10. World nuclear forces

Overview

At the start of 2020, 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 13 400 nuclear weapons, of which 3720 were deployed with operational forces (see table 10.1). Approximately 1800 of these are kept in a state of high operational alert.

Overall, inventories of nuclear warheads continue to decline. This is primarily due to the USA and Russia dismantling retired warheads. 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 are also thought to be increasing the size of their arsenals. North Korea continues to prioritize its military nuclear programme as a central element of its national security strategy, although in 2019 it adhered to its self-declared moratoria on the testing of nuclear weapons and 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 has disclosed important information about its stockpile and nuclear capabilities, but in 2019 the administration of President Donald J. Trump ended the practice of disclosing the size of the US stockpile. The UK and France have also declared some information. Russia refuses to publicly disclose the detailed breakdown of its forces counted under the 2010 Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START), even though it shares the information with the USA. China now publicly displays its nuclear forces more frequently than in the past but 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 its nuclear weapon capabilities. Israel has a long-standing policy of not commenting on its nuclear arsenal.

Table 10.1. World nuclear forces, January 2020

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

Country	Year of first nuclear test	Deployed warheads[a]	Stored warheads[b]	Other warheads	Total inventory
United States	1945	1 750[c]	2 050[d]	2 000[e]	5 800
Russia	1949	1 570[f]	2 745[g]	2 060[e]	6 375
United Kingdom	1952	120	95	–	215[h]
France	1960	280	10	. .	290
China	1964	–	320	–	320
India	1974	–	150	. .	150
Pakistan	1998	–	160	. .	160
Israel	. .	–	90	. .	90
North Korea	2006	–	. .	[30–40]	[30–40][i]
Total[j]		**3 720**	**5 620**	**4 060**	**13 400**

. . = not applicable or not available; – = zero; [ ] = 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. 2020 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 1600 strategic warheads (about 1300 on ballistic missiles and nearly 300 on bomber bases), as well as *c.* 150 non-strategic (tactical) nuclear bombs deployed outside the USA for delivery by US and other North Atlantic Treaty Organization aircraft.

[d] This figure includes *c.* 80 non-strategic nuclear bombs stored in the USA.

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

[f] This figure includes approximately 1370 strategic warheads on ballistic missiles and about 200 deployed at heavy bomber bases.

[g] This figure includes *c.* 870 warheads for strategic bombers and nuclear-powered ballistic missile submarines (SSBNs) in overhaul and *c.* 1875 non-strategic nuclear weapons for use by short-range air, air defence and naval forces.

[h] The British Government has stated that the process to reduce the stockpile to 180 warheads is under way. Although some sources suggest that the stockpile remains at 215 warheads, it is possible that, under this process, the stockpile may have already been reduced to 195 warheads.

[i] There is no publicly available evidence that North Korea has produced an operational nuclear warhead for delivery by an intercontinental-range ballistic missile.

[j] Totals do not include figures for North Korea.

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. 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).

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I. US nuclear forces

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As of January 2020, the United States maintained a military stockpile of approximately 3800 nuclear warheads, roughly the same number as in January 2019. The stockpile included approximately 1750 deployed nuclear warheads, consisting of about 1600 strategic and 150 non-strategic (or tactical) warheads. In addition, about 2050 warheads were held in reserve and around 2000 retired warheads were awaiting dismantlement (385 fewer than the estimate for January 2019), giving a total inventory of approximately 5800 nuclear warheads (see table 10.2).

The USA reached compliance with the final warhead limits prescribed by the 2010 Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START) by the specified deadline of 5 February 2018, at which point it was reported to have 1393 deployed warheads attributed to 660 deployed strategic launchers—that is, deployed intercontinental ballistic missiles (ICBMs), deployed submarine-launched ballistic missiles (SLBMs) and deployed heavy bombers.[1] As of September 2019, the New START aggregate numbers showed the USA deploying 1376 warheads attributed to 668 deployed strategic launchers.[2] The number of deployed warheads reported under New START differs from the estimate 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.

Nuclear modernization

In 2019 the administration of President Donald J. Trump continued to implement the 2018 Nuclear Posture Review (NPR).[3] The NPR recommended maintaining the comprehensive nuclear weapon modernization programme decided by the previous administration but with several new nuclear weapons and an increase in the production of plutonium cores for nuclear weapons. Specifically, the NPR outlined plans to introduce a new class (Columbia) of nuclear-powered ballistic missile submarine (SSBN); a new nuclear-capable strategic bomber (B-21 Raider); a new long-range

[1] US Department of State, Office of the Spokesperson, 'Key facts about New START implementation', Fact Sheet, 5 Feb. 2018. For a summary and other details of New START see annex A, section III, and chapter 11, section I, in this volume.

[2] US Department of State, Bureau of Arms Control, Verification and Compliance, 'New START Treaty aggregate numbers of strategic offensive arms', Fact Sheet, 1 Sep. 2019.

[3] US Department of Defense (DOD), *Nuclear Posture Review 2018* (DOD: Arlington, VA, Feb. 2018). For a summary and other details of the Nuclear Posture Review see Kristensen, H. M., 'US nuclear forces', *SIPRI Yearbook 2019*, pp. 289–94.

Table 10.2. US nuclear forces, January 2020

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

Type	Designation	No. of launchers	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads[b]
Strategic forces						**3 570**
Bombers		*60/107*[c]				*848*[d]
B-52H	Stratofortress	42/87	1961	16 000	20 x ALCMs 5–150 kt[e]	528
B-2A	Spirit	18/20	1994	11 000	16 x B61-7, -11, B83-1 bombs[f]	320
ICBMs		*400*				*800*[g]
LGM-30G	Minuteman III					
	Mk-12A	200	1979	13 000	1–3 x W78 335 kt	600[h]
	Mk-21 SERV	200	2006	13 000	1 x W87 300 kt	200[i]
SSBNs/SLBMs		*240*[j]				*1 920*[k]
UGM-133A	Trident II (D5/D5LE)					
	Mk-4	. .	1992	>12 000	1–8 x W76-0 100 kt	. .[l]
	Mk-4A	. .	2008	>12 000	1–8 x W76-1 90 kt	1 511
	Mk-4A	. .	2019	>12 000	1 x W76-2 8 kt	25[m]
	Mk-5	. .	1990	>12 000	1–8 x W88 455 kt	384
Non-strategic forces						**230**[n]
F-15E	Strike Eagle	. .	1988	3 840	5 x B61-3, -4[o]	80
F-16C/D	Falcon	. .	1987	3 200[p]	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**[q]
Deployed warheads						1 750[r]
Reserve warheads						2 050
Retired warheads awaiting dismantlement[s]						**2 000**
Total inventory						**5 800**[t]

. . = not available or not applicable; 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; SSBN = nuclear-powered ballistic missile submarine.

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

[b] The number shows the total number of warheads assigned to nuclear-capable delivery systems. Only some of these warheads are deployed on missiles and at aircraft bases.

[c] Bombers have two numbers: the first is the number assigned to the nuclear mission; the second is the total inventory. The US Air Force has 66 nuclear-capable bombers (20 B-2As and 46 B-52Hs) of which no more than 60 will be deployed at any given time.

[d] Of the 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] Strategic gravity bombs are only assigned to B-2A bombers. The maximum yields of strategic bombs are: B61-7 (360 kt), B61-11 (400 kt), B83-1 (1200 kt). However, they also have lower yields. Most B83-1s have been moved to the inactive stockpile and B-2As rarely exercise with the B83-1. The administration of President Barack Obama decided that the B83-1 would be retired once the

B61-12 was deployed, but the administration of President Donald J. Trump has indicated that it might retain the B83-1 for a longer period.

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

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

[i] Another 340 W87s are possibly in long-term storage outside the stockpile for planned use in the W78 replacement warhead (W87-1).

[j] Of the 14 SSBNs, 2 are normally undergoing refuelling overhaul at any given time. They are not assigned weapons. Another 2 or more submarines may be undergoing maintenance at any given time and may not be carrying missiles. The number of deployable missiles has been reduced to 240 to meet the 2010 Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START) limit on deployed strategic missile launchers.

[k] Of these warheads, only about 930 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 carry only 1 warhead.

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

[m] 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.

[n] Approximately 150 of the 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 returned to the USA once the B61-12 is deployed.

[o] The maximum yields of tactical bombs are: B61-3 (170 kt) and B61-4 (50 kt). All have selective lower yields. The B61-10 was retired in 2016.

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

[q] Of these weapons, approximately 1750 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.

[r] 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.

[s] Up until 2018, the US Government published the number of warheads dismantled each year, but the Trump administration ended this practice. Based on previous performance and the completion of the W76-1 life-extension programme, it is estimated here that approximately 385 retired warheads were dismantled during 2019.

[t] In addition to these intact warheads, there are more than 20 000 plutonium pits stored at the Pantex Plant, Texas, and perhaps 4000 uranium secondaries 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.

air-launched cruise missile (ALCM), known as the long-range standoff weapon (LRSO); a new intercontinental ballistic missile (Ground Based Strategic Deterrent, GBSD); and a new nuclear-capable, tactical fighter-bomber (F-35A). The programme also aims to upgrade the command and control systems at the US Department of Defense (DOD), and the nuclear warheads and their supporting infrastructure at the US Department of Energy's National Nuclear Security Administration (NNSA).

According to an estimate published in January 2019 by the US Congressional Budget Office (CBO), modernizing and operating the US nuclear arsenal and the facilities that support it will cost around $494 billion for the period 2019–28, $94 billion more than the CBO's 2017 estimate for the period 2017–26. The rise partly reflects the expected increase in costs based on the progression of the modernization programme as well as the 2018 NPR's addition of new nuclear weapons.[4] The nuclear modernization (and maintenance) programme will continue well beyond 2028 and, based on the CBO's estimate, will cost $1.2 trillion over the next three decades. Notably, although the CBO estimate accounts for inflation, other estimates forecast that the total cost will be closer to $1.7 trillion.[5] The NPR acknowledged that cost estimates of the modernization programme vary but stated that the programme is 'an affordable priority' and emphasized that the total cost represented only a small portion of the overall defence budget.[6] There is little doubt, however, that limited resources, competing nuclear and conventional modernization programmes, and the rapidly growing federal budget deficit will present significant challenges for the nuclear modernization programme in the years ahead.

Bombers

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, although only 60 (18 B-2As and 42 B-52Hs) are thought to be assigned nuclear delivery roles. It is estimated here that there are nearly 850 warheads assigned to strategic bombers, of which about 300 are deployed at bomber bases.

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 satellite network used by the US president and military leadership to transmit launch orders and manage nuclear operations.[7]

The development of the next-generation long-range strike bomber, known as the B-21 Raider, is well under way with the first test aircraft under

[4] US Congressional Budget Office, 'Projected costs of US nuclear forces, 2019 to 2028', Jan. 2019, p. 1.
[5] See e.g. Reif, K., 'US nuclear modernization programs', Arms Control Association, Fact Sheet, updated Aug. 2018.
[6] US Department of Defense (note 3), pp. XI, 51–52.
[7] US Department of Defense (DOD), *Fiscal Year (FY) 2020 Budget Estimates, Air Force, Justification Book Volume 3a of 3: Research, Development, Test & Evaluation, Air Force, Vol–III Part 1* (DOD: Arlington, VA, Mar. 2019).

construction.[8] The B-21 will be capable of delivering B61-12 guided nuclear gravity bombs, which are currently in development, and LRSO cruise missiles. The USAF plans to acquire 1000 LRSO missiles, of which about half will be nuclear armed and the rest used for spares and test launches.[9] The new bomber is scheduled to enter service in the mid-2020s.[10] 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.[11] The USAF plans to acquire at least 100 B-21s but the final order may be significantly higher.[12]

Land-based ballistic missiles

As of January 2020, the USA deployed 400 Minuteman III ICBMs in 450 silos across three missile wings. Fifty of the 450 silos are empty but kept in a state of readiness and can be reloaded with stored missiles if necessary.[13]

Each Minuteman III ICBM is armed with one warhead: either a 335-kiloton W78/Mk12A or a 300-kt W87/Mk21. 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). It is estimated here 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 above-mentioned GBSD, which is scheduled to begin replacing the Minuteman III in 2028 and achieve full operational capability in 2036.[14] The plan is to buy 642 missiles, of which 400 would be deployed, 50 stored and the rest used for test launches and as spares.[15] Development and production of the GBSD will go on well into the mid-2030s. The projected cost of the programme continues to increase. It rose from $62.5 billion projected in 2015 to around $100 billion in 2017.[16] In 2019 the CBO estimated that the cost for the 10-year

[8] US Air Force, Secretary of the Air Force Public Affairs, 'Acting SecAF Donovan announces B-21 manufacturing, testing locations', 16 Sep. 2019.

[9] Rand, R. (Gen.), Commander, Air Force Global Strike Command, 'FY19 posture for Department of Defense nuclear forces', Presentation to the Strategic Forces Subcommittee, Armed Services Committee, US House of Representatives, 11 Apr. 2018, p. 13.

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

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

[12] Clark, C., 'More B-21s likely: B-1s to carry up to 8 hypersonic weapons', Breaking Defense, 17 Sep. 2019.

[13] Air Force Technology, 'USAF removes last of 50 Minuteman III ICBMs and meets NST requirements', 3 July 2017.

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

[15] Reif, K., 'Air Force drafts plan for follow-on ICBM', *Arms Control Today*, 8 July 2015.

[16] Reif, K., 'New ICBM replacement cost revealed', *Arms Control Today*, Mar. 2017.

period 2019–28 alone would be $61 billion, $18 billion higher than the 2017 estimate for 2017–26.[17] In late 2019 the USAF confirmed that Northrop Grumman will produce the GBSD. The expectation is that the contract will be signed in the second half of 2020.[18]

The USAF is modernizing the nuclear warheads that will be used to arm the GBSD. These will also be used to arm the Minuteman III for the remainder of its service life. The W87/Mk21 warhead is being upgraded with a new fuze (arming, fuzing and firing unit). 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 that it will use a W87 plutonium pit with insensitive high explosives instead of the conventional high explosives used in the W78.[19] The projected cost of the W87-1 programme is between $10.6 billion and $13.2 billion.[20]

During 2019, the USAF Global Strike Command carried out four operational and developmental test launches of the Minuteman III ICBM weapon system. The missiles were launched from Vandenberg AFB in California with the payload impacting at the Ronald Reagan Ballistic Missile Defense Test Site in the Kwajalein Atoll in the Marshall Islands.[21]

Ballistic missile submarines

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 overhaul at any given time.

