new low-yield nuclear submarine warhead', Federation of American Scientists (FAS) Strategic Security Blog, 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.

[31] US military officials, Private communications with authors, 2019–20.

[32] US Department of Defense (note 4), p. 54–55; and Kristensen, H. M., 'The flawed push for new nuclear weapons capabilities', Federation of American Scientists (FAS) Strategic Security Blog, 29 June 2017. This estimate covers strategic and non-strategic weapons but does not include the B61-11, which has a single high-yield option.

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

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

[35] US Department of Defense, 'W93/Mk7 Navy warhead: Developing modern capabilities to address current and future threats', May 2020, p. 2. Part of this document is available online.

[36] US Department of Defense (note 35), p. 2.

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 currently has 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.[37] An estimated 230 tactical B61 bombs remain in the stockpile.

SIPRI estimates that the USA deploys approximately 100 of the bombs for potential use by fighter-bomber aircraft at six airbases 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.[38] The remaining (*c*. 130) B61 bombs 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.[39]

The USA is close to completing the development of the 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; delivery is now expected to take place in 2022.[40] The new version is equipped with a guided tail kit that enables it to hit targets more accurately, meaning that it could be used with a lower yield and potentially produce less radioactive fallout.[41]

Operations to integrate the incoming B61-12 on existing USAF and NATO aircraft continued in 2020. The USAF plans to integrate the B61-12 on seven types of US- and allied-operated aircraft: 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).[42] Germany plans to retire its Tornado aircraft by 2030. To allow continued participation in the NATO nuclear strike mission, Germany would need replacement nuclear-capable aircraft. In 2020 there were unconfirmed reports that the

[37] 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), figure 1-7, pp. 1–13.

[38] For a detailed overview of the dual-capable aircraft programmes of the USA and its NATO allies see Kristensen (note 9), pp. 299–300; and Andreasen, S. et al., *Building a Safe, Secure, and Credible NATO Nuclear Posture* (Nuclear Threat Initiative: Washington, DC, Jan. 2018).

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

[40] Gould, J. and Mehta, A., 'Nuclear gravity bomb and warhead upgrades face new delays', *Defense News*, 4 Sep. 2019; and Trevithick, J., 'F-15E Strike Eagle first jet cleared to employ Air Force's new B61-12 nuclear bombs', The Drive, 8 June 2020.

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

[42] US Air Force (USAF), *Acquisition Annual Report Fiscal Year 2018: Cost-effective Modernization* (USAF: Arlington, VA, [2019]), p. 24.

German Federal Ministry of Defence had decided to acquire 30 US-made F/A/18 Super Hornets and upgrade them to be capable of delivering the new B61-12 nuclear bomb.[43] However, the German Government denied that a decision had been made on the nuclear strike mission.[44]

Navy weapons

As noted above, the 2018 NPR established a requirement for a new nuclear-armed SLCM—the SLCM-N.[45] In 2019 the US Navy began an 'analysis of alternatives' study for the new weapon. Its Strategic Systems Programs office has been directed to complete the study in time for inclusion in the presidential budget request for financial year 2022.[46]

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.[47] If the administration of President Joe Biden continues 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 increase in the size of the US nuclear weapon stockpile since 1996.

[43] Gebauer, M. and von Hammerstein, K., 'Kramp-Karrenbauer sagt Washington Kauf von US-Kampfjets zu' [Kramp-Karrenbauer promises Washington to buy US fighter jets], *Der Spiegel*, 19 Apr. 2020.

[44] Zeitvogel, K., 'Germany won't be buying US planes to replace aging Tornados before 2022, official says', *Stars and Stripes*, 23 Apr. 2020.

[45] US Department of Defense (note 4), pp. 54–55.

[46] Wolfe (note 34), p. 8.

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

II. Russian nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2021, Russia maintained a military stockpile of approximately 4495 nuclear warheads—around 180 more than the estimate for January 2020. About 2585 of these were offensive strategic warheads, of which roughly 1625 were deployed on land- and sea-based ballistic missiles and at bomber bases. Russia also possessed approximately 1910 non-strategic (tactical) nuclear warheads—a slight increase compared with the estimate for January 2020, largely due to the Russian Navy's fielding of dual-capable non-strategic weapons. All of the non-strategic warheads are thought to be at central storage sites.[1] An estimated additional 1760 retired warheads were awaiting dismantlement (300 fewer than the estimate for 2020), giving a total inventory of approximately 6255 warheads (see table 10.3).

These estimates are based on publicly available information about the Russian nuclear arsenal. 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.

In 2020 Russia remained 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).[2] This treaty places a cap on the numbers of Russian and US deployed strategic nuclear forces. The numbers of deployed warheads reported under New START differ from the estimates presented here because the treaty attributes one weapon to each deployed bomber—even though bombers do not carry weapons under normal circumstances—and does not count warheads stored at bomber bases.

[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] 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. 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.

The role of nuclear weapons in Russian military doctrine

In June 2020 Russian President Vladimir Putin approved an update to the Basic Principles of State Policy of the Russian Federation on Nuclear Deterrence. Russia's deterrence policy 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'.[3] This formulation is consistent with previous public iterations of Russian nuclear policy, and the timing of the policy update is probably intended to push back against the claim in the USA's 2018 Nuclear Posture Review that Russia might use nuclear weapons early in a conflict to 'de-escalate' it on favourable terms (see section I).[4]

Strategic nuclear forces

As of January 2021, Russia had an estimated 2585 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 an increase of approximately 145 warheads compared with January 2020, due to the fielding of RS-24 Yars (SS-27 Mod 2) ICBMs and the fourth Borei-class nuclear-powered ballistic missile submarine (SSBN).[5]

Aircraft and air-delivered weapons

Russia's Long-Range Aviation command operates a fleet of approximately 13 Tu-160 (Blackjack) and 55 Tu-95MS (Bear) bombers.[6] Not all of these are fully operational and some are undergoing various upgrades. The maximum possible loading on the bombers is nearly 740 nuclear weapons but, since only some of the bombers are fully operational, it is estimated here that the number of assigned weapons is lower—around 580. SIPRI estimates that approximately 200 of these might be deployed and stored at the two strategic bomber bases: Engels in Saratov oblast and Ukrainka in Amur

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

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

[5] For the missiles, aircraft and submarines discussed here, a designation in parentheses (in this case SS-27 Mod 2) following the Russian designation (in this case RS-24 Yars) is that assigned by the North Atlantic Treaty Organization (NATO).

[6] The Tu-95MS exists in 2 versions: the Tu-95MS16 (Bear-H16) and the Tu-95MS6 (Bear-H6).

Table 10.3. Russian nuclear forces, January 2021

All figures are approximate and are estimates based on assessments by the authors. Totals for strategic and non-strategic forces are rounded to the nearest 5 warheads.

Type/ Russian designation (NATO designation)	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads[b]
Strategic nuclear forces					**2 585**[c]
Aircraft (bombers)	*68/50*[d]				*580*[e]
Tu-95MS/M (Bear-H)[f]	55/39	1981	6 500–10 500	6–16 x 200 kt AS-15A or AS-23B ALCMs	448
Tu-160/M (Blackjack)	13/11	1987	10 500–13 200	12 x 200 kt AS-15B or AS-23B ALCMs, bombs	132
Land-based missiles (ICBMs)	*310*				*1 189*[g]
RS-20V (SS-18 Satan)	46	1992	11 000–15 000	10 x 500–800 kt	460
RS-18 (SS-19 Stiletto)	. .	1980	10 000	6 x 400 kt	. .[h]
Avangard (SS-19 Mod 4)[i]	4	2019	10 000	1 x HGV [400 kt]	4
RS-12M Topol (SS-25 Sickle)	27	1985	10 500	1 x 800 kt	27
RS-12M2 Topol-M (SS-27 Mod 1/silo)	60	1997	10 500	1 x 800 kt	60
RS-12M1 Topol-M (SS-27 Mod 1/mobile)	18	2006	10 500	1 x [800 kt]	18
RS-24 Yars (SS-27 Mod 2/mobile)	135	2010	10 500	4 x [100 kt]	540
RS-24 Yars (SS-27 Mod 2/silo)	20	2014	10 500	4 x [100 kt]	80
RS-28 Sarmat (SS-X-29)	. .	[2021]	>10 000	MIRV [. . kt]	. .
Sea-based missiles (SLBMs)	*11/176*[j]				*816*[k]
RSM-50 Volna (SS-N-18 M1 Stingray)	1/16	1978	6 500	3 x 50 kt	48
RSM-54 Sineva (SS-N-23 M1)	6/96	1986/2007	9 000	4 x 100 kt	384
RSM-56 Bulava (SS-N-32)	4/64	2014	>8 050	6 x [100 kt]	384
Non-strategic nuclear forces					**1 910**[l]
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[m]	1992/2007	. .	1 x low kt	290
3M-55 Yakhont (SS-N-26)	60	[2014]	>400	1 x [. . kt]	25
SSC-1B (Sepal)	8	1973	500	1 x 350 kt	4
Air force weapons[n]	*260*				*500*
Tu-22M3 (Backfire-C)	60	1974	. .	3 x ASMs, bombs	300
Su-24M/M2 (Fencer-D)	70	1974	. .	2 x bombs	70[o]
Su-34 (Fullback)	120	2006	. .	2 x bombs	120[o]
Su-57 (Felon)	. .	[2020]	. .	[bombs, ASM?]	. .
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]
Army weapons	*164*				*90*
Iskander-M (SS-26 Stone)	144	2005	350[p]	[1 x 10–100 kt]	70[q]
9M729 (SSC-8)	20	2016	2 350	1 x [. . kt]	20
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[r]			
Total stockpile					**4 495**
Deployed warheads					1 625[s]
Reserve warheads					2 870[t]
Retired warheads awaiting dismantlement					**1 760**
Total inventory					**6 255**

. . = not available or not applicable; [ ] = uncertain figure; ALBM = air-launched ballistic missile; ALCM = air-launched cruise missile; ASM = air-to-surface missile; HGV = hypersonic glide vehicle; ICBM = intercontinental ballistic missile; kt = kiloton; MIRV = multiple independently targetable re-entry vehicle; NATO = North Atlantic Treaty Organization; SLBM = submarine-launched ballistic missile.

Note: The table lists the total number of warheads estimated to be available for the delivery systems. Only some of these are deployed and the strategic warheads do not necessarily correspond to the data-counting rules of the 2010 Russian–US Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START).

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

[b] These numbers show the total number of warheads estimated to be assigned to nuclear-capable delivery systems. Only some of these warheads are deployed on missiles and at air bases.

[c] Approximately 1625 of these strategic warheads are deployed on land- and sea-based ballistic missiles and at bomber bases. The remaining warheads are in central storage.

[d] The first figure is the total number of bombers in the inventory; the second is the number of bombers estimated 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 loading on the bombers is nearly 740 nuclear weapons but, since only some of the bombers are fully operational, SIPRI estimates that only about 580 weapons are assigned to the long-range bomber force, of which approximately 200 might be deployed and stored at the 2 strategic bomber bases. The remaining weapons are thought to be in central storage facilities.

[f] There are 2 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 are being modernized. 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 1189 warheads, but it is estimated here that they have been downloaded to carry just over 800 warheads, with the remaining warheads in storage.

[h] It is possible that the remaining RS-18s have been retired.

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

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

carry. Of Russia's 11 operational SSBNs, 1 or 2 are in overhaul at any given time and do not carry their assigned nuclear missiles and warheads.

[k] The warhead loading on SLBMs is thought to have been reduced for Russia to stay below the New START warhead limit. It is estimated here that only about 624 of the 816 SLBM warheads are deployed.

[l] 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.

[m] There are 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.

[n] The subtotal is based on an estimate of the total number of nuclear-capable aircraft. However, only some of them are thought to have nuclear missions. Most can carry more than 1 nuclear weapon. Other potential nuclear-capable aircraft include the Su-25 (Frogfoot) and the Su-30MK.

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

[p] Although many unofficial sources and news media reports state that the Iskander-M has a range of nearly 500 km, the US Air Force's National Air and Space Intelligence Center (NASIC) lists the range as 350 km.

[q] The estimate assumes that around half of the dual-capable launchers have a secondary nuclear role. It is possible that the 9M728 (SSC-7, sometimes called Iskander-K) cruise missile is also nuclear-capable.

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

[s] The deployed warhead number in this table differs from the number declared under New START because the treaty attributes 1 warhead per deployed bomber—even though bombers do not carry warheads under normal circumstances—and does not count warheads stored at bomber bases.

[t] Reserve warheads include *c.* 960 strategic and *c.* 1910 non-strategic warheads in central storage (see note l).

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); US Department of Defense (DOD), *Missile Defense Review 2019* (DOD: Arlington, VA, 2019); US Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020* (US Department of Defense: Arlington, VA, Mar. 2020); US Department of Defense, various Congressional testimonies; BBC Monitoring; Russian news media; Russian Strategic Nuclear Forces website; International Institute for Strategic Studies (IISS), *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; *Proceedings*, US Naval Institute, various issues; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

oblast.[7] An upgrade of the nuclear weapon storage site at Engels is under way.[8]

Modernization of the bombers, which includes upgrades to their avionics suites, engines and long-range nuclear and conventional cruise missiles, is

[7] Podvig, P., 'Strategic aviation', Russian Strategic Nuclear Forces, 4 Jan. 2020.

[8] Kristensen, H. M. and Korda, M., 'Nuclear upgrade at Russian bomber base and storage site', Federation of American Scientists (FAS) Strategic Security Blog, 25 Feb. 2019.

progressing, but with some delays.[9] 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. According to the Kremlin, two Tu-160s and five Tu-95MSs were upgraded in 2020.[10] It seems likely that all of the Tu-160s and most of the Tu-95s will be upgraded to maintain a bomber force of perhaps 50–60 operational aircraft. Russia has also resumed production of the Tu-160 airframes to produce up to 50 Tu-160M2 bombers with new engines and advanced communications suites.[11] The first Tu-160M2 is expected to make its maiden flight in late 2021.[12]

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 that may look similar to the flying-wing design of the USA's B-2 bomber. The PAK-DA's production has been delayed and final assembly of the first aircraft is now scheduled for 2021, with serial production expected to begin in 2028 or 2029.[13] The PAK-DA will eventually replace all Tu-95s and Tu-160s as well as the Tu-22s that are deployed with non-strategic forces (see below).[14]

Land-based missiles

As of January 2021, Russia's Strategic Rocket Forces (SRF)—the branch of the armed forces that controls land-based ICBMs—consisted of 11 missile divisions grouped into 3 armies, deploying an estimated 310 ICBMs of different types and variations (see table 10.3).[15] These ICBMs can carry a maximum of about 1189 warheads, but it is estimated here that they have been downloaded to carry around 800 warheads to keep Russia below the New START limit for deployed strategic warheads. These represent approximately half of Russia's 1625 deployed strategic warheads.

Russia's ICBM force is most of the way through a significant modernization programme to replace all Soviet-era missiles with new types, albeit not on a one-for-one basis. The modernization, which began in the late 1990s, also involves substantial reconstruction of silos, launch control

[9] Trevithick, J., 'Russia rolls out new Tu-160M2, but are Moscow's bomber ambitions realistic?', The Drive, 16. Nov. 2017.

[10] President of Russia, 'Expanded meeting of the Defence Ministry Board', 21 Dec. 2020.

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

[12] TASS, 'First newly-built Tu-160M to make maiden flight in 4th quarter of 2021', 30 Dec. 2020.

[13] TASS, 'Russia begins construction of the first PAK DA strategic bomber—sources', 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).

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

[15] A 12th division, the 40th missile regiment at Yurya, is not nuclear-armed.

centres, garrisons and support facilities.[16] The modernization programme appears to be progressing more slowly than previously envisioned. According to Colonel General Sergey Karakaev, commander of the SRF, over 81 per cent of the ICBM force had been modernized by the end of 2020.[17] This is significantly lower than the goal of 97 per cent announced in 2014 for the end of 2020.[18] In November 2020 the chief designer of the RS-24 suggested that the last Soviet-era ICBM would be phased out by 2024.[19] However, this seems unlikely based on an assessment of the probable time frame for replacing the RS-20V (SS-18; see below).

The bulk of the modernization programme is focused on the RS-24 Yars (SS-27 Mod 2), 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 the Russian Ministry of Defence's television channel declared that approximately 150 mobile and silo-based RS-24 ICBMs had been deployed.[20] Four mobile RS-24 divisions have now been completed (Irkutsk, Nizhniy Tagil, Novosibirsk and Yoshkar-Ola), with two more in progress (Barnaul and Vypolzovo—sometimes referred to as Bologovsky).[21] In addition, one completed mobile division at Teykovo is equipped with single-warhead RS-12M1 Topol-M (SS-27 Mod 1) 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.[22] In December 2020 Karakaev announced that in 2021 the military would begin to install silo-based RS-24s at a third regiment at Kozelsk; however, given how long the previous silo upgrades took, it is unlikely that the third regiment will be completed by the 2024 target date.[23] It is also possible that some of the former RS-18 (SS-19) silos at Tatishchevo Airbase, Saratov oblast, might eventually be upgraded to the RS-24.