All of the 14 Ohio class SSBNs—8 of which are based at Naval Submarine Base Kitsap in Washington State and 6 at Naval Submarine Base Kings Bay in Georgia—can carry up to 20 Trident II D5 SLBMs. To meet the New START limit on deployed launchers, 4 missile tubes on each submarine have been deactivated so that the 12 deployable SSBNs can carry no more than 240 missiles.[22]

[17] US Congressional Budget Office (note 4), p. 9.

[18] Erwin, S., 'Northrop Grumman wins competition to build future ICBM, by default', *Space News*, 14 Dec. 2019.

[19] Padilla, M., 'Sandia on target for first Mk21 Fuze flight test in 2018', *Sandia Lab News*, 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.

[20] US Department of Energy, National Nuclear Security Administration (NNSA), *Fiscal Year 2020 Stockpile Stewardship and Management Plan*, Report to Congress (NNSA: Washington, DC, July 2019), pp. 8–41.

[21] Murray, D., 'Air Force Global Strike Command year in review: 2019', US Air Force Global Strike Command Air Forces Strategic-Air, 3 Jan. 2020.

[22] US Navy, 'Fleet ballistic missile submarines: SSBN', United States Navy Fact File, 29 Jan. 2019.

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.

Since 2017, the navy has been replacing its Trident II D5 SLBMs with an enhanced version known as the D5LE (LE for 'life extended'). Another 24 were deployed in 2018 (and possibly in 2019) and the upgrade is scheduled to be completed in 2024.[23] The D5LE is equipped with the new Mk-6 guidance system. The D5LE will arm Ohio class SSBNs for the remainder of their service lives (up to 2042) and will also be deployed on British Trident submarines (see section III). The D5LE will initially also arm the new Columbia class SSBN, the first of which—the *USS Columbia* (SSBN-826)—is scheduled to start patrols in 2031, but will eventually be replaced with a new SLBM, currently named the SWS (Strategic Weapon System) 534 or D5LE2.[24] The 2018 NPR stated that the navy 'will begin studies in 2020 to define a cost-effective, credible, and effective SLBM that … [can be deployed] throughout the service life of the COLUMBIA SSBN'.[25]

The Trident SLBMs carry two basic warhead types: either the 455-kt W88 or the 90-kt W76-1 (the older W76-0 version has been, or remains in the process of being, retired). The W76-1 is equipped with a new fuze that improves its targeting effectiveness.[26] It is estimated here that around 1920 warheads are assigned to the SSBN fleet, of which about 930 are deployed on missiles.[27] Each SLBM can carry up to eight warheads but normally carries an average of four to five.

In late 2019 the navy started to deploy a new low-yield warhead on some of its SSBNs.[28] The new warhead is the W76-2, which is a modification of the W76-1 and is estimated to have an explosive yield of about 8 kt.[29] The 2018 NPR claimed that the warhead is needed to deter Russian first use of low-yield tactical nuclear weapons.[30] The first SSBN to deploy with the W76-2 was the *USS Tennessee* (SSBN-734), which left the Kings Bay base at the end of 2019 for a deterrent patrol in the Atlantic Ocean.[31] According to US

[23] Wolfe, J., Director, Strategic Systems Programs, Statement before the Subcommittee on Strategic Forces, Armed Services Committee, US Senate, 23 Mar. 2019, p. 4.

[24] Peterson, J., 'Navy strategic missile boss starting concept development for new missile', *Seapower*, 24 May 2017.

[25] US Department of Defense (note 3), p. 49.

[26] 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.

[27] US Department of State (note 2).

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

[29] US military officials, Private communications with the author, 2019–20.

[30] US Department of Defense (note 3), p. 55

[31] Arkin and Kristensen (note 28); and US Department of Defense (note 28).

military officials, the W76-2 has also been deployed in the Pacific Ocean and it is believed that at least two of the SSBNs on patrol in each of these oceans will normally carry one or two D5 missiles, each with one W76-2.[32]

Non-strategic nuclear weapons

The USA has one basic type of non-strategic (tactical) weapon in its stockpile—the B61 gravity bomb, which exists in two versions: B61-3 and B61-4.[33] An estimated 230 tactical B61 bombs remain in the stockpile.

Approximately 150 of the bombs are thought to be deployed for potential use by fighter-bomber aircraft at six North Atlantic Treaty Organization (NATO) airbases in five countries: Aviano and Ghedi, Italy; Büchel, Germany; Incirlik, Turkey; Kleine Brogel, Belgium; and Volkel, the Netherlands.[34] In 2019 the debate on whether the USA should continue to store nuclear weapons in Turkey intensified after incursions by Turkey into northern Syria, and there were reports that the US military was reviewing evacuation plans for the weapons.[35]

The 80 other B61 bombs are stored at bases in the continental USA for potential use by US aircraft in support of allies outside Europe, including in East Asia.

The USA is close to completing the development of the B61-12 guided nuclear bomb, which will replace all existing versions of the B61. Delivery was scheduled to start in 2020 but production problems in 2019 caused delays and delivery is now expected to take place in late 2021.[36] 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.[37]

Integration of the B61-12 on existing USAF and NATO aircraft continued in 2019. The USAF plans to integrate the B61-12 on seven types of aircraft: the B-2A, the B-21, the F-15E, the F-16C/D, the F-16 MLU, the F-35A and the PA-200 (Tornado).[38] To ensure that Germany can continue to participate in

[32] US military officials, Private communications with the author, 2019–20.

[33] 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 Management Plan*, Report to Congress (NNSA: Washington, DC, Nov. 2017), figure 1–7, pp. 1–13.

[34] For a detailed overview of the dual-capable aircraft programmes of the USA and its NATO allies see Kristensen, H. M., 'US nuclear forces', *SIPRI Yearbook 2019*, pp. 299–300; and Andreasen, S. et al., Nuclear Threat Initiative (NTI), *Building a Safe, Secure, and Credible NATO Nuclear Posture* (NTI: Washington, DC, Jan. 2018).

[35] Sanger, D. E., 'Trump followed his gut on Syria. Calamity came fast', *New York Times*, 14 Oct. 2019.

[36] Gould, J. and Mehta, A., 'Nuclear gravity bomb and warhead upgrades face new delays', *Defense News*, 4 Sep. 2019.

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

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

the NATO nuclear strike mission after it has completed the planned replacement of its Tornados with either Eurofighter or F/A-18 aircraft, some of the new aircraft would also need to undergo integration with the B61-12.[39]

During 2019, the US Navy began an 'analysis of alternatives' study for the new nuclear-armed sea-launched cruise missile called for by the 2018 NPR.[40] The development of the weapon would mark a significant change in approach by the US Navy, which completely eliminated all non-strategic naval nuclear weapons after the end of the cold war.[41] If funded by the US Congress, the new missile could be deployed on attack submarines or surface ships by the end of the 2020s and could potentially result in the first increase in the size of the US nuclear weapon stockpile since 1996.

[39] Shalal, A., 'Germany drops F-35 from fighter tender; Boeing F/A-18 and Eurofighter to battle on', Reuters, 31 Jan. 2019.

[40] Burgess, R. R., 'Navy's Trident missile director: Planning for sea-launched nuclear cruise missile set for 2019', *Seapower*, 22 Mar. 2018. See also Kristensen, H. M., 'US nuclear forces', *SIPRI Yearbook 2019*, pp. 292–94.

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

II. Russian nuclear forces

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As of January 2020, Russia maintained a military stockpile of approximately 4315 nuclear warheads—around 15 fewer than the estimate for January 2019.[1] About 2440 of these were offensive strategic warheads, of which roughly 1570 were deployed on land- and sea-based ballistic missiles and at bomber bases. Russia also possessed approximately 1875 non-strategic (tactical) nuclear warheads—a slight increase compared with the estimate for January 2019 due to the fielding of dual-capable non-strategic weapons. All of the non-strategic warheads were in central storage sites.[2] An estimated additional 2060 retired warheads were awaiting dismantlement (110 fewer than the estimate for January 2019), giving a total inventory of approximately 6375 warheads (see table 10.3). As of September 2019, Russia was reported, under the 2010 Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START), to have 1426 deployed warheads attributed to 513 deployed strategic launchers—that is, deployed intercontinental ballistic missiles (ICBMs) deployed submarine-launched ballistic missiles (SLBMs) and deployed heavy bombers.[3] The number of deployed warheads reported under New START differs from the estimate 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.

Strategic bombers

Russia's Long-range Aviation Command operates a fleet of approximately 13 Tu-160 (Blackjack) and 55 Tu-95MS (Bear) bombers.[4] Not all of these are fully operational and some are undergoing various upgrades. The maximum possible loading on the bombers is nearly 750 nuclear weapons but, since only some of the bombers are fully operational, it is estimated that the number of assigned weapons is lower—around 580—of which approximately 200 might be stored at the two strategic bomber bases: Engels in the Saratov oblast and

[1] The data presented in this section is based on assessments by the author.

[2] For a recent 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).

[3] US Department of State, Bureau of Arms Control, Verification and Compliance, 'New START Treaty aggregate numbers of strategic offensive arms', Fact Sheet, 1 Sep. 2019. For a summary and other details of New START see annex A, section III, and chapter 11, section I, in this volume.

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

Ukrainka in the Amur oblast.[5] An upgrade of the nuclear weapon storage site at Engels is under way.[6]

Modernization of the bombers, which includes upgrades to their avionics suites, engines and long-range nuclear and conventional cruise missiles, is progressing, but at a slower pace than anticipated.[7] 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 (ALCM). Six Tu-95MSMs were delivered in 2019.[8] 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.

The Russian Government has also announced plans to resume production of the Tu-160 to produce up to 50 Tu-160M2s, with serial production starting in the early 2020s.[9] These and the other modernized bombers mentioned above are intended to be only a temporary bridge to Russia's next-generation bomber: the PAK-DA, a subsonic aircraft that looks similar to the flying-wing design of the United States' B-2 bomber. The serial production of the PAK-DA has been delayed and is scheduled to begin in 2027.[10] 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).[11]

Russian strategic bombers carried out operations over the Baltic Sea and the Arctic, Atlantic and Pacific oceans in 2019. The Pacific operations included a joint Russian–Chinese exercise, which led to a serious incident in July involving South Korea. South Korean aircraft fired warning shots when a surveillance aircraft, operating together with Tu-95 bombers, allegedly violated South Korean airspace over islands in the Sea of Japan that are the subject of a territorial dispute.[12] Russian bomber operations in 2019 also included the first-ever visit by two Tu-160s to South Africa.[13]

[5] Podvig, P., 'Strategic aviation', Russian Strategic Nuclear Forces, accessed Jan. 2020.

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

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

[8] O'Shaughnessy, T. J. (Gen.), Commander, United States Northern Command and North American Aerospace Defense Command, Statement before the Armed Services Committee, US Senate, 13 Feb. 2020, p. 4.

[9] TASS, [The Russian military will receive four Tu-160M2 bombers by 2023], 30 Jan. 2019 (in Russian).

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

[11] TASS, [Russia to test next-generation stealth strategic bomber], 2 Aug. 2019 (in Russian).

[12] BBC News, 'Russia and South Korea spar over airspace "intrusion"', 24 July 2019.

[13] *Moscow Times*, 'Russia sends nuclear-bombers to South Africa in "friendly" visit', 23 Oct. 2019.

Table 10.3. Russian nuclear forces, January 2020

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

Type/ Russian designation (NATO designation)	No. of launchers	Year first deployed	Range (km)[a]	Warhead loading	No. of warheads[b]
Strategic offensive forces					**2 440**[c]
Bombers	*50/68*[d]				*580*[e]
Tu-95MS/M (Bear-H)[f]	39/55	1981	6 500–10 500	6–16 x AS-15A or AS-23B ALCMs	448
Tu-160/M (Blackjack)	11/13	1987	10 500–13 200	12 x AS-15B or AS-23B ALCMs, bombs	132
ICBMs	*302*				*1 136*[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]	2	2019	10 000	1 x HGV [400 kt]	2
RS-12M Topol (SS-25 Sickle)	36	1985	10 500	1 x 800 kt	36
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)	126	2010	10 500	4 x [100 kt]	504
RS-24 Yars (SS-27 Mod 2/silo)	14	2014	10 500	4 x [100 kt]	56
RS-28 Sarmat (SS-X-29)	. .	[2021]	10 000+	MIRV [. . kt]	. .
SLBMs	*10/160*[j]				*720*[j]
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)	3/48	2014	>8 050	6 x [100 kt]	288
Non-strategic forces					**1 875**[k]
ABM, air/coastal defence	*1 124*				*382*
53T6 (SH-08, Gazelle)	68	1986	30	1 x 10 kt	68
S-300/400 (SA-20/21)	1 000[l]	1992/2007	. .	1 x low kt	290
3M-55 Yakhont (SS-N-26)	48	[2014]	400+	1 x [. . kt]	20
SSC-1B (Sepal)	8	1973	500	1 x 350 kt	4
Air force weapons[m]	*315*				*495*
Tu-22M3 (Backfire-C)	90	1974	. .	3 x ASMs, bombs	270
Su-24M/M2 (Fencer-D)	90	1974	. .	2 x bombs	90[n]
Su-34 (Fullback)	125	2006	. .	2 x bombs	125[n]
Su-57 (Felon)	. .	[2020]	. .	[bombs, ASM?]	. .
MiG-31K (Foxhound)	10	2018	. .	1 x ALBM	10
Army weapons	*164*				*90*
Iskander-M (SS-26 Stone)	144	2005	350[o]	[1 x 10–100 kt]	70[p]
9M729 (SSC-8)	20	2016	2 350	1 x [. . kt]	20

Type/ Russian designation (NATO designation)	No. of launchers	Year first deployed	Range (km)[a]	Warhead loading	No. of warheads[b]
Navy weapons					*905*
Submarines/surface ships/air		LACMs, SLCMs, ASWs, SAMs, depth bombs, torpedoes[q]			
Total stockpile					**4 315**
Deployed warheads					1 570[r]
Reserve warheads					2 745[s]
Retired warheads awaiting dismantlement					**2 060**
Total inventory					**6 375**

. . = not available or not applicable; [ ] = uncertain figure; ABM = anti-ballistic missile; ALBM = air-launched ballistic missile; ALCM = air-launched cruise missile; ASM = air-to-surface missile; ASW = anti-submarine weapon; HGV = hypersonic glide vehicle; ICBM = intercontinental ballistic missile; kt = kiloton; LACM = land-attack cruise missile; MIRV = multiple independently targetable re-entry vehicle; NATO = North Atlantic Treaty Organization; SAM = surface-to-air missile; SLBM = submarine-launched ballistic missile; SLCM = sea-launched cruise 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 they do not necessarily correspond to the 2010 Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START) data counting rules.