In December 2020 two more RS-18 missiles equipped with the Avangard hypersonic glide vehicle (HGV) system were installed in former RS-20V

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

[17] Andreev, D. and Biryulin, R., [Nuclear missile shield guarantees Russia's sovereignty], *Krasnaya Zvezda*, 16 Dec. 2020 (in Russian).

[18] TRK Petersburg Channel 5, 'Russian TV show announces new ICBM to enter service soon', 21 Apr. 2014, Translation from Russian, BBC Monitoring.

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

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

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

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

[23] TASS (note 22).

silos at Dombarovsky Airbase, Orenburg oblast.[24] This missile type has been designated as the SS-19 Mod 4 by the North Atlantic Treaty Organization (NATO).[25] Russia is installing Avangard-equipped missiles at a rate of two per year in upgraded complexes with new facilities and security perimeters. The first Avangard regiment is expected to reach its full complement of six missiles by the end of 2021.[26] Russia plans to install a total of two regiments, each with six missiles, at Dombarovsky by 2027.[27]

Russia is also 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 a few Avangard HGVs. After much delay, full-scale flight testing of the RS-28 is scheduled to begin in mid 2021 at the new proving ground at Severo-Yeniseysky, Krasnoyarsk krai, with serial production expected to begin in 2021—although this would be dependent on a successful flight-test programme.[28] In December 2020 Karakaev announced that the first RS-28 ICBMs would be 'put on combat alert' at the ICBM complex at Uzhur, Krasnoyarsk krai, sometime in 2022.[29]

Russia conducted several large-scale exercises with road-mobile and silo-based ICBMs during 2020. These included combat patrols for road-mobile regiments, simulated launch exercises for silo-based regiments, and participation in command staff exercises.[30]

Sea-based missiles

As of January 2021, the Russian Navy had a fleet of 11 operational nuclear-armed SSBNs. The fleet included 6 Soviet-era Delfin-class or Project 667BDRM (Delta IV) SSBNs, 1 Kalmar-class or Project 667BDR (Delta III) SSBN, and 4 (of a planned total of 10) Borei-class or Project 955 SSBNs.

One of the Borei submarines is of an improved design, known as Borei-A or Project 955A. After delays due to technical issues during sea trials, it

[24] Russian Ministry of Defence, [Installation of the Avangard intercontinental ballistic missile in a silo launcher], YouTube, 16 Dec. 2020 (in Russian).

[25] US Department of Defense (note 4), p. 8; and Kristensen, H. M. and Korda, M., 'Russian nuclear forces, 2019', *Bulletin of the Atomic Scientists*, vol. 75, no. 2 (Mar. 2019), p. 78.

[26] TASS, 'Russia's 1st regiment of Avangard hypersonic missiles to assume full strength in 2021', 23 Dec. 2020.

[27] TASS, [Source: The first Avangard complexes will be on duty in 2019], 29 Oct. 2018 (in Russian).

[28] President of Russia (note 10); 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).

[29] Levin (note 20).

[30] Russian Ministry of Defence, [Strategic offensive force management training], YouTube, 9 Dec. 2020 (in Russian).

was accepted into the navy in June 2020.[31] In December 2020 the Russian defence minister, Sergey Shoigu, announced that the navy would receive the next two Borei-A SSBNs in 2021.[32] Two more Borei-As are currently under construction, and the final two boats are expected to be laid down in 2021.[33] Eventually, five Borei SSBNs will be assigned to the Northern Fleet (in the Arctic Ocean) and five will be assigned to the Pacific Fleet.[34]

Assuming that the one remaining Delta III will be retired, the planned deployment of Borei-A SSBNs would bring the number of SSBNs to 12 by the end of 2021. A former Project 941 (Typhoon) SSBN that has been converted to a test-launch platform for SLBMs is not thought to be nuclear-armed.[35]

Each SSBN can be equipped with 16 ballistic missiles and the Russian fleet can carry a total of 816 warheads. 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 loading on some missiles has been reduced to meet the total warhead limit under New START. As a result, it is estimated here that only about 624 of the 816 warheads are deployed.

The Russian Navy is also developing the Poseidon or Status-6 (Kanyon), a long-range, strategic nuclear-powered torpedo. The torpedo is intended for future deployment on two new types of special-purpose submarine: the K-329 *Belgorod* (Project 09852)—a converted Antei-class or Project 949A (Oscar-II) guided-missile submarine (SSGN)—and the Khabarovsk-class or Project 09851 submarine based on the Borei-class SSBN hull.[36] The *Belgorod* was originally scheduled for delivery to the navy by the end of 2020 but has been delayed until 2021.[37] The *Belgorod* and the Khabarovsk submarines will each be capable of carrying up to six Poseidon torpedoes.[38]

Non-strategic nuclear forces

There is no universally accepted definition of 'tactical', 'non-strategic' or 'theatre' nuclear weapons; however, the US Department of Defense describes them as 'nuclear weapons designed to be used on a battlefield in military

[31] 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).

[32] President of Russia (note 10).

[33] TASS, 'Two Borei-A strategic nuclear subs to be laid down in 2021—Defense Ministry', 30 Dec. 2020.

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

[35] Saranov, V., 'Behemoths of the seas: Why Russia is retiring its Akula strategic nuclear subs', Sputnik, 24 Jan. 2018.

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

[37] TASS, ['Poseidon' drone carrier submarine 'Belgorod' to be handed over to the fleet in 2021], 24 Dec. 2020 (in Russian).

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

situations. This is opposed to strategic nuclear weapons, which are designed to be used against enemy cities, factories, and other larger-area targets to damage the enemy's ability to wage war'.[39]

As of January 2021, Russia had an estimated 1910 warheads assigned for potential use by non-strategic forces, a slight increase of about 35 warheads over early 2020, mainly due to the fielding of the Kalibr land-attack sea-launched cruise missile (SLCM). Russia's non-strategic nuclear weapons—most of which are dual-capable, which means that they can also be armed with conventional warheads—are intended for use by ships and submarines, aircraft, air- and missile-defence systems, and army missiles. In February 2020 the commander of US Strategic Command, Admiral Charles A. Richard, suggested that 'Russia's overall nuclear stockpile is likely to grow significantly over the next decade—growth driven primarily by a projected increase in Russia's non-strategic nuclear weapons'.[40]

Russia's non-strategic nuclear weapons chiefly serve to compensate for perceived weaknesses in its conventional forces 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.[41]

Air, coastal and missile defence

The Russian air-, coastal- and missile-defence forces are estimated to have around 387 nuclear warheads. Most are assigned for use by dual-capable S-300 and S-400 air defence forces and the Moscow A-135 missile defence system, and a small number are assigned to coastal defence units. Russia is also 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.[42]

Air force weapons

The Russian Air Force is estimated to have approximately 500 nuclear warheads for use by Tu-22M3 (Backfire-C) intermediate-range bombers,

[39] US Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2016* (US Department of Defense: Arlington, VA, 2016), p. 17.

[40] Richard, C. A., Commander, US Strategic Command, Statement, US Senate, Armed Services Committee, 13 Feb. 2020, p. 5.

[41] On this debate see e.g. US Department of Defense (note 4), 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 Bruusgaard, K. V., 'The myth of Russia's lowered nuclear threshold', War on the Rocks, 22 Sep. 2017.

[42] 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.

Su-24M (Fencer-D) fighter-bombers, Su-34 (Fullback) fighter-bombers and MiG-31K (Foxhound) attack aircraft.[43] The new Su-57 (Felon) combat aircraft, also known as PAK-FA, is dual-capable. It is currently in production and the first serially built version was delivered to the Russian Air Force in 2020.[44]

The MiG-31K is equipped with the new Kh-47M2 Kinzhal air-launched ballistic missile.[45] Russia is also developing the nuclear-capable Kh-32 air-to-surface missile, an upgrade of the Kh-22N (AS-4) used on the Tu-22M3.[46]

Army weapons

The Russian Army is thought to have approximately 90 warheads to arm Iskander-M (SS-26) short-range ballistic missiles (SRBMs) and 9M729 (SSC-8) ground-launched cruise missiles (GLCMs). The dual-capable Iskander-M has now completely replaced the Tochka (SS-21) SRBM in 12 missile brigades.[47]

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.[48] It is estimated that four or five 9M729 battalions have so far been co-deployed with four or five of the Iskander-M brigades. In October 2020 President Putin declared his willingness to impose a moratorium on future 9M729 deployments in European territory, 'but only provided that NATO countries take reciprocal steps that preclude the deployment in Europe of the weapons earlier prohibited under the INF Treaty'.[49]

There are also rumours that Russia has nuclear artillery and landmines, but the publicly available evidence is conflicting.

[43] US Department of Defense (DOD), 'US nuclear deterrence policy', Fact sheet, 1 Apr. 2019, p. 3; International Institute for Strategic Studies (IISS), *The Military Balance 2021* (Routledge: London, 2021); and authors' estimate.

[44] D'Urso, S., 'First serial production Su-57 Felon delivered to the Russian Aerospace Forces', The Aviationist, 30 Dec. 2020; and US Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020* (US Department of Defense: Arlington, VA, Mar. 2020), p. 3.

[45] TASS, [Sources: First Dagger hypersonic missile tests conducted in Arctic], 30 Nov. 2019 (in Russian).

[46] US Department of Defense (note 4), p. 8.

[47] Authors' assessment based on observation of satellite imagery. It is possible that the 9M728 (SSC-7, sometimes called Iskander-K) cruise missile is also dual-capable.

[48] 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*, pp. 399–405; and Kile, S. N., 'Russian–US nuclear arms control and disarmament', *SIPRI Yearbook 2018*, pp. 321–24.

[49] 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.

Navy weapons

The Russian military service that is assigned the highest number of non-strategic nuclear weapons is the navy, with about 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 SLCM, also known as the 3M-14 (SS-N-30A), is a significant new addition to these weapons.[50] It has been integrated on numerous types of surface ship and attack submarine, including the new Yasen/-M or Project 885/M (Severodvinsk) SSGN. The second boat of this class completed its sea trials in 2020, indicating a potential entry into service in 2021.[51]

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, which is undergoing final test launches.[52]

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

[51] 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. 36; and TASS, 'Newest Russian submarine hits target 1,000 km away with Kalibr cruise missile', 23 Nov. 2020.

[52] TASS, 'Russia plans new trials of Tsirkon hypersonic missile before yearend—source', 22 Nov. 2019.

III. British nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2021, the United Kingdom's nuclear weapon inventory consisted of approximately 225 warheads (see table 10.4).[1] In its 2015 Strategic Defence and Security Review (SDSR), the British Government reaffirmed its intention to cut the size of the nuclear arsenal. By that time, the number of operationally available nuclear warheads had already been reduced from fewer than 160 to no more than 120, and the overall size of the nuclear weapon inventory, including non-deployed warheads, was intended to decrease from no more than 225 in 2010 to no more than 180 by the mid 2020s.[2] These plans changed following the Integrated Review of Security, Defence, Development and Foreign Policy undertaken in 2020 and published in early 2021, which increased the ceiling for the nuclear weapon inventory to 260.[3]

The January 2021 estimate of 225 warheads is based on publicly available information on the British nuclear arsenal, conversations with officials, and assumptions about the scope of the planned reduction. The authors consider the British Government to have been more transparent about its nuclear activities than many other nuclear-armed states—for example by having declared the size of its nuclear 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.

The role of nuclear weapons in British military doctrine

The UK remains 'deliberately ambiguous' about the precise conditions under which it would use nuclear weapons; however, the British Government has stated that such weapons would only be used under 'extreme circumstances of self-defence, including the defence of our NATO Allies'.[4]

The UK is the only nuclear-armed state that operates a single nuclear weapon type: the British 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

[1] This is a revision of SIPRI's estimate of 215 warheads in *SIPRI Yearbook 2020*.

[2] British Government, *National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom*, Cm 9161 (HM Stationery Office: London, Nov. 2015), para. 4.66.

[3] 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). These changes will be discussed in the next edition of the SIPRI Yearbook.

[4] British Government (note 2), para. 4.68.

missiles (SLBMs).[5] In a posture known as Continuous At-Sea Deterrence (CASD), which began in 1969, one British SSBN is on patrol at all times.[6] While the second and third SSBNs 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.

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.[7] The 2015 SDSR stated the government's intention to replace the Vanguard-class submarines with four new SSBNs.[8] In 2016 the House of Commons, the lower house of the British Parliament, approved a motion supporting the government's decision with cross-party support.[9]

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.[10] The UK is participating in the United States Navy's programme to extend the service life of the Trident II D5 missile (the life-extended version is known as D5LE) to the early 2060s (see section I).[11]

The warhead carried on the Trident II D5 is called the Holbrook. Its nuclear explosive package is thought to be a modified version of the USA's W76 warhead and is contained in the US-produced Mk4 re-entry body. The Atomic Weapons Establishment, the research facility responsible for the design and manufacture of the UK's warheads, is currently upgrading the Holbrook to accommodate the US-produced Mk4A re-entry body, in collaboration with US nuclear laboratories.[12]

In February 2020 the British Government announced its intention to replace the Holbrook with a new warhead.[13] The announcement had been pre-empted by the commander of US Strategic Command, Admiral

[5] Mills, C., *Replacing the UK's Strategic Nuclear Deterrent: Progress of the Dreadnought Class*, Briefing Paper no. CBP-8010 (House of Commons Library: London, 17 July 2020), p. 7.

[6] British Ministry of Defence, 'Continuous at sea deterrent 50: What you need to know', 3 May 2019.

[7] Mills (note 5), p. 7.

[8] British Government (note 2), para. 4.73.

[9] British House of Commons, 'UK's nuclear deterrent', *Hansard*, col. 559, vol. 613 (18 July 2016).

[10] British Government (note 2), para. 4.65.

[11] Mills (note 5), p. 7.

[12] British Ministry of Defence, 'The United Kingdom's future nuclear deterrent: 2020 update to Parliament', 17 Dec. 2020; and Kristensen, H. M., 'British submarines to receive upgraded US nuclear warhead', Federation of American Scientists (FAS) Strategic Security Blog, 1 Apr. 2011.

[13] Wallace, B., British Secretary of State for Defence, 'Nuclear deterrent', Written Statement HCWS125, British Parliament, 25 Feb. 2020.

Table 10.4. British nuclear forces, January 2021

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 = kilotons; SLBM = submarine-launched ballistic missile.

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

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

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

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

[e] Of the 120 operationally available warheads, 40 are deployed on the single SSBN that is at sea at any given time.

[f] Of the estimated 105 warheads that are not operationally available, it is thought that about half are spares and the other half are undergoing upgrade from the Mk4 to the Mk4A.

[g] The British Government declared in 2010 that its inventory would not exceed 225 warheads. It is estimated here that the inventory remained at that number in Jan. 2021, a revision of SIPRI's estimate of 215 warheads in *SIPRI Yearbook 2020*. A planned reduction to an inventory of 180 warheads by the mid 2020s was ended by the Integrated Review of Security, Defence, Development and Foreign Policy undertaken in 2020 and published in early 2021. The review 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.

Charles A. Richard, who reported during testimony to the US Senate that the US W93/Mk7 programme 'will also support a parallel Replacement Warhead Program in the United Kingdom'.[14] In April 2020 Ben Wallace, the British Secretary of State for Defence, sent an unprecedented letter to members of the US Congress, lobbying them in support of the W93 warhead programme and claiming that it is 'critical . . . to the long-term viability of the UK's nuclear deterrent'.[15] This letter and the surprise announcement of the W93 decision have sparked fresh concerns that the UK's nuclear

[14] Richard, C. A., Commander, US Strategic Command, Statement, US Senate, Armed Services Committee, 13 Feb. 2020, p. 13.

[15] Borger, J., 'UK lobbies US to support controversial new nuclear warheads', *The Guardian*, 1 Aug. 2020.

deterrent lacks the appropriate independence and parliamentary scrutiny.[16] The British Ministry of Defence (MOD) acknowledged in 2020 that 'It is not exactly the same warhead, but . . . there is a very close connection, in design terms and production terms.'[17]

The new Dreadnought-class submarines will have 12 launch tubes—a reduction from the 16 carried by the Vanguard class (see below). Technical problems resulted in a delay in the delivery of the missile launch tubes; however, as of January 2021 six tubes—half 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.[18]

The cost of the Dreadnought programme has been a source of concern and controversy since its inception. In 2015 the MOD estimated the total cost of the programme to be £31 billion ($47.4 billion). It set aside a contingency of £10 billion ($15.3 billion) to cover possible increases, and approximately £800 million of that fund had been allocated by mid 2020.[19] In 2018 the National Audit Office (NAO) reported that the MOD was facing an 'affordability gap' of £2.9 billion ($3.9 billion) in its military nuclear programmes between 2018 and 2028.[20] In its annual update to the parliament in December 2020, the MOD reported that a total of £8.5 billion ($11.8 billion) had been spent on the programme's concept, assessment and delivery phases—an increase of £1.6 billion ($2.2 billion) from the previous financial year.[21]

In 2020 the NAO and the Commons Public Accounts Committee reported that three key nuclear-regulated infrastructure projects in the UK's nuclear weapon programme would be delayed by 1.7–6.3 years, with costs increasing by over £1.3 billion ($1.7 billion) to a forecasted total of £2.5 billion ($3.2 billion).[22] According to these reports, the delays were largely caused by poor management and premature construction. This suggests that the UK's relative inexperience in building new warheads could lead to further delays and cost overruns.

[16] Mills, C., 'Replacing the UK's strategic nuclear deterrent: The long-awaited warhead decision', Briefing Paper no. CBP-8941, House of Commons Library, 19 June 2020, p. 1.

[17] Lovegrove, S., Permanent Secretary, Ministry of Defence, Statement, British House of Commons, Defence Committee, 8 Dec. 2020, Q31.

[18] British Ministry of Defence (note 12).

[19] Mills (note 5), pp. 18–19.

[20] British National Audit Office (NAO), *The Defence Nuclear Enterprise: A Landscape Review*, Report by the Comptroller and Auditor General, HC 1003, Session 2017–19 (NAO: London, 22 May 2018). Spending on military nuclear programmes was estimated to account for *c.* 14% of the total 2018/19 Ministry of Defence budget, and it could rise to 18% or 19% during the peak of recapitalization.

[21] British Ministry of Defence (note 12).

[22] British National Audit Office, *Managing Infrastructure Projects on Nuclear-regulated Sites*, Report by the Comptroller and Auditor General, HC 19, Session 2019–20 (NAO: London, 10 Jan. 2020), pp. 5–6; and British House of Commons, Committee of Public Accounts, *Defence Nuclear Infrastructure*, 2nd report of session 2019–21, HC 86 (House of Commons: London, 13 May 2020).

Sea-based missiles

The Vanguard-class SSBNs can each be armed with up to 16 Trident II D5 SLBMs. Of the four SSBNs, three (with a total of 48 missile tubes) are considered to be operational at any given time, while the fourth SSBN is in overhaul. 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.[23] Under limits set out in the 2010 SDSR and reaffirmed by the 2015 SDSR, when on patrol, the submarines are armed with no more than 8 operational missiles with a total of 40 nuclear warheads.[24] The missiles are kept in a 'detargeted' mode, meaning that target data would need to be loaded into the guidance system before launch. They also have a reduced alert status: several days' notice would be required to fire the missiles.[25]

[23] Allison, G., 'No, America doesn't control Britain's nuclear weapons', UK Defence Journal, 20 July 2017.

[24] British Government, *Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review*, Cm 7948 (HM Stationery Office: London, Oct. 2010), pp. 5, 38; and British Government (note 2), para. 4.66.

[25] British Government (note 2), para. 4.78.

IV. French nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2021, France's nuclear weapon inventory consisted of about 290 warheads. 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 inventory is based on publicly available information. France is relatively transparent about many of its nuclear weapon activities and has publicly disclosed the size of its stockpile and details of its nuclear-related operations in the past.[1]

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'.[2] While this concept has appeared in various governmental white papers and presidential speeches for several decades, what constitutes France's 'vital interests' appears to be somewhat vague.

In a speech in February 2020, President Emmanuel Macron suggested that the French nuclear deterrent was intended to deter another state from 'threatening our vital interests, whatever they may be'.[3] Macron also noted that, if deterrence were to fail, 'a unique and one-time-only nuclear warning could be issued to the aggressor State to clearly demonstrate that the nature of the conflict has changed and to re-establish deterrence'.[4] Following that, French nuclear weapons could be used for 'inflicting absolutely unacceptable damages upon that State's centres of power: its political, economic and military nerve centres'.[5]

There is no publicly available evidence to indicate that France has considered incorporating pre-emptive first strikes into its nuclear doctrine.[6] However, the weapons carried by the airborne component of its nuclear

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

[2] 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.

[3] Macron (note 1).

[4] Macron (note 1).

[5] Macron (note 1).

[6] Tertrais (note 2), pp. 25–29, 62–63.

Table 10.5. French nuclear forces, January 2021

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 [up to 300 kt] TNA[c]	40
Carrier-based aircraft					
Rafale MF3[b]	10	2010–11	2 000	1 x [up to 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 inventory					**290**[j]

[ ] = uncertain figure; – = nil or a negligible value; kt = kiloton; SLBM = submarine-launched ballistic missile; TNA = tête nucléaire aéroportée (airborne nuclear warhead); TNO = tête nucléaire océanique (oceanic nuclear warhead).

[a] For aircraft, the listed range is for illustrative purposes only; actual mission range will vary according to flight profile, weapon loading 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 km, although some suggest that it might be over 600 km.

[c] The TNA is widely assumed to have a maximum yield of 300 kt, but lower-yield options for this warhead are thought to be available.

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

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

[f] 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 only produced enough SLBMs to equip the 3 operational SSBNs (48 missiles).

[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 small number of the warheads is thought to be undergoing maintenance and surveillance at any given time.

Sources: Macron, E., French President, Speech on defence and deterrence strategy, École de Guerre, Paris, 7 Feb. 2020 (in French); Parly, F., French Minister of the Armed Forces, Speech, ArianeGroup, Les Mureaux, 14 Dec. 2017 (in French); Hollande, F., French President, Speech on nuclear deterrence, Istres Air Base, 25 Feb. 2015 (in French); Sarkozy, N., French President, Speech on the new defence policy, Porte de Versailles, 17 June 2008, (in French); Sarkozy, N., French President, Speech on the white paper on national defence and security, nuclear deterrence and the non-proliferation of nuclear weapons, Cherbourg, 21 Mar. 2008 (in French); Chirac, J., French President, Speech on France's defence policy, Île Longue, Brest, 19 Jan. 2006 (in French); 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.

forces have characteristics (i.e. a limited range) that other nuclear-armed states consider to be tactical.

In his 2020 speech, President Macron suggested that 'France's vital interests now have a European dimension', and he offered to open a strategic dialogue with other European countries to discuss 'the role played by France's nuclear deterrence in our collective security'.[7] However, it appears that this proposal only gained support from a few politicians and has not yet been collectively endorsed by European political parties or governments.[8]

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.[9] Current plans include the modernization of France's nuclear-powered ballistic missile submarines (SSBNs, or sous-marins nucléaires lanceurs d'engins, SNLE), SLBMs and ALCMs (see below). The 2018 Law on Military Planning for 2019–25 allocates €37 billion ($42.2 billion) for maintenance and modernization of France's nuclear forces and infrastructure.[10] This is a significant increase on the €23 billion ($26.2 billion) allocated to nuclear forces and associated infrastructure by the Law on Military Planning for 2014–19.[11]

The 2021 budget of the Ministry of the Armed Forces (France's defence ministry) allocated €5 billion ($5.7 billion) to nuclear weapon-related activity—€0.3 billion ($0.34 billion) more than in the 2020 budget.[12] It also suggests that a total of €25 billion ($28.5 billion) would be spent on nuclear modernization between 2019 and 2023.

[7] Macron (note 1).

[8] Berghofer, J., 'An offer postponed: Berlin's silence on Macron's deterrence thinking', Commentary, European Leadership Network, 25 Aug. 2020.

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

[10] 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', France24, 8 Feb. 2018. The total defence budget approved for the 7-year period was €295 billion ($336 billion). On France's military expenditure see chapter 8, section II, in this volume.

[11] 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.

[12] French Ministry of the Armed Forces (MAF), *Projet de loi de finances: Année 2021* [Finance bill: Year 2021] (MAF: Paris, Sep. 2020), p. 26; Groizeleau, V., 'Dissuasion : 25 milliards en cinq ans pour le renouvellement des deux composantes' [Deterrence: 25 billion in five years for the renewal of the two components], Mer et Marine, 2 Oct. 2019; and Rose, M., 'Amid arms race, Macron offers Europe French nuclear wargames insight', Reuters, 7 Feb. 2020.

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, 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.[13]

The Rafale aircraft are equipped with medium-range air-to-surface cruise missiles (air–sol moyenne portée–améliorée, ASMP-A), which entered service in 2009. France produced 54 ASMP-As, including test missiles.[14] A midlife refurbishment programme for the ASMP-A that began in 2016 will deliver the first upgraded missiles in 2022 or 2023.[15] The first test of an upgraded ASMP-A took place on 9 December 2020.[16] This will be followed by a qualification firing and subsequent force training firings before the missile's entry into service. The missiles are armed with a nuclear warhead (the tête nucléaire aéroportée, TNA) that has a reported yield of up to 300 kilotons.[17]

The French Ministry of the Armed Forces has initiated research on a successor, 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.[18] The ASN4G is scheduled to replace the ASMP-A in 2035.[19]

[13] 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.

[14] Hollande, F., French President, Speech on nuclear deterrence, Istres Air Base, 25 Feb. 2015 (in French); and Tertrais (note 2), p. 62.

[15] French Ministry of the Armed Forces, 'Projet de loi de programmation militaire, 2019–2025' [Military Planning Bill, 2019–2025], Press kit, Feb. 2018, p. 42; Medeiros, J., '"Faire FAS" : 55 ans de dissuasion nucléaire aéroportée' ['Go FAS': 55 years of airborne nuclear deterrence], *Air Actualités*, Oct. 2019, pp. 32–37, p. 36; and Tertrais (note 2), p. 60.

[16] French Ministry of the Armed Forces, 'Premier tir d'essai du missile stratégique ASMPA-rénové' [First test firing of the ASMPA-renovated strategic missile], 23 Dec. 2020.

[17] Groizeleau, V., 'Dissuasion : F. Hollande détaille sa vision et l'arsenal français' [Deterrence: F. Hollande outlines his vision and the French arsenal], Mer et Marine, 20 Feb. 2015.

[18] 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.

[19] Medeiros (note 15), p. 36.

Sea-based missiles

The main component of France's nuclear forces is the Strategic Oceanic Force (Force océanique stratégique, FOST). It consists of four Triomphant-class SSBNs based on the Île Longue peninsula near Brest, north-west France. Each is capable of carrying 16 SLBMs. However, one SSBN is out of service for overhaul and maintenance work at any given time and is not armed. France has produced only 48 SLBMs, enough to equip the 3 operational SSBNs.

The French Navy maintains a continuous at-sea deterrent posture with one SSBN on patrol at all times. It has conducted more than 500 such patrols since 1972.[20]

France continues to modernize its SLBMs and associated warheads. In June 2020 *Le Téméraire*, which had previously been equipped with the older M45 SLBM, became operational with the newer M51 after a successful test launch of the missile.[21] This was the ninth test of the M51.

The M51 is itself 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 kt. Over the past several years, the M51.1 has been gradually replaced by an upgraded version, the M51.2, which has greater range and improved accuracy. With the deployment of the M51.2 on *Le Téméraire* in mid 2020, the final SSBN left to receive this upgrade, *Le Terrible*, began its major refit in late 2020.[22] Thus, as of January 2021, the M51.1 had officially been removed from service.

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.[23] The number of warheads on some of the missiles has been reduced in order to improve targeting flexibility.[24] France has also commenced design work on another upgrade, the M51.3, with improved accuracy. The first M51.3

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

[21] Parly, F. (@florence_parly), 'Le sous-marin nucléaire lanceur d'engins (SNLE) Le Téméraire a tiré avec succès un missile balistique stratégique M51 au large du Finistère. Cet essai démontre notre excellence technologique et notre attachement à la souveraineté française.' [The nuclear-powered ballistic missile submarine Le Téméraire successfully fired an M51 strategic ballistic missile off the coast of Finistère. This test demonstrates our technological excellence and our commitment to French sovereignty.], Twitter, 12 June 2020.

[22] 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.

[23] Groizeleau (note 12); and Groizeleau (note 17).

[24] Tertrais (note 2), p. 57.

missiles are scheduled to replace their M51.2 predecessors and become operational in 2025.[25]

In the Law on Military Planning for 2019–25, the French Government announced that it would produce a third-generation SSBN, designated the SNLE 3G.[26] The programme was officially launched in early 2021.[27] The SNLE 3G will eventually be equipped with a further modification of the M51 SLBM, the M51.4.[28] 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.[29]

[25] 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, ArianeGroup, Les Mureaux, 14 Dec. 2017 (in French).

[26] French Ministry of the Armed Forces (note 15), p. 38.

[27] 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.

[28] Tertrais (note 2), pp. 56, 60, 65.

[29] French Ministry of the Armed Forces (note 27); Groizeleau (note 12); and Mackenzie (note 27).

V. Chinese nuclear forces

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As of January 2021, China maintained an estimated total inventory of about 350 nuclear warheads. This is an increase of 30 from the previous year, due largely to the indication that the DF-5B intercontinental ballistic missile (ICBM) can carry more warheads than previously believed.[1] Just over 270 warheads are assigned to China's operational land- and sea-based ballistic missiles and to nuclear-configured aircraft (see table 10.6). The remainder are assigned to non-operational forces, such as new systems in development, operational systems that may increase in number in the future, and reserves.

This estimate relies on publicly available information on the Chinese nuclear arsenal. China has never declared the size of its nuclear arsenal. Occasionally, Chinese officials reference open-source estimates as a means to discuss China's nuclear weapon programme publicly or in diplomatic negotiations.[2] As a result, many of the assessments here rely on data from the United States Department of Defense (DOD) and must therefore be treated with a degree of caution.

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 weapons against China'.[3] For decades, China did so with a dyad 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. China is now building a fully operational triad of nuclear forces with solid-fuelled land-based missiles, six nuclear-powered ballistic missile submarines (SSBNs), and bombers with a full, re-established nuclear mission in order to strengthen its nuclear deterrence and second-strike capabilities in response to what it sees as a growing threat from other countries.[4]

[1] US Department of Defense (DOD), *Military and Security Developments Involving the People's Republic of China 2020*, Annual Report to Congress (DOD: Arlington, VA, 21 Aug. 2020), p. 56.

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

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

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

Table 10.6. Chinese nuclear forces, January 2021

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)	–	[2022]	. .	1 x ALBM	–
H-20 (B-20)	–	[2020s]	. .	. .	–
Land-based missiles[e]	*244*				*204*
DF-4 (CSS-3)	6[f]	1980	5 500	1 x 3.3 Mt	6[f]
DF-5A (CSS-4 Mod 1)	10	1981	>12 000	1 x 4–5 Mt	10
DF-5B (CSS-4 Mod 2)	10	2015	12 000	5 x 200–300 kt MIRV	50
DF-5C (CSS-4 Mod 3)	–	. .	. .	MIRV	–
DF-21A/E (CSS-5 Mod 2/6)[g]	40	1996/2017	2 100	1 x 200–300 kt	40
DF-26 (CSS-18)	100	2016	>4 000	1 x 200–300 kt	20
DF-31 (CSS-10 Mod 1)	6	2006	>7 000	1 x 200–300 kt	6
DF-31A/AG (CSS-10 Mod 2)	72	2007/2018	>11 200	1 x 200–300 kt	72
DF-41 (CSS-20)	–	[2021][h]	>12 000	3 x 200–300 kt MIRV	–
Sea-based missiles (SLBMs)	*4/48*[i]				*48*[j]
JL-2 (CSS-N-14)	48	2016	>7 000	1 x 200–300 kt	48
Total stockpile	**312**				**272**
Other stored warheads[k]					[78]
Total inventory	**312**				**[350]**[k]

. . = not available or not applicable; – = nil or a negligible value; [ ] = uncertain figure; ALBM = air-launched ballistic missile; kt = kiloton; Mt = megaton; 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 loading and in-flight refuelling.

[b] Warhead yields are listed for illustrative purposes. Actual yields are not known, except that older missile warheads had Mt yields. Newer long-range missile warheads probably have yields of a few hundred kt.

[c] Figures are based on estimates of 1 warhead per nuclear-capable launcher, except the MIRVed DF-5B, which can carry up to 5 warheads. The DF-26 is a dual-capable launcher. It is thought that its mission is primarily conventional and only a few launchers are assigned nuclear warheads. Only 1 missile load is assumed for nuclear missiles. The 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 uncertain) that a small number of H-6 bombers previously had a secondary contingency mission with nuclear bombs. The US Department of Defense (DOD) reported in 2018 that the People's Liberation Army Air Force has been reassigned a nuclear mission.