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

[b] The number shows the total number of available warheads, both deployed and in storage, assigned to the delivery systems.

[c] Approximately 1570 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 number is the number of bombers estimated to be counted as deployed under New START; the second number is the total number of bombers in the inventory. 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 750 nuclear weapons but, since only some of the bombers are fully operational, it is assumed here that only 580 weapons are assigned to the long-range bomber force, of which approximately 200 might be stored at the 2 strategic bomber bases. The remaining weapons are 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 1136 warheads but it is estimated here that they have been downloaded to carry just over 810 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 (SS-19) ICBM booster with an HGV payload.

[j] The Russian Navy has a fleet of 10 operational nuclear-armed nuclear-powered ballistic missile submarines (SSBNs): 6 Delfin class (Delta IV), 1 Kalmar class (Delta III) and 3 Borei class. One or two of the Delta SSBNs are in overhaul at any given time and do not carry their assigned nuclear missiles and warheads. It is estimated here that only about 560 of the 720 warheads are deployed.

[k] According to the Russian Government, non-strategic nuclear warheads are not deployed with their delivery systems but are kept in a central storage facility. Some storage facilities are near operational bases.

[l] 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.

[m] 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.

[n] The estimate assumes that half of the aircraft have a nuclear role.

[o] Although many unofficial sources and news media reports state that the Iskander-M (SS-26) has a range of nearly 500 km, the US Air Force National Air and Space Intelligence Center (NASIC) lists the range as 350 km.

[p] The estimate assumes that half of the dual-capable launchers have a secondary nuclear role.

[q] Only submarines are thought to be assigned nuclear torpedoes.

[r] 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.

[s] Reserve warheads include the 1875 non-strategic warheads in central storage (see note k).

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* (NASIC: Wright-Patterson Air Force Base, OH, July 2017); US Department of Defense (DOD), *Nuclear Posture Review 2018* (DOD: Arlington, VA, Feb. 2018); US DOD, *Missile Defense Review 2019* (DOD: Arlington, VA, 2019); US Department of Defense, Office of the Deputy Assistant Secretary of Defense for Nuclear Matters (ODASDNM), *Nuclear Matters Handbook 2020* (ODASDNM: Arlington, VA, Mar. 2020); US DOD, various Congressional testimonies; BBC Monitoring; Russian news media; Russian Strategic Nuclear Forces website; International Institute for Strategic Studies, *The Military Balance* (Routledge: London, various issues); 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 author's estimates.

Land-based ballistic missiles

As of January 2020, Russia's Strategic Rocket Forces—the branch of the armed forces that controls land-based ICBMs—consisted of 12 missile divisions grouped into 3 armies and deploying an estimated 302 ICBMs of different types and variations (see table 10.3). These ICBMs can carry a total of about 1136 warheads but it is estimated here that they have been downloaded to carry around 810 warheads, approximately 52 per cent of Russia's deployed strategic warheads. This is a slight reduction compared with the estimate for January 2019 and appears to confirm the US Air Force National Intelligence and Space Center's (NASIC) projection from 2017 that 'the number of missiles in the Russian ICBM force will continue to decrease because of arms control agreements, aging missiles, and resource constraints'.[14] It should be noted that, unless Russia and the USA agree to extend or renegotiate New

[14] US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat* (NASIC: Wright-Patterson Air Force Base, OH, July 2017), p. 27.

START before February 2021, the treaty will expire and the limit on deployed warheads will no longer apply. Should this happen, both Russia and the USA could significantly increase the number of warheads deployed on their ICBMs.[15]

Russia's ICBM force is two-thirds through a significant modernization programme to replace all Soviet-era missiles with new types, albeit not on a one-for-one basis. The modernization also involves substantial reconstruction of silos, launch control centres, garrisons and support facilities.[16] The missile modernization programme, which started two decades ago, appears to be progressing more slowly than previously envisioned. According to Sergey Shoygu, the Russian defence minister, over 76 per cent of the ICBM force had been modernized by the end of 2019.[17] This is significantly lower than the 97 per cent modernization by the end of 2020 planned for in 2014.[18] In January 2020 Colonel General Sergey Karakaev, commander of the Strategic Rocket Forces, stated 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).

Russia's ICBM modernization is focused on the multiple-warhead version of the RS-12, known as RS-24 Yars (SS-27 Mod 2). Five of seven mobile divisions have already been completed (Irkutsk, Novosibirsk, Tagil, Teykovo and Yoshkar-Ola), with two more in progress (Barnaul and Vypolzovo—sometimes referred to as Bologovsky).[20] The first silo-based RS-24s have been installed at Kozelsk; one regiment of 10 silos is complete and 4 silos of the second regiment are operational, with 6 more under construction as of late 2019.[21] It is possible that a third regiment will be installed at Kozelsk and that at least some of the former RS-18 (SS-19) silos at the Tatishchevo division might also be upgraded to the RS-24.

In December 2019 two missiles equipped with the Avangard hypersonic glide vehicle (HGV) system were installed in former RS-20V silos of the 621st Regiment at Dombarovsky.[22] This missile type uses former RS-18 boosters and has been designated as the SS-19 Mod 4 by the North

[15] For more detail on this issue see chapter 11, section I, in this volume.

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

[17] President of Russia, 'Defence Ministry Board meeting', 24 Dec. 2019.

[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, [What equipment will the Russian army receive in 2020?], 14 Jan. 2020 (in Russian).

[20] 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 connection], 29 Mar. 2018 (in Russian).

[21] Author's assessment based on observation of satellite imagery.

[22] TASS, 'Russia's 1st two Avangard hypersonic missile systems to assume combat duty—source', 13 Nov. 2019.

Atlantic Treaty Organization (NATO).[23] Russia plans to install a total of two regiments, each with six missiles, at Dombarovsky by 2027.[24]

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 multiple independently targetable re-entry vehicles (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 2020, with possible first entry into service in 2021—although this would be dependent on a successful flight-test programme.[25] Once cleared for service, deployment of the RS-28 will begin at the Dombarovsky and Uzhur missile divisions where replacement of the RS-20V will probably take most of the 2020s.

Russia normally conducts several large-scale exercises with road-mobile and silo-based ICBMs each year. These include combat patrols for road-mobile regiments, simulated launch exercises for silo-based regiments, and participation in command staff exercises. During 2019, the ICBM forces conducted more than 200 tactical and command staff exercises.[26] Russia carried out five ICBM test launches in 2019.[27]

Ballistic missile submarines and sea-launched ballistic missiles

The Russian Navy has a fleet of 10 operational nuclear-armed nuclear-powered ballistic missile submarines (SSBNs). The fleet includes 6 Soviet-era Delfin class (Project 667BDRM, or Delta IV NATO designation) submarines, 1 Kalmar class (Project 667BDR, or Delta III) submarine, and 3 (of a planned total of 10) Borei class (Project 955/A) submarines. A former Project 941 (Typhoon) SSBN has been converted to a test-launch platform for SLBMs but it is not thought to be nuclear armed.[28]

Two of the Borei class SSBNs are operational with the Pacific Fleet and one with the Northern Fleet. The first of an improved design, known as Borei-A (Project 955A), is fitting out. A further four are under construction and

[23] US Department of Defense (DOD), *Nuclear Posture Review 2018* (DOD: Arlington, VA, Feb. 2018), p. 8; and Kristensen, H. M. and Korda, M., 'Russian nuclear forces, 2019', *Bulletin of the Atomic Scientists*, vol. 75, no. 2 (2019), p. 78.

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

[25] 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).

[26] Russian Ministry of Defence, [In 2020, strategic rocketeers plan to conduct more than 200 exercises], 3 Jan. 2020 (in Russian).

[27] Russian Ministry of Defence (note 26).

[28] Saranov, V., [Decommissioning 'Akula': Why Russia abandons the biggest submarines], RIA Novosti, 24 Jan. 2018 (in Russian).

expected to enter service over the next decade.[29] It is likely that Russia aims to maintain an SSBN fleet similar in size to that of the USA.

Each SSBN type is equipped with 16 ballistic missiles and the Russian fleet can carry a total of 720 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 560 of the 720 warheads are deployed.

Non-strategic nuclear weapons

As of January 2020, Russia had an estimated 1875 warheads assigned for potential use by non-strategic forces. These include warheads for ships and submarines, various types of aircraft, air- and missile-defence systems, and army missiles. The US military estimates 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'.[30]

Russia's non-strategic nuclear weapons chiefly serve to compensate for perceived weaknesses in its conventional forces. There has been considerable debate about the role that non-strategic nuclear weapons have in Russian nuclear strategy, including potential first use.[31]

Navy weapons

The Russian military service assigned the highest number of non-strategic nuclear weapons is the navy, with about 905 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. Among these weapons, perhaps the most significant is the nuclear version of the long-range, land-attack Kalibr sea-launched cruise missile (SLCM), known as the 3M-14 (SS-N-30A), which has been deployed on numerous

[29] TASS, 'Russia to complete Borei and Yasen series of nuclear-powered submarines in 2023–2024', 27 June 2019.

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

[31] On the debate about the role of Russian non-strategic nuclear weapons see e.g. US Department of Defense (note 23), p. 30; 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., 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), pp. 33–44; and Ven Bruusgaard, K., 'The myths of Russia's lowered nuclear threshold', War on the Rocks, 22 Sep. 2017.

types of surface ship and attack submarine.[32] Other notable navy weapons include the 3M-55 (SS-N-26) SLCM and the 3M-22 Tsirkon (SS-NX-33) hypersonic anti-ship missile, which is undergoing final test launches.[33] The navy is also developing the Poseidon (Status-6, or Kanyon NATO designation), a long-range nuclear-powered torpedo, for future deployment on modified submarines.[34]

Air force weapons

The Russian Air Force has nearly 500 nuclear warheads for use by Tu-22M3 (Backfire-C) intermediate-range bombers, Su-24M (Fencer-D) fighter-bombers, Su-34 (Fullback) fighter-bombers and MiG-31K (Foxhound) attack aircraft. The new Su-57 (Felon), also known as PAK-FA, which is in production and scheduled to be deployed in 2020, is also dual capable.[35] The MiG-31K is equipped with the new Kh-47M2 Kinzhal air-launched ballistic missile, and a test launch took place in the Arctic in November 2019.[36] Russia is also developing a new nuclear-capable air-to-surface missile (Kh-32) to replace the Kh-22N (AS-4) used on the Tu-22M3.[37]

Air, coastal and missile defence

The Russian air-, coastal- and missile-defence forces are estimated to have around 380 nuclear warheads for use by dual-capable S-300 and S-400 air-defence forces, the Moscow A-135 missile defence system and coastal defence units (although only a small number of warheads are assigned to the coastal defence units). Russia is also developing the S-500 air-defence system that might potentially be dual capable, but there is no publicly available authoritative information confirming a nuclear role.[38]

Army weapons

The Russian Army is thought to have approximately 90 warheads to arm short-range ballistic missiles (SRBMs) and ground-launched cruise missiles (GLCMs). The dual-capable Iskander-M (SS-26) SRBM has now completely

[32] 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; and US Air Force, National Air and Space Intelligence Center (note 14), p. 37.

[33] TASS, 'Russia plans new trials of Tsirkon hypersonic missile before yearend: Source', 22 Nov. 2019.

[34] Sutton, H. I., 'Poseidon torpedo', Covert Shores, 22 Feb. 2019.

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

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

[37] US Department of Defense (note 23), p. 8.

[38] Podvig, P., 'Missile defense in Russia', Working paper, Federation of American Scientists Project on Nuclear Dynamics in a Multipolar Strategic BMD [ballistic missile defence] World, May 2017.

replaced the Tochka (SS-21) SRBM in 12 missile brigades.[39] The other army dual-capable missile is the 9M729 (SSC-8) GLCM that the USA cited as its main reason for withdrawing from the 1987 Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty) in August 2019.[40] It is estimated that five 9M729 battalions have so far been co-deployed with five of the Iskander-M brigades. In 2019 there were press reports that the 9M729 had been deployed to Kamyshlov (Sverdlovsk oblast), Kapustin Yar (Astrakhan oblast), Mozdok (North Ossetia), Shuya (Ivanovo oblast) and Leningrad oblast, presumably at the base in Luga.[41]

[39] Author's assessment based on observation of satellite imagery.

[40] US Department of State, Bureau of Arms Control, Verification and Compliance, 'INF Treaty: At a glance', Fact Sheet, 8 Dec. 2017, p. 1. For a summary and other details of the INF Treaty see annex A, section III, in this volume. See also chapter 11, section I, in this volume; and Kile, S. N., 'Russian–US nuclear arms control and disarmament', *SIPRI Yearbook 2018*, pp. 321–24.

[41] Gutschker, T., 'Russland verfügt über mehr Raketen als bislang bekannt' [America is not planning an arms race], 10 Feb. 2019; and RIA Novosti, [Electronic launches of 9M729 missiles took place in the Leningrad region], 8 Feb. 2019 (in Russian).

III. British nuclear forces

SHANNON N. KILE AND HANS M. KRISTENSEN

As of January 2020, the British nuclear stockpile consisted of approximately 195–215 warheads (see table 10.4). In its 2015 Strategic Defence and Security Review (SDSR), the British Government reaffirmed its plans to cut the size of the nuclear arsenal. The number of operationally available nuclear warheads has been reduced to no more than 120. The overall size of the nuclear stockpile, including non-deployed warheads, will decrease to no more than 180 by the mid-2020s.[1]

The British nuclear deterrent consists exclusively of a sea-based component: four Vanguard class Trident nuclear-powered ballistic missile submarines (SSBNs).[2] The United Kingdom is the only nuclear weapon state that operates a single deterrent capability. In a posture known as continuous at-sea deterrence (CASD), which began in 1969, one British SSBN is on patrol at all times.[3] While the second and third SSBNs can be put to sea rapidly, the fourth would take longer because of the cycle of extensive overhaul and maintenance.