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

In addition to the nuclear-capable missiles listed in this table, the US Central Intelligence Agency concluded in 1993 that China had 'almost certainly' developed a warhead for the DF-15 (CSS-6), but the warhead does not appear to have been fielded.

[f] Although a few liquid-fuelled DF-4s are still in service, they are thought to be in the process of being retired.

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

[h] The DF-41 was publicly displayed for the first time in 2019 and is being integrated into training regiments, but as of Jan. 2021 it had not been declared fully operational. The D-41 is thought to be able to carry at least 3 warheads. SIPRI estimates that *c.* 18 launchers and *c.* 54 warheads might become operational during or after 2021. See note k.

[i] 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. China has 4 operational Type 094 SSBNs, each of which can carry up to 12 SLBMs. Two more Type 094 SSBNs are in development, but were not operational as of Jan. 2021. SIPRI estimates that their armament of 24 additional JL-2 missiles and warheads have probably been produced and might become operational during or after 2021. See note k.

[j] Although Chinese SSBNs conduct patrols, there is no authoritative information suggesting that they have nuclear weapons onboard under normal circumstances.

[k] In addition to the *c.* 272 warheads estimated to be assigned to operational forces, SIPRI estimates that an additional *c.* 78 warheads might have been produced to arm China's new DF-41s (*c.* 54 warheads) and additional JL-2s (*c.* 24 warheads), for a total estimated inventory of *c.* 350 warheads. China's inventory is expected to continue to increase.

Sources: US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat*, various years; US Air Force 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*, 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; and authors' estimates.

Despite the continuing growth in the sophistication and size of its nuclear arsenal, China's ongoing modernization programme (see below) does not, so far, appear to portend changes to its long-standing core nuclear policies, including its no-first-use policy.[5] Although the Chinese military is working to increase the overall readiness of its missile forces, Chinese nuclear warheads are believed to be de-mated from their delivery vehicles—that is, stored separately and not available for immediate use.[6]

Throughout 2020, US officials asserted that there is 'increasing evidence' that China is moving towards adopting a launch-on-warning posture for its land-based ICBMs, which would necessitate the mating of warheads with delivery vehicles; however, while a fully operational SSBN force would require warheads to be loaded on the missiles (see below), there is

[5] US Department of Defense (note 1), p. 86.

[6] 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 1), p. 88.

no publicly available evidence that this has happened yet. Moreover, the evidence of a nascent launch-on-warning posture that US officials have pointed to so far—the development of early-warning systems and new silos for solid-fuelled missiles, in addition to observing the People's Liberation Army Rocket Forces (PLARF) conducting high-alert and combat readiness drills—appears to be relatively circumstantial.[7]

Aircraft and air-delivered weapons

Medium-range combat aircraft were China's earliest means of delivering nuclear weapons and were used to conduct more than 12 atmospheric nuclear tests in the 1960s and 1970s. As of 1993, the US National Security Council stated that 'The [People's Liberation Army Air Force (PLAAF)] has no units whose primary mission is to deliver China's small stockpile of nuclear bombs. Rather, some units may be tasked for nuclear delivery as a contingency mission.'[8]

Before 2018, the US DOD's annual reports on Chinese military developments asserted that PLAAF bombers did not have a nuclear mission. This was probably because China's older bomb-equipped aircraft were unlikely to be useful in the event of a nuclear conflict. This changed in 2018, when the US DOD assessed that 'the PLAAF has been newly re-assigned a nuclear mission'.[9] Throughout this time, SIPRI had continued to assess that China maintained a small inventory of gravity bombs for secondary contingency use by H-6 (B-6) bombers.[10] In its 2020 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'.[11] Legacy H-6 bombers did not include an air-to-air refuelling probe, which significantly limited their long-range targeting capability.

In 2018 the US Defense Intelligence Agency reported that China was developing two new air-launched ballistic missiles (ALBMs), 'one of which

[7] US Department of Defense (note 1), pp. 85–88.

[8] US National Security Council, 'Report to Congress on status of China, India and Pakistan nuclear and ballistic missile programs', 28 July 1993.

[9] US Department of Defense (DOD), *Military and Security Developments Involving the People's Republic of China 2017*, Annual Report to Congress (DOD: Arlington, VA, 15 May 2017), p. 61; and US Department of Defense (DOD), *Military and Security Developments Involving the People's Republic of China 2018*, Annual Report to Congress (DOD: Arlington, VA, 16 May 2018), p. 75.

[10] 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.

[11] US Department of Defense (note 1), p. 50.

may include a nuclear payload'.[12] The missiles may be variants of the Dong Feng-21, or DF-21 (CSS-5), medium-range ballistic missile (MRBM).[13] The first base to be equipped with this capability might be Neixiang, Henan province.[14] Once deployed, the ALBM 'would provide China for the first time with a viable nuclear triad of delivery systems dispersed across land, sea, and air forces', according to the US DOD.[15] 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 is developing its first long-range strategic bomber, known as the H-20 (B-20). The aircraft may have a range of up to 8500 kilometres and a stealthy design. It might be in production within 10 years, according to the US DOD.[16] In its 2020 report, the US DOD also suggested that the H-20 will be able to deliver both conventional and nuclear weapons.[17]

Land-based missiles

China's nuclear-capable land-based ballistic missile arsenal is undergoing gradual modernization as China replaces ageing silo-based, liquid-fuelled missiles with new mobile, solid-fuelled models and increases the number of road-mobile missile launchers. China's shift towards more survivable mobile missiles has been motivated by concerns that the USA's advances in intelligence, surveillance and reconnaissance (ISR) capabilities and in precision-guided conventional weapons pose a pre-emptive threat to fixed missile launch sites and supporting infrastructure.[18]

[12] Ashley, R., Director, US Defense Intelligence Agency, 'Worldwide threat assessment', Statement for the record, US Senate, Armed Services Committee, 6 Mar. 2018, p. 8. See also US Department of Defense (DOD), *Military and Security Developments Involving the People's Republic of China 2019*, Annual Report to Congress (DOD: Arlington, VA, 2 May 2019), p. 67; and 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.

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

[14] Lee, R., 'China's Air Force might be back in the nuclear business', The Diplomat, 9 Sep. 2020.

[15] US Department of Defense (note 1), p. 87.

[16] 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. See also Yeo, M., 'In first, China confirms "new long-range strategic bomber" designation', *Defense News*, 11 Oct. 2018; and Tate, A., 'Details emerge about requirement for China's new strategic bomber', *Jane's Defence Weekly*, 4 Jan. 2017, p. 4.

[17] US Department of Defense (note 1), p. 80.

[18] O'Connor, S., 'Sharpened Fengs: China's ICBM modernisation alters threat profile', *Jane's Intelligence Review*, vol. 27, no. 12 (Dec. 2015), pp. 44–49; and Eveleth, D., 'China's mobile ICBM brigades: The DF-31 and DF-41', A Boy and His Blog, 2 July 2020.

Intercontinental ballistic missiles

In its 2020 report, the US DOD estimated that China's arsenal includes 100 ICBMs, and that the number of warheads on Chinese ICBMs capable of reaching the USA is expected to grow to 200 by 2025.[19] The silo-based, liquid-fuelled, two-stage DF-5 (CSS-4) family of missiles—which first entered into service in the early 1980s—are currently China's longest-range ICBMs. Along with the road-mobile, solid-fuelled, three-stage DF-31A/AG (CSS-10 Mod 2) ICBM, they are the only operational missiles in China's arsenal capable of targeting all of the continental USA and Europe.[20]

The PLARF has been developing a longer-range ICBM—the road-mobile, solid-fuelled, three-stage DF-41 (CSS-20)—since the late 1990s. The DF-41 has an estimated range in excess of 12 000 km, similar to that of the older DF-5. Rail-mobile and silo-based versions of the missile are believed to be under development.[21] Satellite imagery in 2019 and 2020 indicated that the PLARF was building a significant number of silos—16 so far—at a missile training area near Jilantai, Inner Mongolia, possibly for the DF-41.[22] It also indicated that new silo construction might have started at Sundian, Henan province, in 2017.[23] However, it is unclear whether these silos are intended to achieve an operational capability or if they are just for training; the US DOD assessed in 2020 that Jilantai 'is probably being used to at least develop a concept of operations for silo basing [the DF-41] system'.[24] There have been 11 known flight tests of the DF-41 since 2012. The most recent, in November 2019, was presumably one of the last tests of the system before it becomes operational.[25] The DF-41s are currently being integrated into the first PLARF brigades; and a small number of launchers might reach operational status in 2021.[26]

After many years of research and development, China has modified a small number of ICBMs to deliver nuclear multiple independently targetable re-entry vehicles (MIRVs). This is apparently to improve the penetration capabilities of its warheads in response to advances in US and, to a lesser

[19] US Department of Defense (note 1), p. 56.
[20] US Department of Defense (note 1), p. 56.
[21] US Department of Defense (note 1), p. 56.
[22] Kristensen, H. M., 'China's expanding missile training area: More silos, tunnels, and support facilities', Federation of American Scientists (FAS) Strategic Security Blog, 24 Feb. 2021; and Kristensen, H. M., 'New missile silo and DF-41 launchers seen in Chinese nuclear missile training area', FAS Strategic Security Blog, 3 Sep. 2019.
[23] LaFoy, S. and Eveleth, D., 'Possible ICBM modernization underway at Sundian', Arms Control Wonk, 5 Feb. 2020.
[24] US Department of Defense (note 1), p. 89.
[25] Gertz, B., 'Long-range missile test adds to growing Chinese arsenal', *Washington Times*, 25 Nov. 2019.
[26] US Department of Defense (note 16), p. 3; and US Air Force (note 12), p. 29.

extent, Russian and Indian missile defences.[27] The DF-5B (CSS-4 Mod 2) is a MIRVed variant of the DF-5 that can carry up to five MIRVed warheads, two more than previously assumed.[28] A second variant under development, the DF-5C (CSS-4 Mod 3), can reportedly also carry MIRVed 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 the DF-5B version.[29] There has been speculation that the DF-41 is able to carry 6–10 MIRVed 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.[30]

Intermediate- and medium-range ballistic missiles

In 2016 the PLARF began the deployment of the new dual-capable DF-26 (CSS-18) intermediate-range ballistic missile.[31] This missile has an estimated maximum range exceeding 4000 km and can therefore reach targets all over India and the western Pacific Ocean, including the US strategic base on Guam.[32] The missile is equipped with a manoeuvrable re-entry vehicle (MaRV) that is reportedly capable of precision conventional or nuclear strikes against ground targets, as well as conventional strikes against naval targets.[33] In August 2020 China conducted a flight test of a DF-26B, a variant of the DF-26 that could have an anti-ship mission.[34] China appears to be producing the DF-26 in significant numbers, and might have had an inventory of up to 100 launchers as of the beginning of 2021, with many more in production. There were sightings of the missile at several PLARF brigade bases during 2020.[35]

The PLARF currently deploys an estimated 40 nuclear-capable DF-21 (CSS-5) MRBMs. The DF-21 is a two-stage, solid-fuelled mobile missile. The original DF-21 (CSS-5 Mod 1) was first deployed in 1991 but has since been

[27] US Department of Defense (note 12), p. 65; 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.

[28] US Department of Defense (note 12), p. 44; and US Department of Defense (note 1), p. 56.

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

[30] O'Halloran, J. C. (ed.), *IHS Jane's Weapons: Strategic, 2015–16* (IHS Jane's: Coulsdon, 2015), pp. 21–22; and Gertz, B., 'China flight tests new multiple-warhead missile', Washington Free Beacon, 19 Apr. 2016.

[31] US Department of Defense, *Military and Security Developments Involving the People's Republic of China 2018* (note 9), p. 36; and US Department of Defense (note 12), p. 44.

[32] US Department of Defense (note 1), pp. 59, 81; and Deng, X., 'China deploys Dongfeng-26 ballistic missile with PLA Rocket Force', *Global Times*, 26 Apr. 2018.

[33] Tate, A., 'China touts ASBM capabilities of DF-26', Janes, 28 Jan. 2019; and Deng (note 32).

[34] Huang, K., 'Chinese military fires "aircraft-carrier killer" missile into South China Sea in "warning to the United States"', *South China Morning Post*, 26 Aug. 2020; and Pollack, J. H. and LaFoy, S., 'China's DF-26: A hot-swappable missile?', Arms Control Wonk, 17 May 2020.

[35] Kristensen, H. M., 'China's new DF-26 missile shows up at base in eastern China', Federation of American Scientists (FAS) Strategic Security Blog, 21 Jan. 2020.

retired. An upgraded variant, the DF-21A (CSS-5 Mod 2), was first deployed in 1996 and an enhanced version (CSS-5 Mod 6) was fielded in 2017.[36] Two other versions of the missile (DF-21C and DF-21D) were designed for conventional anti-ship and anti-access/area-denial (A2/AD) missions.[37]

In October 2019 the PLARF paraded 16 new DF-17 (CSS-22) MRBMs carrying hypersonic glide vehicles (HGVs), although the missiles are unlikely to have begun combat deployment as of January 2021.[38] The missile's nuclear capability remains unclear: despite the parade announcer referring to the missiles as conventional, in 2020 the commander of US Strategic Command, Admiral Charles A. Richard, described the DF-17 as a 'strategic nuclear system'.[39] Because of the high level of uncertainty about the status of the DF-17, it is not included in SIPRI's estimate for January 2021.

Sea-based missiles

In 2020 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 2020 report, the PLA Navy (PLAN) has constructed six Type 094 SSBNs, although the two latest boats—which are believed to be variants of the original design known as Type 094A—are not yet operational.[40] The US DOD report assessed that the four operational Type 094 SSBNs constitute China's 'first credible, sea-based nuclear deterrent'.[41]

China's four Type 094 submarines can each carry up to 12 three-stage, solid-fuelled Julang-2 (JL-2 or 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.[42]

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 reports that nuclear-armed patrols have commenced. 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

[36] ed. O'Halloran (note 30), pp. 15–17.
[37] US Air Force (note 12), p. 22.
[38] New China TV, 'China holds grand gathering, parade on 70th National Day', YouTube, 1 Oct. 2019.
[39] New China TV (note 38); and Richard, C. A., Commander, US Strategic Command, Statement, US Senate, Armed Services Committee, 13 Feb. 2020, p. 4.
[40] US Department of Defense (note 1), p. 45. The Type 094 SSBN is designated the Jin class by the USA and the North Atlantic Treaty Organization (NATO).
[41] US Department of Defense (note 1), p. 45.
[42] US Department of Defense (note 1), p. 45.

pose operational challenges for its nuclear command-and-control arrangements.[43] 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 the continental USA.

The PLAN is developing its next-generation SSBN, the Type 096. The US DOD predicted in 2020 that construction would probably begin in the early 2020s.[44] Reports vary widely on the design parameters, but the new submarine is expected to be larger and quieter than the Type 094 and might be equipped with more missile launch tubes. Given the expected lifespans of both the current Type 094 and the next-generation Type 096 submarines, the PLAN will probably operate both types of SSBN concurrently. In 2020 the US DOD assessed that China could have up to eight SSBNs by 2030.[45]

The Type 096 will be armed with a successor to the JL-2: the JL-3 SLBM.[46] The new missile 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 (NASIC) assesses that the JL-3 will be capable of carrying multiple warheads and have a range of more than 10 000 km.[47]

[43] China Power, 'Does China have an effective sea-based nuclear deterrent?', Center for Strategic and International Studies (CSIS), Mar. 2020.
[44] US Department of Defense (note 1), p. 45.
[45] US Department of Defense (note 1), p. 45.
[46] US Department of Defense (note 12), p. 36.
[47] US Air Force (note 12), p. 33.

VI. Indian nuclear forces

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As of January 2021, India was estimated to have a growing inventory of about 156 nuclear weapons, an increase of roughly 6 from the previous year (see table 10.7). These weapons are 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 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. The Indian Government itself does not provide much public information about the status of its nuclear forces, other than occasional parade displays and announcements about missile flight tests. India is expanding the size of its nuclear weapon inventory as well as its infrastructure for producing nuclear warheads.

The role of nuclear weapons in Indian military doctrine

In the past, the limited ranges of many of India's initial nuclear systems meant that their only role was to deter Pakistan. India now appears to place increased emphasis on China, with the development of longer-range missiles capable of targeting all of China. It remains to be seen how this development will affect India's nuclear arsenal and strategy. It also remains to be seen if recent border clashes with China and Pakistan will affect India's nuclear posture.[1]

India has long adhered to a nuclear no-first-use policy; however, this pledge is qualified by a caveat that India could use nuclear forces to retaliate against attacks by non-nuclear weapons of mass destruction (WMD).[2] Remarks in recent years by Indian defence ministers have also created doubts about India's commitment to the no-first-use policy.[3] Recent scholarship and government statements have called that policy into further question, with some analysts suggesting that 'India's NFU [no-first-use]

[1] On the border tensions in 2020 between China and India, and between India and Pakistan see chapter 4, section II, in this volume. On the escalation on the India–Pakistan border in 2019 see Smith, D., 'Introduction: International stability and human security in 2019', *SIPRI Yearbook 2020*, pp. 8–12.

[2] Indian Ministry of External Affairs, 'The Cabinet Committee on Security reviews [o]perationalization of India's nuclear doctrine', Press release, 4 Jan. 2003.

[3] E.g. Singh, R., Indian Minister of Defence (@rajnathsingh), 'Pokhran is the area which witnessed Atal Ji's firm resolve to make India a nuclear power and yet remain firmly committed to the doctrine of "No First Use". India has strictly adhered to this doctrine. What happens in future depends on the circumstances.', Twitter, 16 Aug. 2019; and Som, V., 'Defence Minister Manohar Parrikar's nuclear remark stressed as "personal opinion"', NDTV, 10 Nov. 2016.

policy is neither a stable nor a reliable predictor of how the Indian military and political leadership might actually use nuclear weapons'.[4]

In addition, India appears to be taking steps to increase the responsiveness of its arsenal by 'canisterizing' some of its ballistic missiles, initially the Agni-V (see below). This refers to keeping missiles inside a tube to protect them from the elements while being transported. Missiles can also be launched directly from canisters, usually using a 'cold-launch' process that involves using a gas generator to eject the missile from the canister before ignition. Missiles launched from canisters are pre-mated with their warheads to ensure rapid launch. Submarines on deterrence patrol will also have pre-mated warheads; however, it is currently unclear whether India has conducted a true deterrence patrol.

Former senior civilian security officials and former officers of India's Strategic Forces Command (SFC) have reportedly suggested that some portion of India's arsenal, particularly those weapons and capabilities designed for retaliation against Pakistan, 'are now kept at a much higher state of readiness, capable of being operationalized and released within seconds or minutes—not hours, as has been previously assumed'.[5] Whether that means that warheads are mated all the time is unclear; the first canisterized missile (the Agni-V) is not yet deployed. But pre-mating could form the basis of a higher alert posture in the future. Indeed, to provide a credible secure second-strike capability, warheads would have to be mated with missiles on India's nascent fleet of nuclear-powered ballistic missile submarines (SSBNs).

Aircraft and air-delivered weapons

Aircraft are the most mature component of India's nuclear strike capabilities. It is estimated here that approximately 48 nuclear bombs are assigned to aircraft. The Indian Air Force (IAF) has reportedly certified its Mirage 2000H fighter-bombers for delivery of nuclear gravity bombs.[6] It is widely speculated that the IAF's Jaguar IS fighter-bombers may also have a nuclear delivery role.[7]

[4] Sundaram, K. and Ramana, M. V., 'India and the policy of no first use of nuclear weapons', *Journal for Peace and Nuclear Disarmament*, vol. 1, no. 1 (2018), p. 153. See also Clary, C. and Narang, V., 'India's counterforce temptations: Strategic dilemmas, doctrine, and capabilities', *International Security*, vol. 43, no. 3 (winter 2018).

[5] Narang, V., 'Five myths about India's nuclear posture', *Washington Quarterly*, vol. 36, no. 3 (summer 2013), p. 149.

[6] 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.

[7] 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.

Table 10.7. Indian nuclear forces, January 2021

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
Land-based missiles[e]	*64*				*64*
Prithvi-II	24	2003	250[f]	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	–	[2021]	>3 500	1 x 10–40 kt	–
Agni-V	–	[2025]	>5 000	1 x 10–40 kt	–
Sea-based missiles	*3/14*[g]				*16*
Dhanush	2	2013	400	1 x 12 kt	4[h]
K-15 (B-05)[i]	12[j]	2018	700	1 x 12 kt	12
K-4	–[k]	[2025]	3 500	1 x 10–40 kt	–
Total stockpile	**126**				**128**
Other stored warheads[l]					28
Total inventory	**126**				**156**[l]

– = nil or a negligible value; [ ] = uncertain figure; kt = kiloton.

[a] For aircraft, the listed range is for illustrative purposes only; actual mission range will vary according to flight profile, weapon loading 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 1 nuclear warhead per launcher. All estimates are approximate.

[d] Other aircraft that could potentially have a secondary nuclear role include the Su-30MKI. India is also in the process of acquiring Rafale aircraft from France, which could potentially be assigned a nuclear role in the future.

[e] In addition to the land-based missiles listed here, an Agni-VI is thought to be in the design phase. With a range of approximately 6000 km, it would be India's first intercontinental ballistic missile.

[f] The Prithvi-II's range is often reported as 350 km. However, the US Air Force's National Air and Space Intelligence Center (NASIC) sets the range at 250 km.

[g] The first figure is the number of operational vessels—2 ships and 1 nuclear-powered ballistic missile submarine (SSBN); the second is the maximum number of missiles that they can carry. India has launched 2 SSBNs, but only 1—INS *Arihant*—is believed to be operational and probably has only a limited operational capability. The other SSBN—INS *Arighat*—is being fitted out and might become operational during or after 2021.

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

[i] Some sources have referred to the K-15 missile as Sagarika, which was the name of the missile development project.

j 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 an additional *c*. 12 K-15 missiles and warheads have been produced and might become operational during or after 2021 (see notes g and l).

[k] Each missile tube will be able to carry 1 K-4 SLBM once it becomes operational.

[l] In addition to the *c*. 128 warheads estimated to be assigned to operational forces, SIPRI estimates that an additional *c*. 28 warheads might have been produced to arm Agni-IV and Agni-V missiles (*c*. 16 warheads) and K-15 missiles (*c*. 12 warheads for INS *Arighat*), for a total estimated inventory of *c*. 156 warheads. India's inventory 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.

In addition, India has bought 36 Rafale combat aircraft from France, with delivery starting in July 2020.[8] According to the Indian Ministry of Defence, the 'Rafale will provide IAF the strategic deterrence and requisite capability cum technological edge'.[9] It is unclear whether this language indicates a future nuclear role for the Rafales.

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).[10]

Two new and longer-range land-based ballistic missiles are in development: the Agni-IV (>3500 km) and the Agni-V (>5000 km). A variant with an even longer range, the Agni-VI (6000 km), is in the design stage of development.[11] Unlike the other Agni missiles, the Agni-V is designed to be stored in and launched from a new mobile canister system, which will reduce the time required to place the missiles on alert in a crisis.[12] The Agni-V is currently undergoing final development trials. According to one report, the missile might be handed over to the military (inducted) sometime in the first half of 2021.[13]

India is also developing a land-based, short-range version (750 km) of the K-15 submarine-launched ballistic missile (SLBM)—known as the Shaurya.

[8] Deutsche Welle, 'India: French Rafale jets land amid tensions with China', 29 July 2020.

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

[10] The Prithvi-II's range is often reported as 350 km. However, the range is set at 250 km in 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.

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

[12] Aroor, S., 'New chief of India's military research complex reveals brave new mandate', *India Today*, 13 July 2013.

[13] Rout, H. K., 'India plans deployment of nuclear-capable Agni-V this year', *New Indian Express*, 4 Jan. 2021.

Because the K-15 is nuclear-capable, media reports also widely attribute nuclear capability to the Shaurya.[14] No official government statement has confirmed this, however, and with only three or four flight tests, reports about imminent deployment seem premature.[15] The US Air Force's National Air and Space Intelligence Center (NASIC) does not mention the Shaurya in its ballistic and cruise missile reports of 2020 and 2017.[16] Because of the high level of uncertainty about the status of the Shaurya, it is not included in SIPRI's estimate for January 2021.

India reportedly carried out at least five test launches of land-based ballistic missiles in 2020. The known launches included night-time flight tests of four Prithvi-II missiles and one Shaurya missile.[17] An Agni-IV test may have been scheduled for late December; however, it is unclear whether that test took place.

India is reportedly pursuing a technology development programme for multiple independently targetable re-entry vehicles (MIRVs). However, there have been conflicting views among defence planners and officials about how to proceed with the programme, in particular about whether MIRVs should be initially deployed on the intermediate-range Agni-V or on the intercontinental Agni-VI, which will have a heavier payload capacity.[18]

Sea-based missiles

With the aim of creating an assured second-strike capability, India continues to develop the naval component of its nascent nuclear triad and is building a fleet of four to six SSBNs.[19] The first SSBN, the INS *Arihant*, was launched in 2009 and formally commissioned in 2016.[20] It is estimated here

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

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

[16] US Air Force (note 10); and 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).

[17] Express News Service, 'Nuke capable Prithvi-II night trial successful', *New Indian Express*, 24 Sep. 2020; Press Trust of India (PTI), 'Successful night trial of nuclear-capable Prithvi-2 missile', *Times of India*, 16 Oct. 2020; Rout, H. J. (@TheHemantRout), '#FirstVisual of Prithvi #missile night trial from ITR off #Odisha coast. #India test fires 2 variants of #Prithvi in quick succession to reconfirm operational readiness. Developed by @DRDO_India, the tactical #nuclear capable weapons can strike targets at a range up to 350 km.', Twitter, 17 Dec. 2020; and Mohanty, D. and Singh, R., 'India successfully tests nuclear-capable Shaurya missile', *Hindustan Times*, 3 Oct. 2020.

[18] Basrur, R. and Sankaran, J., 'India's slow and unstoppable move to MIRV', 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).

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

[20] Dinakar, P., 'Now, India has a nuclear triad', *The Hindu*, 18 Oct. 2016.

that 12 nuclear warheads have been delivered for potential deployment by the *Arihant* and another 12 produced for a second SSBN, the INS *Arighat*, which is being fitted out.

In November 2018 the Indian Government announced that the *Arihant* had completed its first 'deterrence patrol'.[21] However, it is doubtful that the submarine's missiles carried nuclear warheads during the patrol.[22] The *Arihant* is assessed here to have only a limited operational capability.

The INS *Arighat* was launched in November 2017 and is expected to be commissioned into the Indian Navy in early 2021.[23] Construction work has reportedly begun on a third and fourth submarine, with expected launch dates in 2021 and 2023, respectively.[24]

Photographs indicate that the *Arihant* and *Arighat* are each equipped with a four-tube vertical-launch system and can carry up to 12 two-stage, 700-km range K-15 SLBMs (which the Indian Ministry of Defence calls the B-05).[25] India's third and fourth submarines are expected to be larger than its first two. They will reportedly have 8 launch tubes to hold up to 24 K-15s or 8 K-4 missiles, which are in development.[26]

The K-4 is a two-stage, 3500-km range SLBM that is being developed by the Defence Research and Development Organisation (DRDO). It will eventually replace the K-15, although only with four or eight missiles per submarine, depending on the number of launch tubes.[27] The DRDO has also started to develop extended-range versions: the K-5 SLBM, which will reportedly have a range in excess of 5000 km, and the K-6, which will have an even longer range.[28] The K-4 was tested twice by the DRDO in January 2020 from a submerged pontoon.[29] With only two successful launches (two

[21] Indian Prime Minister's Office, 'Prime Minister felicitates crew of INS Arihant on completion of Nuclear Triad', Press Information Bureau, 5 Nov. 2018; and Davenport (note 19).

[22] Joshi, Y., 'Angels and dangles: Arihant and the dilemma of India's undersea nuclear weapons', War on the Rocks, 14 Jan. 2019.

[23] Bedi, R., 'India to commission second Arihant-class submarine in 2021', Janes, 22 Dec. 2020. Until its launch, the submarine was assumed to be named INS *Aridhaman*.

[24] Unnithan, S., 'A peek into India's top secret and costliest defence project, nuclear submarines', *India Today*, 10 Dec. 2017.

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

[26] Philip, S. A., 'Ballistic missile submarine Arighat in final stages of trials, to be commissioned early 2021', ThePrint, 16 Dec. 2020; and Kristensen, H. (@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.

[27] Jha, S., 'India's undersea deterrent', The Diplomat, 30 Mar. 2016; and US Air Force (note 10), p. 30.

[28] Unnithan (note 24).

[29] 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.

previous attempts failed), and none from a submarine, the K-4 still seems to be several years from operational capability.

India's first naval nuclear weapon was the Dhanush missile, a version of the dual-capable Prithvi-II that can be launched from a surface ship. Two Sukanya-class offshore patrol vessels based at the Karwar Naval Base on India's west coast have been converted to launch the Dhanush. The missile can reportedly carry a 500-kg warhead to a maximum range of 400 km and is designed to be able to hit both sea- and shore-based targets. Its utility as a second-strike deterrence weapon is limited by its relatively short range, which would make its carrier vessels vulnerable to anti-ship missiles and rapid-response combat aircraft.[30] The Dhanush will probably be retired when the SSBN programme with longer-range missiles matures. The most recent known Dhanush test launch was in November 2018.[31]

Cruise missiles

There are 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.[32] There is, however, no official or authoritative source that attributes nuclear capability to India's cruise missiles. Therefore, they are not included in SIPRI's estimate for January 2021.

[30] *New Indian Express*, 'Nuke-capable Dhanush and Prithvi-II launched', 12 Mar. 2011.

[31] Indian Ministry of Defence (note 9), p. 100.

[32] 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

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It is estimated that Pakistan possessed approximately 165 nuclear warheads as of January 2021, an increase of 5 from the previous year (see table 10.8). The Pakistani Government has never publicly disclosed the size of its nuclear arsenal; the estimate made here is based on analysis of Pakistan's nuclear posture, previous statements by Western officials, and private conversations with officials. Analysing the number and types of Pakistani warheads and delivery vehicles is fraught with uncertainty, due to limited official public data and widespread exaggerated news stories about nuclear weapons. Pakistan's nuclear weapon arsenal and fissile material stockpile are likely to continue expanding over the next decade, although projections vary considerably.[1]

The role of nuclear weapons in Pakistani military doctrine

Pakistan is pursuing the development and deployment of new nuclear weapons and delivery systems as part of its 'full spectrum deterrence posture' in relation to India.[2] 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.[3] Pakistan's emphasis on non-strategic nuclear weapons is specifically intended to be a reaction to India's perceived 'Cold Start' doctrine. This alleged doctrine 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 retaliate with nuclear weapons.[4] In 2015 a retired member of Pakistan's National Command Authority suggested that 'by introducing the variety of tactical nuclear

[1] See e.g. Sundaresan, L. and Ashok, K., 'Uranium constraints in Pakistan: How many nuclear weapons does Pakistan have?', *Current Science*, vol. 115, no. 6 (25 Sep. 2018); and Salik, N., 'Pakistan's nuclear force structure in 2025', Regional Insight, Carnegie Endowment for International Peace, 30 June 2016. On Pakistan's fissile material stockpile see Kile, S. N. and Kristensen, H. M., 'Pakistani nuclear forces', *SIPRI Yearbook 2019*, pp. 332–33; and section X of this chapter.

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

[3] Pakistani Inter Services Public Relations, Press Release PR-94/2011-ISPR, 19 Apr. 2011.

[4] Kidwai (note 2). 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.

Table 10.8. Pakistani nuclear forces, January 2021

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	1998	2 100	1 x 5–12 kt bomb or Ra’ad ALCM (in development)[e]	36
Land-based missiles	*118*[f]				*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 (Hatf-4)[g]	–	. .	900	1 x 5–12 kt	–
Shaheen-II (Hatf-6)	16	2014	2 000	1 x 10–40 kt	16
Shaheen-III (Hatf-. .)[h]	–	[2022]	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 (Hatf-. .)	–	. .	2 200	MIRV or MRV	–[i]
Babur GLCM (Hatf-7)	12	2014	350[j]	1 x 5–12 kt	12
Babur-2 GLCM (Hatf-. .)	–	. .[k]	700	1 x 5–12 kt	–
Sea-based missiles					
Babur-3 SLCM (Hatf-. .)	–	. .[l]	450	1 x 5–12 kt	–
Total stockpile	**154**				**154**
Other stored warheads[m]					11
Total inventory	**154**				**165**[m]

. . = not available or not applicable; – = nil or a negligible value; [ ] = uncertain figure; 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 loading 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-based and sea-based missiles) can carry more than 1 missile. This estimate counts an average of 1 nuclear warhead per launcher. Warheads are not deployed on launchers but are kept in separate storage facilities.

[d] There are unconfirmed reports that some of the 40 F-16 aircraft procured from the USA in the 1980s were modified by Pakistan for a nuclear weapon delivery role. 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] 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 so 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.

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

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

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

[i] According to the Pakistani military, the missile is 'capable of delivering multiple warheads, using [MIRV] technology'.

[j] The Pakistani Government claims that the range of the Babur GLCM is 700 km, double the range reported by the United States Air Force's National Air and Space Intelligence Center (NASIC).