The Vanguard class SSBNs can each be armed with up to 16 UGM-133 Trident II D5 submarine-launched ballistic missiles (SLBMs). The UK does not own the missiles but leases them from a pool of 58 Trident SLBMs shared with the United States Navy at the US Strategic Weapons Facility in Kings Bay, Georgia.[4] Under limits set out in the 2010 SDSR, when on patrol, the submarines are armed with no more than 8 operational missiles with a total of 40 nuclear warheads.[5] The missiles are kept in a 'detargeted' mode, meaning that target data would need to be loaded into the guidance system before launch, and have a reduced alert status (i.e. several days' notice would be required to fire the missiles).[6]

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

[2] HMS *Vanguard* entered service in Dec. 1994, while the last submarine in the class, HMS *Vengeance*, entered service in Feb. 2001. Mills, C., 'Replacing the UK's strategic nuclear deterrent: Progress of the Dreadnought class', Commons Briefing Paper CBP-8010, House of Commons Library, 11 Feb. 2020, p. 9.

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

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

[5] British Ministry of Defence, *Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review*, Cm 7948 (Stationery Office: London, Oct. 2010), pp. 5, 38.

[6] British Government (note 1), para. 4.78.

The Trident submarine successor programme

In 2016 the House of Commons approved by a large majority a motion supporting the government's commitment to a replacement of the Vanguard class SSBNs with four new ballistic missile submarines.[7] The new submarine class, which has been named Dreadnought, will have a missile compartment that holds 12 launch tubes—a reduction from the 16 carried by the Vanguard class. As a cost-saving measure, a Common Missile Compartment is being designed in cooperation with the US Navy that will also equip the latter's new Columbia class SSBNs. During 2019, programme contractors continued to work to resolve technical problems with the manufacturing of the missile launch tubes to be used in the compartment.[8]

The Dreadnought submarines were originally expected to begin to enter into service by 2028 but this has been delayed until the early 2030s. The delay was part of the extended development and acquisition programme announced in the 2015 SDSR. The service life of the Vanguard class SSBNs was commensurately extended.[9]

The replacement of the Trident II D5 missile is not part of the Dreadnought development and acquisition programme. Instead, the UK is participating in the US Navy's current programme to extend the service life of the Trident II D5 (D5LE) missile to the early 2060s.[10]

The 2015 SDSR reaffirmed that the replacement of the current British-manufactured warhead, known as Holbrook, for the Trident II missiles would not be required at least until the 2030s. A decision on a new warhead is to be taken by the current parliament, and work continues on developing replacement options.[11] The work includes cooperation between the UK and the USA on warhead safety, security, and manufacturing technologies under the Joint Technology Demonstrator project.[12]

In the meantime, the British Atomic Weapons Establishment (AWE) has begun a programme to improve the performance and extend the life of the Trident Holbrook warhead—which is modelled on the US W76-1 warhead and incorporated into the USA-produced Mk4A re-entry vehicle—in collaboration with US nuclear weapon laboratories.[13]

[7] British Parliament, House of Commons, 'UK's nuclear deterrent', House of Commons Hansard, col. 559, vol. 613, 18 July 2016.

[8] British Ministry of Defence, 'The United Kingdom's future nuclear deterrent: 2019 update to Parliament', 20 Dec. 2019, pp. 1–2.

[9] British Government (note 1), para. 4.65.

[10] Mills (note 2), p. 7.

[11] British Ministry of Defence (note 8), p. 2.

[12] British Ministry of Defence (note 8).

[13] British Ministry of Defence (note 8), p. 3; and Kristensen, H. M., 'British submarines to receive upgraded US nuclear warhead', FAS Strategic Security Blog, Federation of American Scientists, 1 Apr. 2011.

Table 10.4. British nuclear forces, January 2020

Type	Designation	No. deployed	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads
Submarine-launched ballistic missiles[b]						
D5	Trident II	48	1994	>7 400	1–8 x 100 kt[c]	195–215[d]

kt = kilotons.

[a] Range is for illustrative purposes only; actual mission range will vary according to flight profile and weapon loading.

[b] The Vanguard class Trident nuclear-powered ballistic missile submarines (SSBNs) carry a reduced loading of no more than 8 Trident II missiles and 40 nuclear warheads. One submarine is on patrol at any given time.

[c] The British warhead is called the Holbrook, a modified version of the United States' W76-1 warhead, with a lower-yield option.

[d] The British Government has stated that the process to reduce the stockpile to 180 warheads is under way. Although some sources suggest that the stockpile remains at 215 warheads, it is possible that, under this process, the stockpile may have already been reduced to 195 warheads. Of the total warheads in the stockpile, 120 are operationally available.

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.

The cost of the Dreadnought programme has been a source of concern and controversy since its inception. In 2015 the British Ministry of Defence (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.[14] In 2018 the UK's 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.[15] The MOD's budget for 2018–19 received an additional £600 million ($800 million) from the contingency fund to keep the Dreadnought programme on schedule.[16] In its annual update to parliament in December 2019, the MOD reported that a total of £7 billion ($8.9 billion) had been spent on the programme's development, design and early manufacturing phases.[17]

In January 2020 the NAO reported that three key nuclear-regulated infrastructure projects in the UK's nuclear weapon programme faced delays of between one and six years, with costs increasing by over £1.3 billion ($1.7 billion) to a forecasted total of £2.5 billion ($3.2 billion).[18] Specifically,

[14] British Government (note 1), para. 4.76.

[15] British National Audit Office (NAO), *The Defence Nuclear Enterprise: A Landscape Review*, Report by the Comptroller and Auditor General, HC 1003, Session 2017–2019 (NAO: London, 22 May 2018). Spending on defence nuclear programmes was estimated to account for *c.* 14% of the total 2018–19 defence budget.

[16] Mehta, A. and Chuter, A., 'UK releases extra funding, but military relevancy challenges remain', *Defense News*, 29 Mar. 2018.

[17] British Ministry of Defence (note 8), p. 3.

[18] British National Audit Office, *Managing Infrastructure Projects on Nuclear-regulated Sites*, Report by the Comptroller and Auditor General (NAO: London, 10 Jan. 2020), pp. 5–6.

the report identified the work under way to enhance or replace existing facilities at the shipyard in Barrow-in-Furness in Cumbria, where the four Dreadnought class SSBNs are being built. The other projects involved the development of cores for a new generation of nuclear reactors to power the Dreadnought submarines and the construction of a new warhead assembly and disassembly facility (MENSA) in Berkshire to be operated by the AWE. The NAO report attributed the rising costs and delays to poor project management and insufficient oversight by the MOD.[19] It set out a series of recommendations to address identified shortcomings. However, the report also noted that some of the increased costs reflected the need for the MOD to comply with stricter security and safety regulations for the nuclear industry.[20]

[19] British National Audit Office (note 18), p. 8.
[20] British National Audit Office (note 18), p. 13.

IV. French nuclear forces

SHANNON N. KILE AND HANS M. KRISTENSEN

France's nuclear arsenal consists of approximately 290 warheads. The warheads are earmarked for delivery by 48 submarine-launched ballistic missiles (SLBMs) and 50 air-launched cruise missiles (ALCMs) produced for land- and carrier-based aircraft (see table 10.5). France considers all of its nuclear weapons to be strategic, even though the weapons carried by the airborne component of its nuclear forces have characteristics (i.e. a limited range and yield) that other nuclear-armed states consider to be tactical.[1]

The main component of France's nuclear forces is the Strategic Oceanic Force (Force Océanique Stratégique, FOST). It consists of four Triomphant class nuclear-powered ballistic missile submarines (SSBNs) based on the Île Longue peninsula near Brest. Each of the SSBNs 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. The submarines began to enter operational service in 1997, replacing six older Redoubtable class SSBNs.[2] The French Navy has maintained a continuous at-sea deterrent posture, whereby one SSBN is on patrol at all times, since the establishment of the FOST in 1972.[3]

France continues to modernize its SLBMs and associated warheads. In 2018 the French Navy completed work to modify the Triomphant class submarines to carry the M51 SLBM, which replaced the M45 missile.[4] The M51 is currently deployed in two versions. The M51.1 is capable of carrying up to six multiple independently targetable re-entry vehicle (MIRV) TN-75 warheads, each with an explosive yield of 100 kilotons. It is being replaced by an upgraded version known as M51.2, which has greater range and improved accuracy. The M51.2 is designed to carry the new, stealthier oceanic nuclear warhead (tête nucléaire océanique, TNO), which has a reported yield of up to 100 kilotons.[5] The number of warheads on some of the missiles has been

[1] Hollande, F., French President, 'Discours sur la dissuasion nucléaire : Déplacement auprès des forces aériennes stratégiques' [Speech on nuclear deterrence: Visit to the strategic air forces], Istres, 25 Feb. 2015.

[2] *Le Triomphant* entered active service in July 1997, while the fourth and final submarine in the class, *Le Terrible*, entered service in Sep. 2010. Tertrais, B., *French Nuclear Deterrence Policy, Forces and Future*, Recherches & Documents no. 01/2019 (Fondation pour la Recherche Stratégique: Paris, Jan. 2019), p. 61.

[3] 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.

[4] Navy Recognition, 'Final French Navy SSBN "Le Temeraire" upgraded for M51 SLBM', 18 Aug. 2018. *Le Terrible* was equipped with launch tubes for the M51 missile during its construction.

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

reduced in order to improve targeting flexibility.[6] France has commenced design work on a new M51.3 SLBM with improved accuracy. It is scheduled to replace the M51.2 and become operational in 2025.[7]

France has also begun preliminary design work on a third-generation SSBN, designated the SNLE 3G, which will eventually be equipped with a new modification of the M51 (M51.4) SLBM.[8] The construction of the first of four submarines in the class is scheduled to begin in 2023.[9] The aim is to have an operational successor to the Triomphant class submarine in service by the early 2030s.[10]

The airborne component of the French nuclear forces consists of land- and carrier-based aircraft. The French Air Force has 40 deployed land-based nuclear-capable Rafale BF3 aircraft. It retired the last of its nuclear-capable Mirage 2000N aircraft in 2018.[11] All the Rafale BF3s are normally based at Saint-Dizier Air Base. The year 2019 marked 55 years of continuous nuclear alert by the French Air Force.[12]

The French Naval Nuclear Air Force (Force Aéronavale Nucléaire, FANu) consists of a squadron of 10 Rafale MF3 aircraft aboard the aircraft carrier the *Charles de Gaulle*. The ship returned to operational service in early 2019 after completing a mid-life refit that included refuelling its two nuclear reactors. Its first deployment following the refit was to Singapore and lasted from March to July.[13] The year 2019 marked the 40th anniversary of the FANu.[14]

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.[15] A mid-life refurbishment programme for the ASMP-A that began in 2016 will

[6] Tertrais (note 2), p. 63.

[7] French Ministry of the Armed Forces, 'Missiles balistiques stratégiques (MSBS)' [Strategic ballistic missiles], 28 Jan. 2020; and French Ministry of the Armed Forces, 'Discours de Florence Parly, ministre des Armées prononcé à l'usine des Mureaux, ArianeGroup, le 14 décembre 2017' [Speech by Florence Parly, Minister of the Armed Forces, presented at the Mureaux factory, ArianeGroup], 14 Dec. 2017.

[8] Tertrais (note 2), pp. 63, 67.

[9] Groizeleau, 'Deterrence: 25 billion in five years for the renewal of the two components' (note 5).

[10] Hollande (note 1); and Le Drian, J. Y., French Minister of Defence, 'Discours de clôture du colloque pour les 50 ans de la dissuasion' [Conference closing speech on the 50th anniversary of deterrence], French Ministry of Defence, Paris, 20 Nov. 2014.

[11] French Ministry of the Armed Forces, 'La dissuasion aéroportée passe au tout Rafale' [Airborne deterrence goes to the Rafale], 5 Sep. 2018; and Huberdeau, E., 'L'Adieu au Mirage 2000N' [Farewell to the Mirage 2000N], *Air & Cosmos*, 22 June 2018.

[12] French Ministry of the Armed Forces, 'Les FAS à l'honneur dans le nouveau numéro d'Air actualités' [FAS in the spotlight in the new issue of Air actualités], 18 Oct. 2019.

[13] French Ministry of the Armed Forces, 'CLEMENCEAU: Fin de mission pour le groupe aéronaval' [CLEMENCEAU: End of mission for the Carrier Strike Group], 9 July 2019.

[14] French Ministry of the Armed Forces, 'Fin des travaux de refonte à mi-vie du porte-avions : la ministre des Armées sur le Charles de Gaulle' [Completion of the mid-life refit of the aircraft carrier: The minister of defence on the Charles de Gaulle], 9 Nov. 2018.

[15] Hollande (note 1); Tertrais (note 2), p. 65.

Table 10.5. French nuclear forces, January 2020

Type	No. deployed	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
Submarine-launched ballistic missiles[d]					
M51.1	16	2010	>6 000	4–6 x 100 kt TN-75	80[e]
M51.2	32[f]	2017	>9 000[g]	4–6 x 100 kt TNO	160
M51.3[h]	0	[2025]	>[9 000]	[up to 6 x 100 kt] TNO	0
Total					**290**[i]

[ ] = uncertain figure; kt = kiloton; TNA = tête nucléaire aéroportée (airborne nuclear warhead); TNO = tête nucléaire océanique (oceanic nuclear warhead).

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

[b] The Rafale BF3s and MF3s carry the ASMP-A 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 has a reported maximum yield of 300 kt but lower-yield options are thought to be available.

[d] France has only produced enough submarine-launched ballistic missiles (SLBMs) to equip 3 operational nuclear-powered ballistic missile submarines (SSBNs); the fourth SSBN is out of service for overhaul and maintenance work at any given time.

[e] Although the M51 SLBM can carry up to 6 warheads, the number of warheads is believed to have been reduced on some of the missiles in order to improve targeting flexibility.

[f] The French Navy is transitioning from the M51.1 to the M51.2. The last M51.1 missiles will be replaced in 2020.

[g] The M51.2 has a 'much greater range' than the M51.1, according to the French Ministry of the Armed Forces.

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

[i] In a speech in Feb. 2020, President Emmanuel Macron reaffirmed that the arsenal 'is currently under 300 nuclear weapons'. A small number of stockpiled warheads are undergoing maintenance and surveillance at factories.