[k] The Babur-2, which was first test launched on 14 Dec. 2016, is an improved version of the original Babur GLCM and will probably replace it. A failed test in 2020 indicates additional development is needed before it can be fielded.

[l] The first test launch of a Babur-3 SLCM was carried out from an underwater platform in 2017. A second test occurred in 2018.

[m] In addition to the *c.* 154 warheads estimated to be assigned to operational forces, a small number of additional warheads (*c.* 11) are thought to have been produced to arm future Shaheen-III and cruise missiles, for a total estimated inventory of *c.* 165 warheads. Pakistan's warhead inventory is expected to continue to increase.

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

weapons in Pakistan's inventory . . . , we have blocked the avenues for serious military operations by the other side'.[5]

Aircraft and air-delivered weapons

Pakistan has a small stockpile of gravity bombs. The Ra'ad (Hatf-8) air-launched cruise missile (ALCM) is being developed to supplement this stockpile by providing the Pakistan Air Force (PAF) with a nuclear-capable standoff capability at a range of 350 kilometres. The most recent reported flight test—believed to be the seventh test since 2007—was in 2016.[6] An improved version, the Ra'ad-II, was displayed for the first time in 2017 and is reported to have a range of 600 km due to its more advanced engine.[7] This would theoretically allow Pakistan's aircraft to reach critical targets inside India while remaining within Pakistani airspace. The Ra'ad-II was tested for the first time in February 2020.[8] There is no available evidence to suggest that either version of the Ra'ad ALCM had been deployed as of January 2021.

The aircraft that are most likely to have a nuclear delivery role are the PAF's Mirage III and Mirage V aircraft. The Mirage III has been used for developmental test flights of the nuclear-capable Ra'ad ALCM, while the

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

[6] Pakistani Inter Services Public Relations, Press Release PR-16/2016-ISPR, 19 Jan. 2016.

[7] Pakistani Inter Services Public Relations, 'Pakistan conducted successful flight test of air launched cruise missile "Ra'ad-II"', Press Release PR-27/2020-ISPR, 18 Feb. 2020.

[8] Pakistani Inter Services Public Relations (note 7).

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 due to reports in the late 1980s that Pakistan was in the process of modifying them to deliver nuclear weapons.[10] In the light of this uncertainty, Pakistan's F-16s are not identified here as having a dedicated nuclear weapon delivery system (and so are omitted from table 10.8).

Pakistan also operates about 100 JF-17 aircraft, which it has acquired from China. It intends to acquire a total of approximately 150 to replace the ageing Mirage III and Mirage V aircraft.[11] Initial reports from 2016 on upgrades to the JF-17 suggested that the PAF aimed to integrate the dual-capable Ra'ad ALCM onto the aircraft.[12] More recent reporting has not mentioned the weapon, which could indicate that its primary carrier will remain the Mirage III for the foreseeable future. When the Mirage aircraft are eventually phased out, it is possible that the JF-17 will take over their nuclear role in the PAF.[13]

Land-based missiles

Pakistan's current nuclear-capable ballistic missile arsenal comprises short- and medium-range systems.

As of January 2021, Pakistan deployed the Abdali (also designated Hatf-2), Ghaznavi (Hatf-3), Shaheen-I (Hatf-4) and Nasr (Hatf-9) solid-fuelled, road-mobile short-range ballistic missiles. In an important milestone for testing the readiness of Pakistan's nuclear forces, the Ghaznavi was test launched at night in January 2020.[14] The Shaheen-IA, an extended-range version of the Shaheen-I, is still in development.

[9] Kerr, P. and Nikitin, M. B. D., *Pakistan's Nuclear Weapons*, Congressional Research Service (CRS) Report for Congress RL34248 (US Congress, CRS: Washington, DC, 1 Aug. 2016), p. 7.

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

[11] Khan, B., 'Pakistan inches closer to inducting the JF-17 Block 3', Quwa Defence News and Analysis Group, 1 July 2019; Waldron, G., 'Paris: JK-17 Block III to have first flight by year-end', FlightGlobal, 20 June 2019; 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; and Quwa Defence News and Analysis Group, 'Pakistan Aeronautical Complex delivers new JF-17B batch', 2 Jan. 2021.

[12] Fisher, R., 'JF-17 Block II advances with new refuelling probe', *Jane's Defence Weekly*, 27 Jan. 2016.

[13] PakDefense, 'Ra'ad ALCM: The custodian of Pakistan's airborne nuclear deterrence', 6 Dec. 2020.

[14] Pakistani Inter Services Public Relations, 'Pakistan today conducted a successful training launch of surface to surface ballistic missile Ghaznavi, capable of delivering multiple types of warheads up to a range of 290 kilometers', Press Release PR-8/2020-ISPR, 23 Jan. 2020.

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.[15] The Shaheen-II has been test launched seven times since 2004, with the most recent launch taking place in 2019.[16] A longer-range variant, the Shaheen-III, is currently in development but has been test launched only twice—in 2015 and early 2021—and is not yet deployed.[17] This missile has a claimed range of 2750 km, making it the longest-range system to be tested by Pakistan to date. A variant of the Shaheen-III, the Ababeel, is also in development. After the most recent test launch of the Ababeel in 2017, the Pakistani Government claimed that the missile would be 'capable of delivering multiple warheads, using Multiple Independent[ly Targetable] Re-entry Vehicle (MIRV) technology'.[18]

In addition to expanding its arsenal of land-based ballistic missiles, in 2020 Pakistan continued to develop the nuclear-capable Babur (Hatf-7) ground-launched cruise missile. The United States Air Force's National Air and Space Intelligence Center (NASIC) claims the Babur has a range of 350 km.[19] It has been test launched at least 12 times since 2005 and has been used in army field training since 2011, indicating that the system is likely to be operational. An extended-range version, which is known as the Babur-2 and sometimes referred to as Babur Weapon System-1 (B), has a claimed range of 700 km. It was first test launched in 2016 and was subsequently tested in 2018 and 2020, the latter of which failed.[20]

Sea-based missiles

As part of its efforts to achieve a secure second-strike capability, Pakistan is seeking to create a nuclear triad by developing a sea-based nuclear force. The Babur-3 submarine-launched cruise missile (SLCM) is intended to

[15] 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. 25.

[16] Pakistani Inter Services Public Relations, 'Pakistan conducted successful training launch of surface to surface ballistic missile Shaheen-II', Press Release PR-104/2019-ISPR, 23 May 2019.

[17] Pakistani Inter Services Public Relations, 'Shaheen 3 missile test', Press Release PR-61/2015-ISPR, 9 Mar. 2015; and Jamal, S., 'Pakistan tests nuclear-capable Shaheen-III ballistic missile', *Gulf News*, 20 Jan. 2021.

[18] Pakistani Inter Services Public Relations, Press Release PR-34/2017-ISPR, 24 Jan. 2017. The US National Air and Space Intelligence Center also describes the 2017 test as involving 'the MIRV version of the Ababeel'. US Air Force (note 15), p. 25. On the Ababeel see also Kile and Kristensen (note 1), p. 335.

[19] 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.

[20] Pakistan Inter Services Public Relations, 'Pakistan today conducted a successful test of an enhanced range version of the indigenously developed Babur cruise missile', Press Release PR-142/2018-ISPR, 14 Apr. 2018; and Gupta, S., 'Pakistan's effort to launch 750km range missile crashes', *Hindustan Times*, 23 Mar. 2020.

establish a nuclear capability for the Pakistan Navy's Hashmat-class diesel–electric submarines.[21] The Babur-3 was first test launched in 2017 and was tested for a second time in 2018.[22]

Pakistan has ordered eight air-independent propulsion-powered submarines from China, the first of which is expected to be delivered in 2022. It is possible that these Hangor-class submarines might also be given a nuclear role with the Babur-3 SLCM.[23]

[21] Panda, A. and Narang, V., 'Pakistan tests new sub-launched nuclear-capable cruise missile. What now?', The Diplomat, 10 Jan. 2017.

[22] Pakistani Inter Services Public Relations, 'Pakistan conducted another successful test fire of indigenously developed submarine launched cruise missile Babur having a range of 450 kms', Press Release 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.

[23] Khan, B., 'Profile: Pakistan's new Hangor submarine', Quwa Defence News and Analysis Group, 11 Nov. 2019.

VIII. Israeli nuclear forces

HANS M. KRISTENSEN AND MATT KORDA

As of January 2021, Israel was estimated to have an inventory of around 90 nuclear warheads (see table 10.9), the same number as in January 2020. Israel continues to maintain its long-standing policy of nuclear opacity: it neither officially confirms nor denies that it possesses nuclear weapons.[1] Due to Israel's unique lack of transparency, there is significant uncertainty about the size of its nuclear arsenal and associated warhead capabilities. 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

For decades, the Israeli Government has repeated that Israel 'won't be the first to introduce nuclear weapons into the Middle East'.[2] However, the government's interpretation of 'introducing' nuclear weapons appears to have significant caveats, in order to accommodate the high likelihood that Israel in reality possesses a significant nuclear stockpile. Israeli policy-makers have previously suggested that 'introducing' nuclear weapons would necessarily require Israel to test, publicly declare or actually use its nuclear capability, which, according to available open-access sources, it has not yet done.[3] Another caveat may be that the warheads are not fully assembled under normal circumstances.

It is unclear what 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.

[1] On the role of this policy in Israel's national security decision making see Cohen, A., 'Israel', eds H. Born, B. Gill and H. Hänggi, SIPRI, *Governing the Bomb: Civilian Control and Democratic Accountability of Nuclear Weapons* (Oxford University Press: Oxford, 2010).

[2] E.g. Netanyahu, B., Interview, *Piers Morgan Tonight*, CNN, 17 Mar. 2011.

[3] US Department of Defense, Office of the Assistant Secretary of Defense, 'Negotiations with Israel—F-4 and advanced weapons', Memorandum of Conversation, 12 Nov. 1968, via National Security Archive; and Kissinger, H., 'Israeli nuclear program', Memorandum for the President, 19 July 1969, via National Security Archive. For a summary and discussion of available evidence that Israel may have participated in a nuclear test in 1979 see Cohen, A. and Burr, W., 'Revisiting the 1979 VELA mystery: A report on a critical oral history conference', Wilson Center, History and Public Policy Program, Sources and Methods Blog, 31 Aug. 2020.

Table 10.9. Israeli nuclear forces, January 2021

Type/designation	Range (km)[a]	Payload (kg)	Status	No. of warheads
Aircraft[b]				*30*
F-16I	1 600	5 400	A small number (1–2 squadrons) of Israel's F-16s is believed to be equipped for nuclear weapon delivery (2 bombs per aircraft).	30
Land-based missiles[c]				*50*
Jericho II	1 500–1 800	750–1 000	First deployed in 1990. Being replaced by the Jericho III.	25
Jericho III	>4 000	1 000–1 300	Became operational in 2011–15 and is gradually replacing the Jericho II.	25
Sea-based missiles				*10*
. .	. .	. .	Unconfirmed reports suggest that Dolphin- and Dolphin 2-class diesel–electric submarines have been equipped with nuclear-armed SLCMs.	10
Total inventory				**90**[d]

. . = not available or not applicable; SLCM = sea-launched cruise missile.

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

[b] It is possible that some of Israel's F-15 aircraft may also serve a nuclear strike role.

[c] The Jericho III is gradually replacing the Jericho II, if it has not happened already. A longer-range version of the Jericho ballistic missile with a new rocket motor may be under development.

[d] SIPRI's estimate is that Israel has *c.* 90 nuclear warheads that are stored partially assembled. There is significant uncertainty about the size and capabilities of Israel's nuclear arsenal.

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); 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.

Military fissile material production

Declassified government documents (mostly from the United States) indicate that Israel began building a stockpile of nuclear weapons in the early 1960s, using plutonium produced by the Israel Research Reactor 2 (IRR-2) at the Negev Nuclear Research Center near Dimona, Southern Israel.[4] This heavy-

[4] 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); and Burr, W. and Cohen, A., 'Duplicity and self-deception: Israel, the United States, and the Dimona inspections, 1964-65', Briefing Book no. 732, National Security Archive, 10 Nov. 2020.

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).[5]

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.[6] 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.[7] Meanwhile, satellite imagery shows that significant construction started at the Negev Nuclear Research Center in late 2018 or early 2019, although the purpose of the construction remains unknown.[8]

Aircraft and air-delivered weapons

Approximately 30 of Israel's nuclear weapons are estimated to be gravity bombs for delivery by F-16I aircraft. Given that the Israeli Air Force refers to its F-15I aircraft as 'strategic', it is possible that some of these aircraft could also play a nuclear role.[9] Nuclear gravity bombs would probably be stored at underground facilities near one or two air force bases, which would contain nuclear-certified aircraft with specially trained crews and unique deployment procedures.

Land-based missiles

Up to 50 warheads are thought to be assigned for delivery by land-based Jericho ballistic missiles. These are believed to be based, along with their mobile transporter-erector-launchers (TELs), in caves at a base near Zekharia, about 25 kilometres west of Jerusalem.[10] The Israeli Government has never publicly confirmed that it possesses the Jericho missiles.

Israel is upgrading its arsenal 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

[5] 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.

[6] 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 Material (IPFM), 'Countries: Israel', 18 May 2020.

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

[8] International Panel on Fissile Materials (IPFM), 'Significant new construction at the Dimona site', IPFM Blog, 18 Feb. 2021.

[9] Israeli Air Force, 'The F-15I as the IAF's Strategic Aircraft', Defense-Aerospace.com, 19 Jan. 2016.

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

with a longer range, exceeding 4000 km. It first became operational in 2011 and might now have replaced the Jericho II.[11] In 2013 Israel tested a Jericho III missile, possibly designated the Jericho IIIA, with a new motor that some sources believe may give the missile an intercontinental range—that is, a range exceeding 5500 km.[12]

On 6 December 2019 the Israeli Ministry of Defense (MOD) announced that it had conducted a test launch of an unspecified rocket propulsion system from a military base in central Israel.[13] It did not identify which missile or military base was used for the test. According to unconfirmed reports, the base was the Palmachim Airbase, which is located on Israel's Mediterranean coast and is used as a test launch site for Jericho missiles.[14] The launch led to renewed speculation that Israel might be developing a new Jericho IV missile.[15] On 31 January 2020 the MOD again acknowledged the test of an unspecified rocket propulsion system, also from a base in central Israel.[16]

Sea-based missiles

Israel operates five German-built Dolphin- and Dolphin 2-class diesel–electric submarines. A sixth boat is being fitted out.[17] Plans to buy three more have been put on hold due to investigations into allegations of corruption.[18] There have been numerous unconfirmed reports 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.[19] In line with Israel's policy of nuclear opacity, Israeli officials have declined to comment publicly on the reports. If they are true, the naval arsenal might include about 10 cruise missile warheads, assuming two warheads per submarine.

[11] ed. O'Halloran (note 10).

[12] Ben David, A., 'Israel tests Jericho III missile', *Aviation Week & Space Technology*, 22 July 2013.

[13] Gross, J. A., 'Defense ministry conducts missile test over central Israel', *Times of Israel*, 6 Dec. 2019; and Melman, Y., 'Why would Israel reportedly have missiles that reach beyond Iran', *Haaretz*, 11 Dec. 2019.

[14] Trevithick, J., 'Did Israel just conduct a ballistic missile test from a base on its Mediterranean coast?', The Drive, 6 Dec. 2019.

[15] Ahronheim, A., 'IDF tests rocket propulsion system', *Jerusalem Post*, 7 Dec. 2019.

[16] 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.

[17] Naval Today, 'Israel changes name of sixth Dolphin submarine', 11 Jan. 2019.

[18] Bandel, N., 'Gantz agrees to pause commission of inquiry into submarine affair after request by Attorney General', *Haaretz*, 29 Nov. 2020.

[19] See e.g. Cohen (note 4), p. 83; Bergman, R. et al., 'Israel's deployment of nuclear missiles on subs from Germany', *Der Spiegel*, 4 June 2012; and Frantz, D., 'Israel's arsenal is point of contention', *Los Angeles Times*, 12 Oct. 2003.

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. As of January 2021, it is estimated that North Korea possessed sufficient fissile material for approximately 40–50 nuclear weapons (see table 10.10). This is an increase of 10 from the previous year's estimate due to additional production of fissile material. The estimate is based on calculations of the amount of fissile material—plutonium and highly enriched uranium (HEU)—that North Korea is estimated to have produced for use in nuclear weapons (see section X). It is unknown how much of this material has been used to produce warheads for North Korea's ballistic missiles.[1] Analysing the numbers and types of North Korean warheads and delivery vehicles is fraught with uncertainty due to limited official public data; some of the data presented here is derived from satellite imagery and North Korean media sources, which can be subject to manipulation or exaggeration.

In January 2020 North Korean diplomats stated that the country would no longer observe its self-imposed moratoriums on nuclear explosive tests and flight tests of long-range ballistic missiles.[2] These had been announced by the Supreme Leader of North Korea, Kim Jong Un, in April 2018.[3] Despite this announcement, North Korea did not conduct any such test in 2020. Instead, it conducted multiple tests of short-range ballistic missiles (SRBMs).

The role of nuclear weapons in North Korean military doctrine

In a speech marking the 75th anniversary of the ruling Korean Workers' Party in October 2020, Kim Jong Un reiterated North Korea's pledge not to use nuclear weapons 'preemptively'.[4] 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'.[5] However, as with other nuclear-armed states, it seems unlikely that North Korea

[1] For a discussion of US intelligence and other assessments of North Korea's nuclear warhead status see Kile, S. N. and Kristensen, H. M., 'North Korea's military nuclear capabilities', *SIPRI Yearbook 2020*, pp. 343–44.

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

[3] Korean Central News Agency, 'Third plenary meeting of seventh CC, WPK held in presence of Kim Jong Un', 21 Apr. 2018. On North Korea's 6 underground nuclear test explosions in 2006–17 see Fedchencko, V., 'Nuclear explosions, 1945–2017', *SIPRI Yearbook 2018*.

[4] 38 North, 'Kim Jong Un's October speech: More than missiles', 13 Oct. 2020.

[5] 38 North (note 4).

Table 10.10. North Korean forces with potential nuclear capability, January 2021

Type/designation[a]	Range (km)	Payload (kg)	Status	No. of warheads
Land-based missiles				
Hwasong-7 (Nodong)	>1 200	1 000	Single-stage, liquid-fuel ballistic missile. Fewer than 100 launchers; first deployed in 1990.	Some
Hwasong-9 (Scud-ER)	1 000	500	Scud ballistic missile variant, lengthened to carry additional fuel.	Some
Pukguksong-2 (KN15)	>1 000	..	Two-stage, solid-fuel ballistic missile under development. Launched from canister TEL. Land-based version of Pukguksong-1 SLBM. Test launched in 2017.	..
Hwasong-10 (BM-25, Musudan)	>3 000	[1 000]	Single-stage, liquid-fuel ballistic missile under development. Several failed tests in 2016.	..
Hwasong-12 (KN17)	>4 500	1 000	Single-stage, liquid-fuel ballistic missile under development. Tested several times in 2017 with mixed success.	..
Hwasong-13 (KN08)[b]	12 000	..	Three-stage, liquid-fuel ballistic missile with potential intercontinental range under development. No known test launches.	..
Hwasong-14 (KN20)	>10 000	500–1 000	Two-stage, liquid-fuel ballistic missile under development. Tested in 2017.	..
Hwasong-15 (KN22)	>12 000	1 000–1 500	Two-stage, liquid-fuel ballistic missile under development. Two tests in 2017.	..
Hwasong-16 (KN27)	..	..	Two-stage, liquid-fuel ballistic missile under development. First displayed at a parade in Oct. 2020. No known flight tests.	..
Taepodong-2[c]	12 000	..	Under development. Three-stage ballistic space launch vehicle variant placed satellites in orbit in Dec. 2012 and Feb. 2016. ICBM status unclear.	..
Sea-based missiles				
Pukguksong-1 (KN11)	>1 000	..	Two-stage, solid-fuel ballistic missile. Tested several times in 2015 and 2016 with mixed success.	..
Pukguksong-3 (KN-26)	≤1 900	..	Two-stage, solid-fuel SLBM under development. Likely replacing earlier Pukguksong-1 version. First flight tested in Oct. 2019.	..
Pukguksong-4	..	..	Two-stage, solid-fuel SLBM. First displayed at a parade in Oct. 2020. No known flight tests.	..
Total warhead potential				**[40–50]**[d]

. . = not available or not applicable; [] = uncertain figure; ICBM = intercontinental ballistic missile; SLBM = submarine-launched ballistic missile; TEL = transporter-erector-launcher.

[a] This table lists the ballistic missiles that could potentially have a nuclear capability. There is no publicly available evidence that North Korea has produced an operational nuclear warhead for delivery by an ICBM. The first name of each system is the North Korean designation; the second name, in parentheses, is the designation used by the United States Department of Defense.

[b] A two-stage variant, the KN14, may be under development but had not been test launched as of Jan. 2021. It is possible that both the KN08 and KN14 have been abandoned in favour of newer, more advanced ICBM systems.

[c] A two-stage Taepodong-1 missile was unsuccessfully flight tested in 1998.

[d] SIPRI's estimate is that North Korea may have produced enough fissile material to build between 40 and 50 nuclear warheads. It is unknown how many warheads may have been assembled. SIPRI estimates that only a few of these would be hydrogen warheads and nearly all would be lower-yield single-stage fission 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.

Sources: US Department of Defense (DOD), *2019 Missile Defense Review* (DOD: Arlington, VA, 2019); US Air Force, National Air and Space Intelligence Center (NASIC), *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; and authors' estimates.

would use its nuclear weapons outside of extreme circumstances when the continued existence of the state and its leadership was in question.

Fissile material and warhead production

North Korea's plutonium production and separation capabilities for manufacturing nuclear weapons are located at the Yongbyon Nuclear Scientific Research Centre (YNSRC) in North Pyongan province.[6] In 2020 some of the nuclear facilities located there appeared not to be operating. In September 2020 the International Atomic Energy Agency (IAEA) reported that there had been no indications of steam or cooling water discharge from the ageing 5-megawatt-electric (MW(e)) graphite-moderated research reactor located at the YNSRC. It therefore concluded, 'it is almost certain that the reactor has remained shut down since early December 2018'.[7] The IAEA also reported that there were no indications that reprocessing activities were under way at the adjacent Radiochemical Laboratory used to separate plutonium from the 5-MW(e) reactor's spent fuel rods, which can be used for

[6] 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 (CISAC), 11 Feb. 2019, p. 3.

[7] International Atomic Energy Agency (IAEA), Board of Governors and General Conference, 'Application of safeguards in the Democratic People's Republic of Korea', Report by the Director General, GOV/2020/42-GC(64)/18, 3 Sep. 2020, para. 12.

the production of nuclear weapons.[8] In October 2020 commercial satellite imagery indicated that activity was increasing at a building used to produce uranium dioxide (UO_2); however, it is unclear whether the observed smoke or vapour emissions are an indication of UO_2 production or a different operation.[9] The IAEA report noted that North Korea may have conducted an infrastructure test at the experimental light water reactor that is under construction at Yongbyon, which is also capable of producing plutonium for nuclear weapons; however, the reactor had not yet commenced operation.[10]

There is considerable uncertainty about North Korea's uranium enrichment capabilities and its stock of HEU. 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 2020 the IAEA assessed that North Korea continued to operate the gas centrifuge enrichment plant located at the Yongbyon complex that it had declared in 2010.[11] Using commercial satellite imagery, several non-governmental researchers have identified a suspected covert uranium enrichment plant located at Kangsong, to the south-west of Pyongyang.[12] However, analysts cautioned that, without access to the plant, it was not possible to confirm the nature and purpose of the activities being conducted on-site.[13] A classified intelligence assessment by the United States 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.[14]

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 only demonstrated a thermonuclear capability (or a capability with demonstrated thermonuclear yield) once, in 2017.[15] US intelligence sources have not yet confirmed North Korea's capability to deliver a functioning warhead on an intercontinental ballistic missile (ICBM). Moreover, most of North Korea's nuclear tests demonstrated yields in the range 5–15 kilotons. As a result,

[8] International Atomic Energy Agency, GOV/2020/42-GC(64)/18 (note 7).

[9] Pabian, F. V., Makowsky, P. and Liu, J., 'North Korea's Yongbyon complex: Activity picks up', 38 North, 30 Oct. 2020.

[10] International Atomic Energy Agency, GOV/2020/42-GC(64)/18 (note 7).

[11] International Atomic Energy Agency, GOV/2020/42-GC(64)/18 (note 7). See also Hecker et al. (note 6), pp. 3–4.

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

[13] Hecker et al. (note 6), p. 4; and Madden, M., 'Much ado about Kangson', 38 North, 3 Aug. 2018.

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

[15] Fedchencko (note 3).

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 or boosted single-stage weapons deliverable by medium-range ballistic missile (MRBM) or possibly by intermediate-range ballistic missile (IRBM). For this reason, SIPRI estimates that North Korea could potentially produce 40–50 nuclear weapons with its current inventory of fissile materials.[16]

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.[17] In recent years it has pursued the serial production of several missile systems with progressively longer ranges and increasingly sophisticated delivery capabilities.[18] There is considerable uncertainty about the operational capability of North Korea's long-range ballistic missiles. According to an independent analysis, North Korea has deployed long-range missiles at several missile bases.[19] However, in 2019 the US Department of Defense (DOD) indicated that many of North Korea's newer ballistic missiles (Hwasong-10/12/13/14/15 or Pukguksong-1/2) had not yet been 'fielded'.[20]

It is unclear which of North Korea's missiles would carry nuclear weapons. The available evidence suggests that the longer-range missiles in particular are being developed to fulfil a nuclear role in North Korea's military doctrine. However, North Korea has not yet publicly demonstrated a reliable atmospheric re-entry vehicle or a capability for terminal-stage guidance and warhead activation.[21] As such, it remains unclear whether its missiles would be able to reliably deliver a nuclear warhead to an intercontinental-range target without further development.[22]

[16] For a recent assessment 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, slide 5.

[17] 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).

[18] James Martin Center for Nonproliferation Studies (CNS), The CNS North Korea Missile Test Database, 31 Mar. 2021.

[19] Bermudez, J. and Cha, V., 'Undeclared North Korea: The Yusang-ni missile operating base', Beyond Parallel, Center for Strategic and International Studies (CSIS), 9 May 2019.

[20] US Department of Defense (DOD), *2019 Missile Defense Review* (DOD: Arlington, VA, 2019), p. 7.

[21] Ali, I., 'US general says North Korea not demonstrated all components of ICBM', Reuters, 30 Jan. 2018.

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

Short-range ballistic missiles

North Korea has several types of SRBM, including older systems possibly based on Soviet R-17 Scud missiles and newer missiles with indigenous designs. In 2020 North Korea conducted several initial launches of at least two new types of solid-fuelled SRBM: the KN24 and the KN25.[23] These systems could be nearing or have possibly begun operational deployment.

While older, inaccurate 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.[24] Independent assessments suggest 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. However, as North Korea seeks to miniaturize its nuclear warheads, these types of missile could adopt a dual-capable role in the future.[25]

Medium- and intermediate-range ballistic missiles

Assuming that North Korea is able to produce a sufficiently compact warhead, independent assessments indicate that the size, range and operational status of the Hwasong-7 (Nodong or Rodong) MRBM make it the system most likely to be given a nuclear delivery role.[26] Possibly based on a Soviet-era R-17 (Scud) missile design, the Hwasong-7 is a single-stage, liquid-fuelled ballistic missile with an estimated range exceeding 1200 km. In addition, North Korea has developed the single-stage, liquid-fuelled Hwasong-9 (Scud-ER for extended-range), which has an estimated range of 1000 km and may also be a nuclear-capable delivery system. According to the 2020 ballistic and cruise missile report of the US Air Force's National Air and Space Intelligence Center (NASIC), the system has not yet been deployed.[27]

The Hwasong-10 (Musudan or BM-25) is a single-stage, liquid-fuelled missile with an estimated range exceeding 3000 km. It was first unveiled at a military parade in 2010. Flight testing began in 2016, with multiple failures.[28] No flight tests of the Hwasong-10 are known to have been con-

[23] Panda, A., 'What was behind North Korea's busy March 2020 missile launches?', The Diplomat, 8 Apr. 2020; and Dempsey, J., 'Assessment of the March 9 KN-25 test launch', 38 North, 10 Mar. 2020.

[24] James Martin Center for Nonproliferation Studies (note 18); and Panda (note 23).

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

[26] See e.g. Fitzpatrick, M., 'North Korea nuclear test on hold?', Shangri-La Voices, International Institute for Strategic Studies (IISS), 27 May 2014; and Albright, D., 'North Korean miniaturization', 38 North, 13 Feb. 2013. For the missiles and submarines discussed here, a designation in parentheses (in this case Nodong or Rodong) following the North Korean designation (in this case Hwasong-7) is that assigned by the US Department of Defense (DOD).

[27] US Air Force (note 17), pp. 18, 21, 25.

[28] Savelsberg, R. and Kiessling, J., 'North Korea's Musudan missile: A performance assessment', 38 North, 20 Dec. 2016.

ducted since 2016–17, and the status of the missile's development programme is unclear.

The Hwasong-12 (KN17) is a single-stage IRBM that is believed to have a new liquid-propellant booster engine, as well as design features that may serve as a technology test bed for a future ICBM.[29] NASIC estimated in 2020 that it has a range of more than 4500 km.[30] Some analysts have speculated that the missile carries a small post-boost vehicle that, in addition to increasing its maximum range, can be used to improve warhead accuracy.[31] The missile was last test launched in 2017 but has not been deployed.[32]

North Korea is developing the Pukguksong-2 missile (KN15), which is a land-based variant of the Pukguksong-1 submarine-launched ballistic missile (SLBM). The two-stage, solid-fuelled missile has an estimated range of approximately 1000 km.[33] It was flight tested twice in 2017. Some analysts have noted that North Korea's development of the Pukguksong-2 is probably 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, and uniquely for a North Korean missile, the Pukguksong-2 is coupled with a tracked transporter-erector-launcher (TEL). This would allow North Korea to launch it from hidden, off-road sites, whereas other systems use wheeled launchers and thus require paved or relatively smooth roads—a rarity in North Korea's mountainous terrain.[34]

Intercontinental-range ballistic missiles

North Korea is widely believed to have prioritized building and deploying an ICBM that could potentially deliver a nuclear warhead to targets in the continental USA. However, as mentioned above, there remains considerable uncertainty in assessments of North Korea's current long-range missile capabilities, and NASIC does not list any of North Korea's ICBMs as deployed.[35]

[29] Yi, Y., 'Hwasong-12 a stepping-stone in North Korea's ICBM development', *The Hankyoreh*, 16 May 2017; and Savelsberg, R., 'A quick technical analysis of the Hwasong-12 missile', 38 North, 19 May 2017.

[30] US Air Force (note 17), p. 25.

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

[32] Panda, A., 'North Korea shows increased operational confidence in the Hwasong-12 IRBM', The Diplomat, 17 Sep. 2017.

[33] US Air Force (note 17), p. 25.

[34] Panda, A., 'It wasn't an ICBM, but North Korea's first missile test of 2017 is a big deal', The Diplomat, 14 Feb. 2017.

[35] Albert, E., 'North Korea's military capabilities', Council on Foreign Relations, 16 Nov. 2020; and US Air Force (note 17), p. 29.

The Hwasong-13 (KN08) was first presented by North Korea as a road-mobile, three-stage missile with intercontinental range at a military parade in April 2012. Some non-governmental analysts have suggested that the missiles displayed were only mock-ups.[36] Estimates of the range and payload capabilities of the missile are highly speculative. As of 2020, it had not been flight tested.

North Korea has twice tested the Hwasong-14 (KN20), a prototype ICBM that first appeared in 2015 at a military parade in Pyongyang.[37] The two-stage missile appears to use the same high-energy liquid-propellant booster engine as the single-stage Hwasong-12 IRBM.[38] In 2020 NASIC assessed that the range of the Hwasong-14 could exceed 10 000 km, putting it in range of most of the continental USA but not Washington, DC, or other targets on the east coast.[39]

North Korea is 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. The first flight test was conducted in 2017, when a Hwasong-15 was launched on an elevated trajectory and flew higher and for a longer duration than any previous North Korean missile.[40] In 2020 NASIC assessed that the range of the Hwasong-15 could exceed 12 000 km, putting it in range of Washington, DC, and other targets on the east coast of the USA.[41] The missile was assessed to be carrying a light payload, however, and the range would be significantly reduced if it were carrying an actual nuclear warhead.[42] Four Hwasong-15 ICBMs were displayed during North Korea's October 2020 military parade.[43]

During the October 2020 parade, North Korea also unveiled four units of a new liquid-fuelled type of ICBM, which has not yet been tested but appears to be the largest road-mobile, liquid-fuelled ICBM on the planet.[44] The new ICBM, which is presumably called the Hwasong-16 in line with North Korea's naming conventions (with likely US DOD designation KN27), would hypothetically be large enough to accommodate multiple warheads; however, such capabilities have not yet been demonstrated.

[36] Schiller, M. and Kelley, R., 'Evolving threat: North Korea's quest for an ICBM', *Jane's Defence Weekly*, 18 Jan. 2017, p. 24.

[37] James Martin Center for Nonproliferation Studies (note 18).