Sources: Macron, E., French President, 'Discours du Président Emmanuel Macron sur la stratégie de défense et de dissuasion devant les stagiaires de la 27ème promotion de l'école de guerre' [Speech by President Emmanuel Macron on strategic defence and deterrence to officers of the 27th graduation of the military academy], Paris, 7 Feb. 2020; French Ministry of the Armed Forces, 'Discours de Florence Parly, ministre des Armées prononcé à l'usine des Mureaux, ArianeGroup, le 14 décembre 2017' [Speech by Florence Parly, Minister of the Armed Forces, presented at the Mureaux factory, ArianeGroup], 14 Dec. 2017; Hollande, F., French President, 'Discours sur la dissuasion nucléaire: Déplacement auprès des forces aériennes stratégiques' [Speech on nuclear deterrence: Visit to the strategic air forces], Istres, 25 Feb. 2015; Sarkozy, N., French President, Speech on defence and national security, Porte de Versailles, 17 June 2008; Sarkozy, N., French President, 'Presentation of SSBM "Le Terrible"', Speech, Cherbourg, 21 Mar. 2008; Chirac, J., French President, Speech during visit to the Strategic Forces, Landivisiau, L'Île Longue, Brest, 19 Jan. 2006; 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*, Recherches & Documents no. 01/2019 (Fondation pour la Recherche Stratégique: Paris, Jan. 2019); and authors' estimates.

deliver the first upgraded missiles in 2022 or 2023.[16] The missiles are armed with a nuclear warhead (tête nucléaire aéroportée, TNA) that has a reported yield of up to 300 kt.[17] The French Ministry of the Armed Forces has initiated research on a successor missile—air-sol nucléaire (air-to-surface nuclear), fourth-generation (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]

French President Emmanuel Macron has reaffirmed the government's commitment to the long-term modernization of France's air- and sea-based nuclear deterrent forces.[20] In 2018 he signed the law on military planning for 2019–25 following its approval by the French parliament.[21] Among other provisions, the law allocated €37 billion ($43.7 billion) to maintain and modernize France's nuclear forces and infrastructure.[22] This marked a significant increase on the €23 billion ($27.1 billion) allocated to nuclear forces and associated infrastructure in the law on military planning for 2014–19.[23] The Ministry of the Armed Forces' budget for 2020 allocated €4.7 billion ($5.3 billion) for the modernization of nuclear forces.[24]

[16] French Ministry of the Armed Forces, 'Projet de loi de programmation militaire, 2019–2025' [Law on military planning, 2019–2025], Dossier de presse [Press kit], Feb. 2018, p. 42; and Medeiros, J., '"Faire FAS" : 55 ans de dissuasion nucléaire aéroportée' ['Go FAS' : 55 years of airborne nuclear deterrence], *Air Actualités*, Oct. 2019, p. 36; and Tertrais (note 2), p. 67.

[17] Groizeleau, 'Deterrence: F. Hollande outlines his vision and the French arsenal' (note 5).

[18] French Ministry of the Armed Forces, 'La dissuasion nucléaire: synthèse du point-presse du Ministère des Armées' [Nuclear deterrence: Summary of the press briefing by the Ministry of the Armed Forces], Actu Défense, 14 June 2018, p. 1; and Tran, P., 'France studies nuclear missile replacement', *Defense News*, 29 Nov. 2014.

[19] Medeiros (note 16).

[20] Macron, E., French President, 'Déclaration de M. Emmanuel Macron, Président de la République, sur les défis et priorités de la politique de défense' [Statement by Emmanuel Macron, President of the Republic, on the challenges and priorities of defense policy], Toulon, 19 Jan. 2018.

[21] AFP, 'Macron promulgue la loi de programmation militaire 2019–2025' [Macron signs the law on military programming 2019–2025], *Le Figaro*, 13 July 2018.

[22] AFP, '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 ($348 billion).

[23] 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.

[24] Groizeleau, 'Deterrence: 25 billion in five years for the renewal of the two components' (note 5); and Rose, M., 'Amid arms race, Macron offers Europe French nuclear wargames insight', Reuters, 7 Feb. 2020.

V. Chinese nuclear forces

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China has been slowly increasing the size of its nuclear weapon stockpile over the past decade. The pace of growth has increased in recent years with the fielding of new weapon systems. As of January 2020, China maintained an estimated total stockpile of about 320 nuclear warheads, compared with an estimated total of 260 warheads in 2015.[1] Around 240 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.

China is modernizing and diversifying its nuclear forces as part of a long-term programme to develop a more survivable and robust deterrence posture consistent with its nuclear strategy of assured retaliation.[2] The Chinese Government's declared aim is to maintain its nuclear capabilities at the minimum level required for safeguarding national security. China has adopted a nuclear strategy of self-defence, the goal of which is 'deterring other countries from using or threatening to use nuclear weapons' against it.[3] In this context, China has prioritized building an operational triad of land-, sea- and air-based nuclear forces to strengthen its nuclear deterrence and counterstrike capabilities in response to the evolving nuclear strategies of other countries.[4]

Despite the continuing growth in its nuclear arsenal, China's ongoing modernization programmes do not appear to portend changes to its long-standing nuclear policies. In 2019 the Chinese Government reaffirmed its commitment to 'a nuclear policy of no first use of nuclear weapons at any time and under any circumstances and not using or threatening to use nuclear weapons against non-nuclear-weapon states or nuclear-weapon-free zones unconditionally'.[5] In its 2019 annual report to the United States Congress on Chinese military developments, the US Department of Defense (DOD) stated that while there has been some debate in China about the conditions

[1] See Schell, P. P. and Kristensen, H. M., 'Chinese nuclear forces', *SIPRI Yearbook 2015*, pp. 491–95.

[2] Cunningham, F. and Fravel, T., 'Assuring assured retaliation: China's nuclear posture and US–China strategic stability', *International Security*, vol. 40, no. 2 (Oct. 2015), pp. 7–50. Assured retaliation is the ability to survive an initial attack and retaliate with nuclear strikes that inflict unacceptable damage on the attacker.

[3] Chinese State Council, *China's Military Strategy*, Defence White Paper (Information Office of the State Council: Beijing, July 2019), section 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.

[5] Chinese State Council (note 3). See also Pan, Z., 'A study of China's no-first-use policy on nuclear weapons', *Journal for Peace and Nuclear Disarmament*, vol. 1, no. 1 (2018), pp. 115–36.

for the application of its no-first-use policy, there ‘has been no indication that national leaders are willing to attach such nuances and caveats’ to China’s existing policy.[6] 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.[7]

As part of the Chinese Government’s move to restructure and modernize the military under a streamlined command system, it established the People’s Liberation Army (PLA) Rocket Force (PLARF) in 2016 as the fourth service in China’s armed forces.[8] As the ‘core force of strategic deterrence’, the PLARF has assumed command responsibility for all of China’s nuclear forces, and exercises custodial and operational control over the country’s nuclear warheads.[9] In addition, the PLARF has been put in charge of conventional missiles and support forces and tasked with strengthening China’s medium- and long-range strike capabilities in accordance with the requirements of ‘full-area war deterrence’.[10]

Land-based ballistic 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 US 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.[11]

Intercontinental ballistic missiles

In its 2019 annual report on Chinese military developments, the US DOD estimated that China had deployed a total of 90 intercontinental ballistic

[6] US Department of Defense (DOD), Office of the Secretary of Defense, *Military and Security Developments Involving the People’s Republic of China 2019*, Annual Report to Congress (DOD: Arlington, VA, May 2019), pp. 65–67.

[7] Stokes, M. A., *China’s Nuclear Warhead Storage and Handling System* (Project 2049 Institute: Arlington, VA, 12 Mar. 2010), p. 8; and Bin, L., ‘China’s potential to contribute to multilateral nuclear disarmament’, *Arms Control Today*, vol. 41, no. 2 (Mar. 2011), pp. 17–21.

[8] Chinese Ministry of National Defense, ‘China establishes Rocket Force and Strategic Support Force’, 1 Jan. 2016. The PLARF replaced the PLA Second Artillery Corps.

[9] Gill, B. and Ni, A., ‘The People’s Liberation Army Rocket Force: Reshaping China’s approach to strategic deterrence’, *Australian Journal of International Affairs*, vol. 73, no. 2 (Jan. 2019), p. 163.

[10] Gill and Ni (note 9), p. 164.

[11] 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.

Table 10.6. Chinese nuclear forces, January 2020

Type/Chinese designation (US designation)	Launchers deployed	Year first deployed	Range (km)[a]	Warheads x yield	No. of warheads[b]
Land-based ballistic missiles[c]	*188*[d]				*172*
DF-4 (CSS-3)	. .[e]	1980	5 500	1 x 3.3 Mt	. .
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	3 x 200–300 kt MIRV	30
DF-5C (CSS-4 Mod 3)	. .	. .	. .	MIRV	. .
DF-15 (CCS-6 Mod 1)	. .	1994	600	[1 x 10–50 kt]	. .[f]
DF-21 (CSS-5 Mod 2/6)[g]	40	1996/2017	2 100	1 x 200–300 kt	40
DF-26 (CSS-. .)	72	2017	>4 000	1 x 200–300 kt	36
DF-31 (CSS-10 Mod 1)	8	2006	>7 000	1 x 200–300 kt	8
DF-31A/AG (CSS-10 Mod 2)	48	2007/2018	>11 200	1 x 200–300 kt	48
DF-41 (CSS-X-20)	. .	[2020][h]	>12 000	3 x 200–300 kt MIRV	. .
Sea-based ballistic missiles[i]	*48*				*48*[j]
JL-2 (CSS-NX-14)	48	2016	>7 000	1 x 200–300 kt	48
Aircraft[k]	*20*				*20*
H-6K (B-6)	20	2009	3 100	1 x bomb	20
H-6N (B-6)	. .	[2025]	. .	1 x ALBM	. .
H-20 (B-20)	. .	[2020s]	. .	. .	. .
Cruise missiles[l]	. .	. .	. .	. .	. .
Other stored warheads[m]					*80*
Total	**256**				**320**[m]

. . = not available or not applicable; [ ] = uncertain figure; ALBM = air-launched ballistic missile; kt = kiloton; Mt = megaton; MIRV = multiple independently targetable re-entry vehicle.

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

[b] Figures are based on estimates of 1 warhead per nuclear-capable launcher, except the MIRVed DF-5B, which is estimated to have 3 warheads. The DF-26 is a dual capable launcher. It is estimated that half of the dual-capable missiles 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.

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

[d] The estimate only counts nuclear launchers. Some launchers with non-nuclear capability (for medium or intermediate-range ballistic missiles) might have 1 or more reloads of missiles.

[e] It is thought that the DF-4 has been withdrawn from service or is in the process of being retired.

[f] The US Central Intelligence Agency concluded in 1993 that China had ‘almost certainly’ developed a warhead for the DF-15, although it is unclear whether the capability was ever fielded.

[g] The range of the nuclear-armed DF-21 variants (CSS-5 Mods 2 and 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 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 but has not yet been declared operational.

[i] China has 4 operational Type 094 nuclear-powered ballistic missile submarines (SSBNs), each of which can carry up to 12 sea-launched ballistic missiles (SLBMs), giving a total of 48 launchers. Two additional Type 094 SSBNs are in development but are not yet operational.

[j] There is no authoritative information that Chinese SLBMs are armed with nuclear warheads under normal circumstances.

[k] The US Department of Defense (DOD) reported in 2018 that the People's Liberation Army Air Force has been reassigned a nuclear mission. H-6 bombers were used to deliver nuclear weapons during China's nuclear weapon testing programme (one test used a fighter) and models of nuclear bombs are displayed in military museums. It is thought (but uncertain) that a small number of H-6K bombers might have been assigned a nuclear mission. The new H-20 is expected to be nuclear capable.

[l] Official US Government documents are inconsistent and contradictory about possible Chinese nuclear cruise missiles. US Air Force Global Strike Command in 2013 listed the CJ-20 as nuclear capable. In 2013 NASIC listed the CJ-10 as 'conventional or nuclear' but in 2017 it listed the CJ-10 as conventional. A US DOD fact sheet from 2018 listed both an air-launched cruise missile (ALCM) and a sea-launched cruise missile (SLCM). No estimate is provided here because of the very high degree of uncertainty.

[m] In addition to the *c.* 240 warheads estimated to be assigned to operational forces, an additional *c.* 80 warheads are thought to have been produced (or be in production) to arm China's new DF-41s (*c.* 56 warheads) and additional JL-2s (*c.* 24 warheads), for a total estimated stockpile of *c.* 320 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.

missiles (ICBMs).[12] The silo-based, liquid-fuelled, two-stage Dong Feng-5 (DF-5 or CSS-4) family of missiles 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.[13]

The PLARF has been developing a longer-range ICBM, the road-mobile, solid-fuelled, three-stage DF-41 (CSS-X-20), since the late 1990s. With an estimated range in excess of 12 000 kilometres, the DF-41 will have a range similar to that of the older DF-5. Rail-mobile and silo-based versions of the missile are believed to be under development.[14] Open-source imagery in 2019 indicated that the PLARF was building a new type of silo at a missile training area near Jilantai in northern China, possibly for the DF-41, and new silo construction might have started in Henan Province in 2017.[15]

[12] US Department of Defense (note 6), pp. 44, 66.

[13] US Department of Defense (note 6), p. 46.

[14] US Department of Defense (note 6), p. 45.

[15] Kristensen, H. M., 'New missile silo and DF-41 launchers seen in Chinese nuclear missile training area', FAS Strategic Security Blog, Federation of American Scientists, 3 Sep. 2019; and LaFoy, S. and Eveleth, D., 'Possible ICBM modernization underway at Sundian', Arms Control Wonk, 5 Feb. 2020.

There have been 10 known flight tests of the DF-41 since 2012.[16] In January 2019 the DF-41 might have been part of a simulated second-strike exercise conducted by the PLARF.[17] DF-41 launchers operated at the Jilantai training area in April–May 2019 and were publicly displayed for the first time during the annual National Day parade held in Beijing on 1 October 2019.[18] While there has been speculation that the missile has completed its development and testing cycle and achieved an initial operational capability, it had not entered into service by the end of 2019.[19]

After many years of research and development, China has modified a small number of ICBMs to deliver nuclear warheads in multiple independently targetable re-entry vehicles (MIRVs). China has prioritized the deployment of MIRVs in order to improve its warhead penetration capabilities in response to advances in US and, to a lesser extent, Russian (and Indian) missile defences.[20] It has modified the liquid-fuelled, silo-based DF-5A (CSS-4 Mod 1) ICBM, which first went into service in the early 1980s, to carry multiple warheads.[21] One variant of the missile, the DF-5B (CSS-4 Mod 2), is assessed to carry up to three MIRVed warheads.[22] 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.[23] The deployment of MIRVs on the ageing DF-5 missiles may have been an interim arrangement necessitated by delays in the development of the DF-41 mobile ICBM.[24] 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.[25]

Intermediate- and medium-range ballistic missiles

In 2018 the PLARF began the deployment of the new dual-capable DF-26 intermediate-range ballistic missile, which has an estimated maximum range exceeding 4000 km and can reach targets in the western Pacific Ocean,

[16] Gertz, B., 'China flight tests new multi-warhead ICBM', Washington Free Beacon, 6 June 2018.

[17] Liu, X., 'China's rocket force conducts mock ICBM strike exercise', *Global Times*, 22 Jan. 2019.

[18] Kristensen (note 15); and Yang, S. and Liu, X., 'China debuts most advanced ICBM DF-41 at parade', *Global Times*, 1 Oct. 2019.

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

[20] US Department of Defense (note 6), p. 65; and Lewis, J., '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.

[21] US Department of Defense (note 6), p. 44.

[22] O'Halloran, J. (ed.), 'DF-5', *IHS Jane's Weapons: Strategic, 2015–16* (IHS Jane's: Coulsdon, 2015), pp. 7–8.

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

[24] Minnick, W., 'Chinese parade proves Xi in charge', *Defense News*, 6 Sep. 2015.

[25] O'Halloran, ed. (note 22), pp. 21–22; and Gertz, B., 'China flight tests new multiple-warhead missile', Washington Free Beacon, 16 Apr. 2016.

including Guam.[26] The missile is equipped with a manoeuvrable re-entry vehicle (MaRV) warhead that is capable of precision conventional or nuclear strikes against ground targets, as well as conventional strikes against naval targets.[27] A flight test of a DF-26 was carried out on 27 January 2019.[28] China appears to be producing the DF-26 in significant numbers and there were sightings of the missile at several brigade bases during 2019.[29]

The PLARF currently possesses one nuclear-capable medium-range ballistic missile (MRBM). The DF-21 (CSS-5) is a two-stage, solid-fuelled mobile missile that was first deployed in 1991. An upgraded variant, the DF-21A (SSC-5 Mod 2), was first deployed in 1996 and an enhanced version (SSC-5 Mod 6) was fielded in 2017.[30] 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.

Ballistic missile submarines

China continues to pursue its long-standing strategic goal of developing and deploying a sea-based nuclear deterrent. According to the US DOD's 2019 annual report on Chinese military developments, the PLA Navy (PLAN) has commissioned four Type 094 nuclear-powered ballistic missile submarines (SSBNs).[31] Two additional submarines are being outfitted at a shipyard in Huludao.[32] The DOD report assessed that the four operational Type 094 SSBNs represent China's 'first credible, sea-based nuclear deterrent'.[33]

The Type 094 submarine can carry up to 12 three-stage, solid-fuelled Julang-2 (JL-2) 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. The JL-2 SLBM has been deployed on China's four operational Type 094 SSBNs.[34]

[26] US Department of Defense (note 19), pp. 31, 49; and *Global Times*, 'China deploys Dongfeng-26 ballistic missile with PLA Rocket Force', 27 Apr. 2018.

[27] Tate, A., 'China touts ASBM capabilities of DF-26', *Jane's Defence Weekly*, 6 Feb. 2019, p. 6; and *Global Times* (note 26).

[28] Liu, X., 'Missile launch shows China's DF-26 able to adjust position mid-flight, attack moving aircraft carriers: Expert', *Global Times*, 27 Jan. 2019.

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

[30] O'Halloran, ed. (note 22), pp. 15–17; and US Department of Defense (note 6), p. 66.

[31] US Department of Defense (note 6), p. 36. The Type 094 SSBN is designated the Jin class by the United States and the North Atlantic Treaty Organization.

[32] Dill, C., 'Counting Type 094 Jin-Class SSBNs with planet imagery', Arms Control Wonk, 21 Nov. 2018; and Tate, A., 'Satellite imagery shows two Chinese SSBNs in Huludao', *Jane's Defence Weekly*, 5 Dec. 2018.

[33] US Department of Defense (note 6), p. 36.

[34] US Department of Defense (note 6), p. 36.

There has been considerable speculation about when a Type 094 SSBN carrying nuclear-armed JL-2 SLBMs will begin deterrence patrols. Although there were media reports in 2016 that China would soon commence patrols, there was no evidence in 2019 to suggest that they had begun.[35] In its 2014 report on Chinese military developments, the US DOD predicted that China would commence submarine deterrence patrols imminently. Some of the subsequent reports have made the same claim but the 2019 report did not refer to the issue. The routine deployment by China of nuclear weapons on its SSBNs would constitute a significant change to the country's long-held practice of keeping nuclear warheads in central storage in peacetime and would pose operational challenges for its nuclear command and control arrangements.[36]

The PLAN is developing its next-generation SSBN, the Type 096. In 2019 the US DOD assessed that construction would probably begin in the early 2020s.[37] 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.[38]

The Type 096 will be armed with a successor to the JL-2: the JL-3 SLBM.[39] The new missile is thought to use technologies from the land-based DF-41 ICBM and have a longer range than the JL-2. It might also be MIRV capable. On 2 June 2019 the PLAN reportedly conducted the second flight test of the JL-3 SLBM from a modified conventional submarine in the Bohai Sea, following an initial test in November 2018.[40] The Chinese Government did not officially confirm the tests. It has yet to reveal publicly the number of missiles to be carried by the Type 096 or how many submarines will be built.

Aircraft and cruise missiles

According to the US DOD's 2018 annual report on Chinese military developments, the PLA Air Force (PLAAF) had been 're-assigned a nuclear mission'.[41]

[35] See e.g. Borger, J., 'China to send nuclear-armed submarines into Pacific amid tensions with US', *The Guardian*, 26 May 2016.

[36] Center for Strategic and International Studies, 'Does China have an effective sea-based nuclear deterrent?', China Power, updated Mar. 2020.

[37] US Department of Defense (note 6), p. 36.

[38] US Department of Defense (note 6), p. 66.

[39] US Department of Defense (note 6), p. 36.

[40] Tate, A., 'China conducts probable test launch of JL-3 SLBM', *Jane's Defence Weekly*, 3 June 2019.

[41] US Department of Defense (DOD), Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2018*, Annual Report to Congress (DOD: Arlington, VA, Aug. 2018), p. 75. 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.

The previous year's DOD report had stated that the PLAAF 'does not currently have a nuclear mission'.[42]

China possesses a small number of H-6K bombers that may have been given a nuclear weapon delivery role as an interim measure until a new bomber is available.[43] The PLAAF is currently developing its first long-range strategic bomber known as the H-20. The aircraft, which may have a range of up to 8500 km, reportedly will have stealth characteristics similar to those of the US B-2 bomber.[44] The H-20 will be able to deliver both conventional and nuclear weapons and is expected to be fielded sometime in the 2020s.[45]

The US Defense Intelligence Agency reported in 2018 that China was developing two new air-launched ballistic missiles, 'one of which may include a nuclear payload'.[46] The missiles may be variants of the DF-21 MRBM for delivery by a modified H-6N bomber.[47] The H-6N was displayed at the National Day parade in Beijing in October 2019 but there was no reference to a possible future nuclear capability.[48]

The PLA currently deploys several types of ground-, sea- and air-launched cruise missiles, but there is considerable uncertainty about whether these may have nuclear delivery roles. For example, in its 2017 assessment of ballistic missile and cruise missile threats, the US Air Force National Air and Space Intelligence Center (NASIC) did not list any Chinese cruise missile as being nuclear capable.[49] In its previous assessment, published in 2013, NASIC had listed the ground-launched Donghai-10 (DH-10, also designated Changjian-10, CJ-10) as a 'conventional or nuclear' (dual-capable) system.[50]

[42] US Department of Defense (DOD), Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2017*, Annual Report to Congress (DOD: Arlington, VA, May 2017), p. 61.

[43] US Department of Defense (note 6), p 41; and Military-Today, 'H-6K: Long-range strategic bomber', [n.d.].

[44] US Department of Defense (note 6), p 61; 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.

[45] US Department of Defense (note 6), p. 61.

[46] Ashley, R., Director, Defense Intelligence Agency, Statement for the Record: Worldwide Threat Assessment, Armed Services Committee, US Senate, 6 Mar. 2018, p. 8. See also US Department of Defense (note 6), p. 67.

[47] Panda, A., 'Revealed: China's nuclear-capable air-launched ballistic missile', The Diplomat, 10 Apr. 2018.

[48] Yang, S. and Liu, X., 'China unveils new H-6N bomber with extended range, extra capabilities', *Global Times*, 1 Oct. 2019.

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

[50] US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat* (NASIC: Wright-Patterson Air Force Base, OH, 2013), p. 29.

VI. Indian nuclear forces

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As of January 2020, India was estimated to have a growing arsenal of approximately 150 nuclear weapons (see table 10.7). This figure is based on calculations of India's inventory of weapon-grade plutonium and the number of operational nuclear-capable delivery systems. India is expanding the size of its nuclear weapon stockpile as well as its infrastructure for producing nuclear warheads.

Indian nuclear doctrine

During 2019, there was renewed speculation that India was considering modifying or scrapping the no-first-use nuclear doctrine that it adopted in 1998.[1] On 16 August, Indian defence minister Rajnath Singh posted on Twitter that 'India has strictly adhered to this doctrine. What happens in future depends on the circumstances'.[2] Singh's statement added to a growing number of similar statements by Indian defence officials issued over the past decade.[3] It cast further doubt on India's commitment to no-first-use and revived discussions both inside and outside India about the scope and limits of the doctrine and whether India would continue to maintain it.[4] Singh's statement was particularly noteworthy because it followed on the heels of a debate about whether India's modernization of its nuclear weapons was gradually moving the country closer to a more aggressive nuclear policy similar to the counterforce strategy (the capability for pre-emptive or retaliatory strikes on targets of military value) of many other nuclear-armed states.[5]

[1] Although India publicly stated in 2003 that the no-first-use doctrine would not prevent it from responding with nuclear weapons to chemical and biological attacks, it remained fairly clear that the doctrine covered nuclear scenarios. For further detail see e.g. Boyd, K., 'India established formal nuclear command structure', *Arms Control Today*, Jan. 2003.

[2] Rajnath Singh (@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.

[3] For examples of earlier statements by Indian defence officials see e.g. Chaudhury, D. R., 'Why bind ourselves to "no first use policy", says Manahar Parrika on India's nuke doctrine', *Economic Times*, 11 Nov. 2016.

[4] See e.g. *The Hindu*, 'Unclear doctrine: on "no first use" nuclear policy', 19 Aug. 2019; and Panda, A., 'If India rethinks nuclear no first use, it won't surprise Pakistan or China', The Diplomat, 26 Aug. 2019.

[5] Clary, C. and Narang, V., 'India's counterforce temptations: strategic dilemmas, doctrine, and capabilities', *International Security*, vol. 43, no. 3 (winter 2018), pp. 7–52; and Sundaram, K. and Ramana, M. V., 'India and the nuclear policy of no first use of nuclear weapons', *Journal for Peace and Nuclear Disarmament*, vol. 1, no. 1 (2018), pp. 152–68.

Military fissile material production

India's nuclear weapons are believed to be single-stage plutonium-based implosion designs. The plutonium was produced at the Bhabha Atomic Research Centre (BARC) in Trombay, Mumbai, by the 40-megawatt-thermal (MW(t)) heavy water CIRUS reactor, which was shut down at the end of 2010, and the 100-MW(t) Dhruva heavy water reactor. India reportedly has plans to build a new 100 MW(t) reactor near Visakhapatnam, Andhra Pradesh.[6] To extract the plutonium, India operates a plutonium reprocessing plant for military purposes at the BARC as well as three dual-use plants elsewhere.[7]

The Indian Department of Atomic Energy has proposed plans to build six fast breeder reactors—at three sites with twin reactor units—by 2039.[8] This would significantly increase India's capacity to produce plutonium that could be used for building weapons.[9] The unsafeguarded 500-megawatt-electric (MW(e)) prototype fast breeder reactor (PFBR) at the Indira Gandhi Centre for Atomic Research complex at Kalpakkam, Tamil Nadu, was expected to achieve criticality in 2019 following a series of technical delays, but by the end of that year it remained unclear whether this had happened.[10] A new reprocessing plant is also under construction at Kalpakkam to reprocess spent fuel from the PFBR and future fast breeder reactors. The plant is scheduled to be commissioned by 2022.[11]

India is also increasing its uranium enrichment capabilities and continues to produce enriched uranium at the expanded gas centrifuge facility at the Rattehalli Rare Materials Plant near Mysore, Karnataka, for highly enriched uranium (HEU) for use as naval reactor fuel.[12] India is building a new industrial-scale centrifuge enrichment plant, the Special Material Enrichment Facility, near Challakere, Karnataka. This will be a dual-use facility that produces HEU for both military and civilian purposes.[13] India's expanding centrifuge enrichment capacity is motivated by plans to build new

[6] International Panel on Fissile Materials, 'Countries: India', 12 Feb. 2018.

[7] International Panel on Fissile Materials (note 6).

[8] Indian Government, Department of Atomic Energy, 'Statement referred to in reply to Lok Sabha starred question no. 2 due for answer on 18.07.2018 by Shri Rahul Shewale regarding nuclear power plants', [n.d.], p. 2.

[9] Sharma, R., 'India to have six fast breeder reactors by 2039; first to become operational in 2018', Nuclear Asia, 8 Nov. 2017; and Ramana, M. V., 'A fast reactor at any cost: The perverse pursuit of breeder reactors in India', *Bulletin of the Atomic Scientists*, 3 Nov. 2016.

[10] Press Trust of India (PTI), 'Kalpakkam fast breeder reactor may achieve criticality in 2019', *Times of India*, 20 Sep. 2018.

[11] *The Hindu*, 'HCC to construct fuel processing facility at Kalpakkam', 7 Aug. 2017; and World Nuclear News, 'India awards contract for fast reactor fuel cycle facility', 8 Aug. 2017.

[12] International Panel on Fissile Materials (note 6); and Naval Technology, 'India builds reactors to power nuclear submarines', 8 Sep. 2010.

[13] Albright, D. and Kelleher-Vergantini, S., *India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014* (Institute for Science and International Security: Washington, DC, 2 Nov. 2015).