[38] According to one non-governmental analyst, North Korea probably acquired the engine through illicit channels operating in Russia, Ukraine or both. Elleman, M., 'The secret to North Korea's ICBM success', Analysis, International Institute for Strategic Studies (IISS), 14 Aug. 2017.

[39] US Air Force (note 17), pp. 27, 29.

[40] Wright, D., 'North Korea's longest missile test yet', All Things Nuclear, Union of Concerned Scientists, 28 Nov. 2017.

[41] US Air Force (note 17), pp. 27, 29.

[42] Elleman, M., 'North Korea's third ICBM launch', 38 North, 29 Nov. 2017.

[43] NK News, 'North Korea military parade 2020—Livestream & analysis', 10 Oct. 2020.

[44] NK News (note 43).

In 2019 the US DOD indicated that North Korea had deployed one ICBM, the Taepodong-2.[45] However, other official US sources list the missile as a space-launch vehicle that would need reconfiguration to be used as an ICBM.[46]

Sea-based missiles

North Korea continues to pursue the development of a solid-fuelled SLBM system as part of an effort to improve the survivability of its nuclear-capable ballistic missile systems. North Korea's first SLBM, the Pukguksong-1 (KN11), was tested with mixed success throughout 2015 and 2016. A 'new type' of SLBM, called the Pukguksong-3 (KN-26), was tested in October 2019.[47] With an estimated maximum range of more than 1000 km—and perhaps as much as 1900 km—the Pukguksong-3 at that time was the longest-range, solid-fuelled missile that North Korea had displayed.[48] However, during the parade in October 2020, North Korea unveiled yet another new type of SLBM—the Pukguksong-4, that might have a longer range.[49] The two-stage, solid-fuelled missile—which is wider than the Pukguksong-1 and possibly a little shorter than the Pukguksong-3—has not yet been flight tested. Its larger diameter indicates that it could hypothetically carry multiple warheads or penetration aids to overcome US ballistic missile defences.

During 2020, there were indications that North Korea had made progress towards achieving its goal of designing, building and eventually deploying an operational ballistic missile submarine. Currently, North Korea has one Gorae-class (Sinpo) experimental submarine in service, which can hold and launch one SLBM. This is likely to be the Pukguksong-1 until it is replaced by the more advanced SLBMs under development. In November 2020 the National Intelligence Service of the Republic of Korea (South Korea) announced that North Korea was building a new ballistic missile

[45] US Department of Defense (note 20), p. 7.

[46] See e.g. US Defense Intelligence Agency (DIA), *Global Nuclear Landscape 2018* (DIA: Washington, DC, 2018), p. 22.

[47] Ji, D., 'Pukguksong-3 SLBM test-launch is "powerful blow" to hostile forces: Rodong Sinmun', NK News, 4 Oct. 2019.

[48] US Air Force (note 17), p. 33; Panda, A., 'North Korea finally unveils the Pukguksong-3 SLBM: First takeaways', The Diplomat, 3 Oct. 2019; Lee, J., 'North Korea says it successfully tested new submarine-launched ballistic missile', Reuters, 2 Oct. 2019; and Wright, D., 'North Korea's latest missile test', All Things Nuclear, Union of Concerned Scientists, 1 Oct. 2019.

[49] Kuhn, A., 'Kim Jong Un puts new missiles on display at military parade in North Korea', National Public Radio (NPR), 10 Oct. 2020; and Barrie, D. and Dempsey, J., 'What North Korea's latest missile parade tells us, and what it doesn't', Analysis, International Institute for Strategic Studies (IISS), 12 Oct. 2020.

submarine.[50] 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.[51] According to a 2019 report by North Korea's state-run Korean Central News Agency (KCNA), the submarine's operational deployment was 'near at hand'.[52]

[50] Bermudez, J. and Cha, V., 'Sinpo South Shipyard: Construction of a new ballistic missile submarine?', Beyond Parallel, Center for Strategic and International Studies (CSIS), 28 Aug. 2019; and Cha, S., 'North Korea building two submarines, one capable of firing ballistic missiles—lawmaker', Reuters, 3 Nov. 2020.

[51] Hotham, O., 'New North Korean submarine capable of carrying three SLBMs: South Korean MND', NK News, 31 July 2019; and Cha (note 50).

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

X. Global stocks and production of fissile materials, 2020

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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 2020, of HEU (table 10.11) and separated plutonium (table 10.12), including in weapons. It also provides details of the current capacity to produce these materials (tables 10.13 and 10.14, respectively). The information in the tables is based on estimates prepared for the International Panel on Fissile Materials (IPFM). The most recent annual declarations (INFCIRC/549 declarations) on civilian plutonium and HEU stocks to the International Atomic Energy Agency (IAEA) give data for 31 December 2019.

The production of both HEU and plutonium starts with natural uranium. Natural uranium consists almost entirely of the non-chain-reacting isotope uranium-238 (U-238) and is only about 0.7 per cent uranium-235 (U-235). The concentration of U-235 can be increased through enrichment—typically using gas centrifuges. Uranium that has been enriched to less than 20 per cent U-235 (typically, 3–5 per cent)—known as low-enriched uranium—is suitable for use in power reactors. Uranium that has been enriched to contain at least 20 per cent U-235—known as HEU—is generally taken to be the lowest concentration practicable for use in weapons. However, in order 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 is exposed to neutrons. The plutonium is subsequently chemically separated from spent fuel in a reprocessing operation. Plutonium comes in a variety of isotopic mixtures, most of which are weapon-usable. Weapon designers prefer to work with a mixture that predominantly consists of plutonium-239 (Pu-239) because of its relatively low rate of spontaneous emission of neutrons and gamma rays and the low level of heat generation from radioactive alpha decay. Weapon-grade plutonium typically contains more than 90 per cent of the isotope Pu-239. The plutonium in typical spent fuel from power reactors (reactor-grade plutonium) contains 50–60 per cent Pu-239 but is weapon-usable, even in a first-generation weapon design.

All states that have a civil nuclear industry (i.e. that operate a nuclear reactor or a uranium enrichment plant) have some capability to produce fissile materials that could be used for weapons.

Table 10.11. Global stocks of highly enriched uranium, 2020

State	National stockpile (tonnes)[a]	Production status	Comments
China	14 ± 3	Stopped 1987–89	
France[b]	30 ± 6	Stopped 1996	Includes 5.4 tonnes declared civilian[c]
India[d]	5.2 ± 1.8	Continuing	Includes HEU in naval reactor cores
Israel[e]	0.3	Unknown	
Korea, North[f]	Uncertain	Uncertain	
Pakistan[g]	3.9 ± 0.4	Continuing	
Russia[h]	678 ± 120	Continuing[i]	Includes *c.* 6 tonnes in use in research applications
UK[j]	22.6	Stopped 1962	Includes HEU in naval reactor cores and 0.7 tonnes declared civilian
USA[k]	562 (83 not available for military purposes)	Stopped 1992	Includes HEU in a naval reserve
Other states[l]	~15		
Total[m]	**~1 330**		

HEU = highly enriched uranium.

[a] Most of this material is enriched uranium that contains 90–93% uranium-235 (U-235), which is typically considered weapon-grade. The estimates are for the start of 2020. Important exceptions are noted.

[b] The uncertainty in the estimate for France applies only to the military stockpile of *c.* 25 tonnes and does not apply to the declared civilian stock. A 2014 analysis offers grounds for a significantly lower estimate of the stockpile of weapon-grade HEU (as high as 10 ± 2 tonnes or as low as 6 ± 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] This figure is from France's INFCIRC/549 declaration to the International Atomic Energy Agency (IAEA) for the start of 2020.

[d] 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%.

[e] Israel may have acquired illicitly *c.* 300 kg 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 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 end of 2019 suggest that an accumulated HEU stockpile could be in the range of 230–1180 kg.

[g] This estimate for Pakistan assumes total HEU production of 4 tonnes, of which *c.* 100 kg was used in nuclear weapon tests.

[h] This estimate is for the amount of 90% enriched uranium that would contain all U-235 in HEU. The actual amount of HEU might be different. It assumes that the Soviet Union stopped all HEU production in 1988. It may therefore understate the amount of HEU in Russia (see also note i). The material in discharged naval cores is not included in the current stock since the enrichment of uranium in these cores is believed to be less than 20% U-235.

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

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

naval reactors, the value contains an increasing fraction of spent naval fuel. In 2018 the UK transferred *c.* 500 kg of HEU to the USA for downblending into low-enriched uranium.

[k] The amount of US HEU is given in actual tonnes, not 93%-enriched equivalent. In 2016 the USA declared that, as of 30 Sep. 2013, its HEU inventory was 585.6 tonnes, of which 499.4 tonnes was declared to be for 'national security or non-national security programs including nuclear weapons, naval propulsion, nuclear energy, and science'. The remaining 86.2 tonnes 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 2019, another 19 tonnes had been downblended or shipped for blending down. The amount available for use had been reduced to *c.* 480 tonnes, mostly by consumption in naval reactors. The 83 tonnes declared excess includes *c.* 67 tonnes remaining for downblending as well as 16 tonnes remaining for HEU fuel for research reactors.

[l] The IAEA's 2019 annual report lists 156 significant quantities of HEU under comprehensive safeguards in non-nuclear weapon states as of the end of 2019. In order to reflect the uncertainty in the enrichment levels of this material, mostly in research reactor fuel, a total of 15 tonnes of HEU is assumed. About 10 tonnes of this is in Kazakhstan and has been irradiated; it was initially slightly higher than 20%-enriched fuel. It is possible that this material is no longer HEU.

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

[m] 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.5/24, 28 Aug. 2020; and Philippe, S. and Glaser, A., 'Nuclear archaeology for gaseous diffusion enrichment plants', *Science & Global Security*, vol. 22, no. 1 (2014), pp. 27–49. *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.8/23, 11 Jan. 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 Department of Energy (DOE), *FY 2021 Congressional Budget Request*, vol. 1, *National Nuclear Security Administration* (DOE: Washington, DC, Feb. 2020), p. 593; and US Department of Energy (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 2019* (IAEA: Vienna, 2019), Annex, Table A4, p. 113; 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, 2020

State	Military stocks (tonnes)[a]	Military production status	Civilian stocks (tonnes)[b]
China	2.9 ± 0.6	Stopped in 1991	0.04[c]
France	6 ± 1.0	Stopped in 1992	74.7 (excludes foreign owned)
India[d]	0.62 ± 0.14	Continuing	8.2 ± 4.3 (includes 0.4 under safeguards)
Israel[e]	0.98 ± 0.13	Continuing	–
Japan	–	–	45.5 (includes 36.6 in France and UK)
Korea, North[f]	0.04	Continuing	–
Pakistan[g]	0.41 ± 0.1	Continuing	–
Russia[h]	128 ± 8 (40 not available for weapons)	Stopped in 2010	63
UK	3.2	Stopped in 1995	115.8 (excludes 24.1 foreign owned)
USA[i]	79.7 (41.3 not available for weapons)	Stopped in 1988	8[j]
Other states[k]	–	–	3.0
Total[l]	**~220 (81 not available for weapons)**		**~320**

– = nil or a negligible value.

[a] The estimates are for the start of 2020. Important exceptions are noted.

[b] The data for France, Japan, Russia and the UK is for the end of 2019, reflecting their most recent INFCIRC/549 declaration to the International Atomic Energy Agency (IAEA). Some countries with civilian plutonium stocks do not submit an INFCIRC/549 declaration. Of these countries, Italy, the Netherlands, Spain and Sweden store their plutonium abroad.

[c] These numbers are based on China's INFCIRC/549 declaration to the IAEA for the end of 2016. As of Mar. 2021, this is the most recent declaration.

[d] As part of the 2005 Indian–US Civil Nuclear Cooperation Initiative, India has included in the military sector much of the plutonium separated from its spent power-reactor fuel. While it is labelled civilian here since it is intended for breeder reactor fuel, this plutonium 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 still operating the Dimona plutonium production reactor but may be using it primarily for tritium production. The estimate is for the end of 2019.

[f] North Korea reportedly declared a plutonium stock of 37 kg in June 2008. It is believed that it subsequently unloaded its 5-MWe reactor 3 additional times, in 2009, 2016 and 2018. The stockpile estimate has been reduced to account for the 6 nuclear tests conducted by the country.

[g] As of the end of 2019, Pakistan was operating 4 plutonium production reactors at its Khushab site. This estimate assumes that Pakistan is separating plutonium from the cooled spent fuel from all 4 reactors.

[h] The 40 tonnes of plutonium not available to Russia for weapons comprises 25 tonnes of weapon-origin plutonium stored at the Mayak Fissile Material Storage Facility and *c.* 15 tonnes of weapon-grade plutonium produced between 1 Jan. 1995 and 15 Apr. 2010, when the last plutonium production reactor was shut down. The post-1994 plutonium, which is currently stored at Zheleznogorsk, cannot be used for weapon purposes under the terms of a 1997 Russian–US agreement on plutonium production reactors. Russia made a commitment to eliminate 34 tonnes of that material (including all 25 tonnes of plutonium stored at Mayak) as part of the 2000 Russian–US Plutonium Management and Disposition Agreement. Russia does

not include the plutonium that is not available for weapons in its INFCIRC/549 declaration; nor does it make the plutonium it reports as civilian available to IAEA safeguards.

[i] In 2012 the USA declared a government-owned plutonium inventory of 95.4 tonnes as of 30 Sep. 2009. In its 2019 INFCIRC/549 declaration, the most recent submitted, the USA declared 49.3 tonnes of unirradiated plutonium (both separated and in mixed oxide, MOX) as part of the stock that was identified as excess for military purposes (declaration for 31 Dec. 2018). Since most of this material is stored in classified form, it is considered military stock. The USA considers a total of 61.5 tonnes of plutonium to be declared excess to national security needs.

[j] The USA has placed *c.* 3 tonnes of its excess plutonium, stored at the K-Area Material Storage Facility at the Savannah River Plant, under IAEA safeguards. In addition, it reported that 4.6 tonnes of plutonium was contained in unirradiated MOX fuel, and also declared 0.4 tonnes of plutonium that was brought to the USA in 2016 from Japan, Germany and Switzerland (331 kg, 30 kg and 18 kg, respectively). All this material is considered civilian.

[k] This is estimated by reconciling the amounts of plutonium declared as 'held in locations in other countries' and 'belonging to foreign bodies' in the INFCIRC/549 declarations.

[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). *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–US Agreement Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation (Plutonium Management and Disposition Agreement), signed 29 Aug. and 1 Sep. 2000, amendment signed 5 Sep. 2006, entered into force 13 July 2011. *USA*: National Nuclear Security Administration (NNSA), *The United States Plutonium Balance, 1944–2009* (NNSA: Washington, DC, June 2012); and Gunter, A., 'K-Area overview/update', US Department of Energy, Savanah River Site, 28 July 2015.

Table 10.13. Significant uranium enrichment facilities and capacity worldwide, 2020

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	35
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	3 900
India	Rattehalli	Military	Operational	GC	15–30
Iran[e]	Natanz	Civilian	Limited operation	GC	3.5–5
	Qom (Fordow)	Civilian	Limited operation	GC	. .
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	Capenhurst	Civilian	Operational	GC	4 600
USA	Urenco Eunice	Civilian	Operational	GC	4 900

[a] The gas centrifuge (GC) is the main isotope-separation technology used to increase the percentage of uranium-235 (U-235) in uranium, 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. In Nov. 2019, following the USA's withdrawal from the JCPOA, Iran announced a limited restart of enrichment at Natanz and Fordow.

[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 revealed its Yongbyon enrichment facility in 2010. It appears to be operational as of 2019. It is believed that North Korea is operating at least one other enrichment facility located elsewhere.

[h] Zelenogorsk operates a cascade for highly enriched uranium 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; 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* (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; Pabian, F. V., Liu, J. and Town, J., 'North Korea's Yongbyon Nuclear Center: Continuing activity at the uranium enrichment plant', 38 North, 5 June 2019; and Wolgelenter, M. and Sanger, D. E., 'Iran steps further from nuclear deal with move on centrifuges', *New York Times*, 5 Nov. 2019. Enrichment capacity data is based on International Atomic Energy Agency, Integrated Nuclear Fuel Cycle Information Systems (iNFCIS); Urenco, 'Global operations', [n.d.]; and International Panel on Fissile Materials (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, 2020

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 2021	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.

[c] As part of the 2005 Indian–US Civil Nuclear Cooperation Initiative, India has decided that none of its reprocessing plants will be opened for International Atomic Energy Agency safeguards inspections.

[d] In 2014 the Japan Atomic Energy Agency announced the planned closure of the head-end of its Tokai reprocessing plant, effectively ending further plutonium separation activity. In 2018 the Japanese Nuclear Regulation Authority approved a plan to decommission the plant.

[e] Russia continues to construct 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. The centre is scheduled to begin operations in 2021.

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).