Table 10.7. Indian nuclear forces, January 2020

Type (US/Indian designation)	Launchers deployed	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 bomb	32
Jaguar IS	16	1981	1 600	1 x bomb	16
Land-based ballistic missiles	*70*				*70*
Prithvi-II	30	2003	250[e]	1 x 12 kt	30
Agni-I	20	2007	>700	1 x 10–40 kt	20
Agni-II	12	2011	>2 000	1 x 10–40 kt	12
Agni-III	8	[2014]	>3 200	1 x 10–40 kt	8
Agni-IV	0	[2020]	>3 500	1 x 10–40 kt	0
Agni-V	0	[2025]	>5 000	1 x 10–40 kt	0
Sea-based ballistic missiles	*14*				*16*
Dhanush	2	2013	400	1 x 12 kt	4[f]
K-15 (B05)[g]	1/12[h]	2018	700	1 x 12 kt	12
K-4	. .[i]	. .	3 000	1 x 10–40 kt	. .
Cruise missiles[j]	. .	. .	. .	. .	. .
Other stored warheads[k]					*16*
Total					**150**[k]

. . = not available or not applicable; [ ] = uncertain figure; kt = kiloton.

[a] Aircraft range is for illustrative purposes only; actual mission range will vary according to flight profile and weapon loading. Missile payloads may have to be reduced in order to achieve maximum range.

[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. This estimate counts an average of 1 warhead per launcher. Warheads are not deployed on launchers but kept in separate storage facilities. All estimates are approximate.

[d] Other aircraft that could potentially have a secondary nuclear role include the Su-30MKI.

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

[f] Each Dhanush-equipped ship is thought to have possibly 1 reload.

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

[h] The first figure is the number of operational nuclear-powered ballistic missile submarines (SSBNs); the second is the number of missiles they can carry. Only 1 of India's 2 SSBNs—*INS Arihant*—is believed to be operational and probably has only limited capability. The other SSBN—*INS Arighat*—is fitting out. The SSBNs have 4 missile tubes, each of which can carry 3 K-15 submarine-launched ballistic missiles (SLBMs), for a total of 12 missiles per SSBN.

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

[j] There have been reports suggesting that the Nirbhay cruise missile might be nuclear capable but no official sources have confirmed this.

[k] In addition to the *c.* 134 warheads estimated to be assigned to operational forces, an additional *c.* 16 warheads are thought to have been produced (or be in production) to arm additional Agni and K-15 missiles, for a total estimated stockpile of *c.* 150 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 2019* (Routledge: London, 2019); US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat* (NASIC: Wright-Patterson Air Force Base, OH, July 2017); Indian news media reports; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

naval propulsion reactors. However, the HEU produced at the plants could also hypothetically be used to manufacture thermonuclear or boosted-fission nuclear weapons.[14]

Aircraft

Aircraft are the most mature component of India's nuclear strike capabilities. It is estimated here that there are approximately 48 nuclear bombs assigned to aircraft.

The Indian Air Force (IAF) has reportedly certified its Mirage 2000H fighter-bombers for delivery of nuclear gravity bombs.[15] It is widely speculated that the IAF's Jaguar IS fighter-bombers may also have a nuclear delivery role.[16]

India is acquiring a planned total of 36 Rafale aircraft from France. The majority of the aircraft are scheduled for delivery in 2021–22.[17] The French Air Force uses the Rafale in a nuclear strike role. The Rafale aircraft could therefore potentially replace India's Jaguar IS fighter-bomber in that role. However, as of January 2020, there had been no official confirmation of this. According to the Indian Ministry of Defence, the 'Rafale will provide IAF the strategic deterrence and requisite capability cum technological edge'.[18]

Land-based missiles

Other than occasional parade displays and announcements about missile flight tests, the Indian Government does not provide much public information about the status of its nuclear-capable, land-based ballistic 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

[14] Levy, A., 'India is building a top-secret nuclear city to produce thermonuclear weapons, experts say', *Foreign Policy*, 16 Dec. 2015.

[15] 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.

[16] Cohen, S. and Dasgupta, S., *Arming Without Aiming: India's Military Modernization* (Brookings Institution Press: Washington, DC, 2010), pp. 77–78; and India Defence Update, 'SEPECAT Jaguar is India's only tactical nuclear carrying and ground attack aircraft', 13 Dec. 2016.

[17] Rajnath Singh (@rajnathsingh), Video footage, Twitter, 8 Oct. 2019; and Indian Ministry of Defence, Press Information Bureau, 'Rafale Jet', 20 Nov. 2019. For further detail see chapter 9, section II, in this volume.

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

intermediate-range Agni-III (3200+ km).[19] It is estimated here that India has approximately 70 nuclear warheads for its land-based ballistic missiles.

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.[20] Unlike the other Agni missiles, the Agni-V is designed to be stored in and launched from a new mobile canister system—an arrangement that, among other things, increases operational readiness by reducing the time required to place the missiles on alert in a crisis.[21]

India reportedly carried out at least six test launches of ballistic missiles in 2019. The known launches included flight tests of four Prithvi-II missiles, one Agni-II, and one Agni-III, which failed.[22]

India is 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 Agni-V or on the longer-range Agni-VI, which will have a heavier payload capacity.[23]

Sea-based missiles

With the aim of creating an assured second-strike capability, India continues to develop the naval component of its triad of nuclear forces and is building a fleet of four to six nuclear-powered ballistic missile submarines (SSBNs).[24] The first of the four SSBNs, the *INS Arihant*, was launched in 2009 and formally commissioned in 2016.[25] It is estimated here that 12 nuclear warheads have been delivered for potential deployment by the *Arihant* and more are in production.

[19] The Prithvi-II's range is often reported as 350 km. However, the US Air Force, National Air and Space Intelligence Center (NASIC) sets the range at 250 km. NASIC, *Ballistic and Cruise Missile Threat* (NASIC: Wright-Patterson Air Force Base, OH, July 2017), p. 17.

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

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

[22] Press Trust of India (PTI), 'Nuclear-capable Prithvi II successfully test-fired', *Times of India*, 27 June 2019; PTI, 'DRDO successfully conducts Agni II missile's night trial for first time', *The Hindu*, 16 Nov. 2019; Asian News International (ANI), 'India successfully carries out night-time tests of Prithvi ballistic missile off Odisha coast', *Economic Times*, 20 Nov. 2019; Rout, H. K., 'Nuclear capable Agni-III missile fails in maiden night trial', *New Indian Express*, 1 Dec. 2019; and PTI, 'India conducts another night trial of Prithvi-II missile', *India Today*, 4 Dec. 2019.

[23] 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), pp. 149–76.

[24] Davenport, K., 'Indian submarine completes first patrol', *Arms Control Today*, Dec. 2018.

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

In November 2018 the Indian Government announced that the *Arihant* had completed its first 'deterrence patrol'.[26] However, it is doubtful that the submarine's missiles carried nuclear warheads during the patrol.[27] The *Arihant* is assessed here to have only a limited operational capability.

A second SSBN, the *INS Arighat*, was launched in November 2017 and is fitting out at the naval base near Visakhapatnam.[28] Construction work has reportedly begun on a third and fourth submarine, with expected launch dates in 2020 and 2022, respectively.[29]

India seems to be developing a new SSBN class that would be able to carry more missiles than the *Arihant* and *Arighat*, which are each equipped with a four-tube vertical launch system and can carry up to 12 two-stage, 700-km range K-15 (also known as B05) submarine-launched ballistic missiles (SLBMs). After a visit to the Defence Research and Development Organization's (DRDO) Naval Science and Technological Laboratory, the Indian Vice President, Muppavarapu Venkaiah Naidu, posted a photograph on his Twitter account that appeared to show part of a model of a new SSBN.[30] The missile compartment looked wider and taller than on the *Arihant*, leading to speculation that the compartment might be able to carry eight or more SLBMs.[31]

The DRDO is developing a two-stage, 3500-km range SLBM, known as the K-4, which will eventually replace the K-15.[32] It has also started to develop extended-range versions: the K-5 SLBM, which reportedly will have a range in excess of 5000 km, and the K-6, which will have an even longer range.[33]

India's first naval nuclear weapon was the Dhanush missile, a version of the Prithvi-II that can be launched from a surface ship. Two Sukanya class coastal patrol ships based at the Karwar naval base on India's east coast have been converted to launch the Dhanush. The missile reportedly can carry a 500-kg warhead to a maximum range of 400 km and is designed to be able

[26] Indian Government, Prime Minister's Office, Press Information Bureau, 'Prime Minister felicitates crew of INS Arihant on completion of Nuclear Triad', 5 Nov. 2018; and Davenport (note 24).

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

[28] Unnithan, S., 'A peek into India's top secret and costliest defence project, nuclear submarines', *India Today*, 10 Dec. 2017. The submarine was originally assumed to be named *INS Aridhaman*, but when launched it was named *INS Arighat*.

[29] Unnithan (note 28).

[30] Vice President of India (@VPSecretariat), 'Went around an exhibition displaying Naval Weapons and Systems at Naval Science & Technological Laboratory (NSTL), DRDO at Vizag, Andhra Pradesh today. I am here to participate in the Golden Jubilee Celebrations of NSTL', Twitter, 28 Aug. 2019.

[31] Sutton, H. I., 'Tweet may have inadvertently revealed India's next-Gen nuclear weapons platform with global reach', *Forbes*, 8 Sep. 2019.

[32] Jha, S., 'India's undersea deterrent', The Diplomat, 30 Mar. 2016; and the US Air Force, National Air and Space Intelligence Center (note 19), p. 25.

[33] Rout (note 22); and Unnithan (note 28).

to hit both sea- and shore-based targets.[34] The last known test launch was in November 2018.[35]

Cruise missiles

There have been unconfirmed reports that the Nirbhay long-range subsonic cruise missile is nuclear capable.[36] However, neither the Indian Government nor the United States' intelligence sources have stated that the Nirbhay is a nuclear-capable system.

[34] Indian Defence Research and Development Organization, 'Successful launch of Dhanush and Prithvi missiles', Press release, 11 Mar. 2011; and *New Indian Express*, 'Nuke-capable Dhanush and Prithvi-II launched', 12 Mar. 2011.

[35] Indian Ministry of Defence (note 18), p. 100.

[36] Pandit, R., 'India successfully tests its first nuclear-capable cruise missile', *Times of India*, 8 Nov. 2017; and Gady, F. S., 'India successfully test fires indigenous nuclear-capable cruise missile', The Diplomat, 8 Nov. 2017.

VII. Pakistani nuclear forces

HANS M. KRISTENSEN AND SHANNON N. KILE

Pakistan continues to prioritize the development and deployment of new nuclear weapons and delivery systems as part of its 'full spectrum deterrence posture' vis-à-vis India.[1] It is estimated that Pakistan possessed approximately 160 nuclear warheads as of January 2020 (see table 10.8). Pakistan's nuclear weapon arsenal is likely to continue to expand over the next decade, although projections vary considerably.[2]

Pakistan is believed to be gradually increasing its military fissile material holdings, which include both weapon-grade plutonium and highly enriched uranium (see section X).[3]

Aircraft

The aircraft that are most likely to have a nuclear delivery role are the Pakistan Air Force's (PAF) Mirage III and Mirage V aircraft. The Mirage III has been used for developmental test flights of the nuclear-capable Ra'ad (Hatf-8) air-launched cruise missile (ALCM; see below), while the Mirage V is believed to have been given a strike role with nuclear gravity bombs.[4] The PAF currently operates about 160 Mirage aircraft, of which approximately 120 are fighter-bombers.[5] According to reports in 2019, Pakistan plans to buy an additional 36 Mirage V aircraft from Egypt.[6]

The nuclear capability of Pakistan's F-16 fighter-bombers is unclear but many analysts continue to assign a potential nuclear role to the aircraft (see box 10.1).[7] In the light of this, the table in this edition of the Yearbook has been updated: Pakistan's F-16s are listed as having a potential nuclear role but the nuclear weapons carried by airborne nuclear forces are assigned to Mirage aircraft.

[1] 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), pp. 135–55.

[2] See e.g. Sundaresan, L. and Ashok, K., 'Uranium constraints in Pakistan: How many nuclear weapons does Pakistan have?', *Current Science*, vol. 115, no. 6 (25 Sep. 2018); and Salik, N., 'Pakistan's nuclear force structure in 2025', Carnegie Endowment for International Peace, Regional Insight, 30 June 2016.

[3] For further detail on Pakistan's plutonium production and uranium enrichment facilities see Kile, S. N. and Kristensen, H. M., 'Pakistani nuclear forces', *SIPRI Yearbook 2019*, pp. 332–33.

[4] Kerr, P. and Nikitin, M. B., *Pakistan's Nuclear Weapons*, Congressional Research Service (CRS) Report for Congress RL3248 (US Congress, CRS: Washington, DC, 1 Aug. 2016), p. 7.

[5] International Institute for Strategic Studies, *The Military Balance 2019* (Routledge: London, 2019), pp. 298–99.

[6] *News International*, 'Pakistan to buy 36 Mirage V jets from Egypt', 5 Sep. 2019.

[7] See e.g. International Institute for Strategic Studies (note 5), p. 297.

Box 10.1. The uncertain nuclear capability of Pakistan's F-16s

Pakistan procured 40 F-16A/B aircraft from the United States between 1983 and 1987. In 1989 the US Department of Defense assured the US Congress that Pakistan did not have the capability to convert the aircraft to deliver nuclear weapons, even though experts at US nuclear weapon laboratories and the Central Intelligence Agency reportedly concluded that the F-16s could carry a nuclear payload with relatively minor modifications that were well within the capabilities of Pakistani technicians. In 1990 the USA cancelled the sales of additional F-16s to Pakistan in response to Pakistan's ongoing development of nuclear weapons. At the time, Western intelligence sources stated that Pakistan, 'in violation of agreements with Washington, is busily converting US-supplied F-16 fighter planes … into potential nuclear-weapons carriers'.[a] In 1993 the US National Security Council informed the US Congress that 'Currently, Pakistan probably would rely on its F-16 fighters, and possibly Mirage III and V aircraft' for a nuclear mission.[b]

In 2006 the USA controversially decided to restart sales of F-16s to Pakistan, apparently under tightened use requirements. During a congressional hearing in 2006, the US State Department gave an assurance that 'The F-16s we are giving them … will not be nuclear capable'.[c] In response to concerns that it might be possible for Pakistan to equip the F-16s with its own technology to deliver Pakistani nuclear weapons, the US State Department stated that a new security programme involving US personnel on the ground in Pakistan would make it difficult for Pakistan to convert the aircraft in secret. Extension of the onsite security programme was most recently authorized by the US State Department in July 2019.

The mechanisms under the security programme were triggered in 2019 after India complained that Pakistan had used an F-16 to shoot down one of its aircraft during a border dispute. The US Government subsequently reprimanded Pakistan for violating the conditions of use, which are to operate the F-16s and their USA-produced air-defence missiles at the Mushaf and Shahbaz air bases only for counterterror operations. It is unclear whether the restrictions also cover the original 40 F-16s acquired by Pakistan in the 1980s, but the aircraft have since been upgraded and might therefore be covered.

Whether the restrictions make it impossible for Pakistan to use some of the F-16s in a nuclear role is uncertain. However, it is possible that they might have prompted Pakistan to focus the nuclear mission on its Mirage aircraft, which do not appear to be subject to similar user restrictions.

[a] US Senate, Congressional Record, 20 Sep. 1995, p. S 13966.

[b] US National Security Council, 'Report to Congress on status of China, India and Pakistan nuclear and ballistic missile programs', July 1993, p. 7.

[c] US House of Representatives, Committee on International Relations, 'Proposed sale of F-16 aircraft and weapons systems to Pakistan', Serial no. 109–220, 20 July 2006, p. 41.

Sources: US National Security Council, 'Report to Congress on status of China, India and Pakistan nuclear and ballistic missile programs', July 1993; US Senate, Congressional Record, 20 Sep. 1995; US House of Representatives, Committee on International Relations, 'Proposed sale of F-16 aircraft and weapons systems to Pakistan', Serial no. 109–220, 20 July 2006; Frantz, D. and Collins, C., *The Nuclear Jihadist: The True Story of the Man Who Sold the World's Most Dangerous Secrets … and How We Could Have Stopped Him* (Hachette Book Group: New York, 2007), pp. 162–80; US Department of Defense, Defense Security Cooperation Agency, 'Pakistan: Technical Security Team (TST) in continued support of F-16 program', News Release no. 19-29, 26 July 2019; and Shinkman, P. D., 'State Department reprimanded Pakistan for misusing F-16s, document shows', US News and World Report, 11 Dec. 2019.

Pakistan is acquiring a significant number of JF-17 aircraft, jointly developed with China, to replace the ageing Mirage aircraft. Pakistan currently operates about 100 JF-17s in four to six squadrons, with upgraded aircraft being added.[8] Initial reports on upgrades to the JF-17 suggested that the PAF aimed to integrate the dual-capable Ra'ad ALCM onto the aircraft, but more recent reports on upgrades have not mentioned the weapon.[9]

The Ra'ad ALCM is intended to provide the PAF's fighter-bombers with a standoff nuclear capability. It has been flight tested seven times since 2007. The last reported flight test was in 2016.[10] An improved version, the Ra'ad-II, was displayed for the first time in 2017 and is reported to have a range of 600 kilometres. The Ra'ad-II appears to have new engine air-intake and tail-wing configurations.[11]

Land-based missiles

Pakistan is expanding its nuclear-capable ballistic missile arsenal, which consists of short- and medium-range systems (see table 10.8). It currently deploys the Abdali (also designated Hatf-2), the Ghaznavi (Hatf-3), Shaheen-I (Hatf-4) and Nasr (Hatf-9) solid-fuelled, road-mobile short-range ballistic missiles. An extended-range version of the Shaheen-I, the Shaheen-IA, is still in development. The Ghaznavi, Nasr and Shaheen-I were all test launched in 2019.[12]

The arsenal currently includes 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.[13] The Shaheen-II was test launched in May 2019.[14] A longer-range variant, the Shaheen-III, is currently in development but

[8] 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', Flight Global, 20 June 2019; and International Institute for Strategic Studies (note 5), pp. 298–99.

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

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

[11] Pakistan 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.

[12] Pakistan Inter Services Public Relations, 'Pakistan today conducted another successful launch of short range surface to surface ballistic missile "Nasr"', Press Release PR-37/2019-ISPR, 31 Jan. 2019; Pakistan Inter Services Public Relations, 'Pakistan successfully carried out night 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-156/2019-ISPR, 29 Aug. 2019; and Pakistan Inter Services Public Relations, 'Pakistan today successfully conducted training launch of surface to surface ballistic missile Shaheen-1', Press Release PR-194/2019-ISPR, 18 Nov. 2019.

[13] US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat* (NASIC: Wright-Patterson Air Force Base, OH, July 2017), p. 25.

[14] Pakistan 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.

Table 10.8. Pakistani nuclear forces, January 2020

Type (US/Pakistani designation)	Launchers deployed	Year first deployed	Range (km)[a]	Warheads x yield[b]	No. of warheads[c]
Aircraft	*36*				*36*
F-16A/B[d]	. .	1998	1 600	1 x bomb	. .
Mirage III/V	36	1998	2 100	1 x bomb or Ra'ad ALCM[e]	36
Land-based missiles	*120*[f]				*120*
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]	. .	[2020]	900	1 x 5–12 kt	. .
Shaheen-II (Hatf-6)	18	2014	2 000	1 x 10–40 kt	18
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-. .)	0	. .[l]	450	1 x 5–12 kt	0
Other stored warheads[m]					*4*
Total	**156**				**160**[m]

. . = not available or not applicable; [ ] = 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] Aircraft range is for illustrative purposes only; actual mission range will vary according to flight profile and weapon loading. Missile payloads may have to be reduced in order to achieve maximum range.

[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. Cruise missile launchers carry more than 1 missile. This estimate counts an average of 1 warhead per launcher. Warheads are not deployed on launchers but 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 (see box 10.1). However, it is assumed here that the nuclear weapons carried by airborne nuclear forces are assigned to Mirage aircraft.

[e] The Ra'ad (Hatf-8) ALCM has a declared 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. In 2017 the Pakistani military displayed a Ra'ad-II variant with a reported range of 600 km. It is estimated here that the new version might be deployed in around 2021 in place of the original version.

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

[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 the range is 700 km, double the range reported by the US Air Force 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.

[l] The first test launch of a Babur-3 SLCM was carried out from an underwater platform on 9 Jan. 2017.

[m] In addition to the *c*. 156 warheads estimated to be assigned to operational forces, a small number of additional warheads are thought to have been produced (or be in production) to arm future Shaheen-III and cruise missiles, for a total estimated stockpile of *c*. 160 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* (NASIC: Wright-Patterson Air Force Base, OH, July 2017); International Institute for Strategic Studies, *The Military Balance 2019* (Routledge: London, 2019); *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

has been test launched once—in 2015.[15] The missile has a declared 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, which is possibly equipped with multiple independently targetable re-entry vehicle (MIRV) technology, is also in development. It was last test launched in 2017.[16]

In addition to expanding its arsenal of land-based ballistic missiles, Pakistan continues to develop the nuclear-capable Babur (Hatf-7) ground-launched cruise missile. The Babur has been test launched at least 12 times since 2005 and has been used in army field training since 2011. An extended-range version, which is known as Babur-2 and sometimes referred to as Babur Weapon System-1 (B), has a claimed range of 700 km, as against the 350-km range of the original version. It was first test launched in 2016 and was tested for a second time in 2018.[17]

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) appears to be intended to develop a nuclear capability for the Pakistan Navy's three diesel-electric

[15] Pakistan Inter Services Public Relations, 'Shaheen 3 missile test', Press Release PR-61/2015-ISPR, 9 Mar. 2015.

[16] For further detail on the Ababeel see Kile and Kristensen (note 3), p. 335.

[17] 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.

Agosta class submarines.[18] The Babur-3 was first test launched in 2017 and was tested for a second time in 2018.[19]

Pakistan has ordered eight air-independent propulsion-powered conventional submarines from China, the first of which is expected to be delivered in 2022. It is possible that these submarines, known as the Hangor class, might also be given a nuclear role with the Babur-3 SLCM.[20]

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

[19] Pakistan 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.

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

VIII. Israeli nuclear forces

SHANNON N. KILE AND HANS M. KRISTENSEN

Israel continues to maintain its long-standing policy of nuclear opacity: it neither officially confirms nor denies that it possesses nuclear weapons.[1] Like India and Pakistan, Israel has never been a party to the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT).[2]

Declassified government documents (from Israel and 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.[3] There is little publicly available information about the operating history and power capacity of the unsafeguarded IRR-2, which was commissioned in 1963.[4] It may now be operated primarily to produce tritium.[5] The ageing heavy water reactor, which was originally scheduled to be shut down in 2003, remains in operation despite the existence of a number of identified structural problems in its core.[6] The reactor is due to be shut down in 2023, but the Israeli Atomic Energy Commission is reportedly examining ways to extend its service life until the 2040s.[7]

It is estimated that Israel has approximately 90 operational nuclear weapons (see table 10.9). The locations of the storage sites for the warheads, which are thought to be stored partially unassembled, are unknown. Approximately 30 of the weapons are believed to be gravity bombs for delivery by F-16I aircraft. It is possible that some of Israel's F-15 aircraft may also serve a nuclear strike role, but this is unconfirmed.

Up to 50 warheads are thought to be for delivery by land-based Jericho ballistic missiles. However, the Israeli Government has never publicly confirmed that it possesses the Jericho missiles.

Israel's arsenal probably still includes solid-fuelled, two-stage Jericho II medium-range ballistic missiles, which are believed to be based, along with

[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), pp. 152–70.

[2] For a summary and other details of the NPT see annex A, section I, in this volume.

[3] 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).

[4] Glaser, A. and Miller, M., 'Estimating plutonium production at Israel's Dimona reactor', Science, Technology and Global Security Working Group, Massachusetts Institute of Technology, 2011.

[5] 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', 12 Feb. 2018.

[6] Levinson, C., 'Israel's Dimona nuclear reactor plagued by 1,537 defects, scientists say', *Haaretz*, 16 Apr. 2016.

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

Table 10.9. Israeli nuclear forces, January 2020

Type	Range (km)[a]	Payload (kg)	Status	No. of warheads
Aircraft[b]				. .
F-16I	1 600	5 400	98 aircraft in the inventory; a small number (1–2 squadrons) is believed to be equipped for nuclear weapon delivery.	30
Land-based ballistic missiles[c]				. .
Jericho II	1 500–1 800	750–1 000	*c*. 50 missiles; first deployed in 1990.	25
Jericho III[d]	>4 000	1 000–1 300	Became operational in 2011–15 and is gradually replacing Jericho II.	25
Cruise missiles				. .
. .	. .	. .	Unconfirmed reports suggest that Dolphin class diesel-electric submarines have been equipped with nuclear-armed SLCMs; Israeli officials have declined to comment publicly on the reports.	10
Total				**90**[e]

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

[a] Aircraft range is for illustrative purposes only; actual mission range will vary. Weapon payloads may have to be reduced in order to achieve maximum range.

[b] It is assumed here that only the I-version of the F-16 is used in the nuclear role. It is possible that some of Israel's F-15 aircraft may also serve a nuclear strike role, but this is unconfirmed.

[c] The Israeli Government has never publicly acknowledged that it possesses Jericho missiles.

[d] A longer-range version of the missile with a new rocket motor may be under development.

[e] SIPRI's estimate, which is approximate, is that Israel has *c*. 90 stored nuclear warheads. There is significant uncertainty about the size of Israel's nuclear arsenal and its warhead capabilities.

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 2019* (Routledge: London, 2019); *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.

their mobile transporter-erector-launchers (TELs), in caves at a base near Zekharia, about 25 kilometres west of Jerusalem.[8] Israel's Shavit space-launch vehicle, which carried a military satellite into orbit on its maiden flight in 1988, is based on the Jericho II.[9]

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

[9] Graham, W., 'Israel launches Ofek spy satellite: Officials confirm malfunctions', NASASpaceflight.com, 13 Sep. 2016.

A three-stage Jericho III intermediate-range ballistic missile, with a range exceeding 4000 km, was declared operational in 2011 and might be replacing (or might possibly have already replaced) the Jericho II.[10] 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.[11] On 6 December 2019 the Israeli Ministry of Defense announced that it had conducted a test launch of an unspecified rocket propulsion system from a military base in central Israel, but it did not identify the missile that was used.[12] According to unconfirmed reports, the base was the Palmachim Air Base, which is located on Israel's Mediterranean coast and used as a test launch site for Jericho missiles.[13] The launch led to renewed speculation that Israel might be developing a new Jericho IV missile.[14]

Israel currently operates five German-built Dolphin and Dolphin-2 class diesel-electric submarines.[15] 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 second-strike capability.[16] Israeli officials have consistently declined to comment publicly on the reports. If they are true, the naval arsenal might include about 10 warheads, assuming a couple of warheads per submarine.

[10] O'Halloran, ed. (note 8).

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

[12] 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.

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

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

[15] Naval Today, 'Israel changes name of sixth Dolphin submarine', 11 Jan. 2019. A 6th submarine is scheduled to be delivered to Israel in 2020.

[16] See e.g. Cohen (note 3), 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 Korea's military nuclear capabilities

SHANNON N. KILE AND HANS M. KRISTENSEN

The Democratic People's Republic of Korea (DPRK, or North Korea) maintains an active but highly opaque nuclear weapon programme. As of January 2020, it is estimated that North Korea possessed approximately 30–40 nuclear weapons (see table 10.10). This 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) and on assumptions about its weapon design and fabrication skills.[1]

In 2019 North Korea continued to adhere to the moratoria on nuclear explosive tests and flight tests of long-range ballistic missiles that had been announced by North Korean leader Kim Jong Un in April 2018.[2] North Korea did, however, conduct multiple tests of guided artillery rocket systems and several new types of short-range ballistic missile (SRBM) in 2019. It also conducted the first flight test of a new submarine-launched ballistic missile (SLBM).

Fissile material production

North Korea's plutonium production and separation capabilities for manufacturing nuclear weapons are located at the Yongbyon Nuclear Scientific Research Centre (YNSRC).[3] In 2019 some of the nuclear facilities located there appeared not to be operating. In August the International Atomic Energy Agency (IAEA) reported that its analysis of satellite imagery and remote-sensor data showed no indications that the ageing 5 megawatt-electric (MW(e)) graphite-moderated research reactor located at the YNSCR had been in operation since the end of 2018.[4] In addition, the IAEA reported that there were no indications that reprocessing activities were under way at the adjacent Radiochemical Laboratory used to separate plutonium from

[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 2019*, pp. 343–44.

[2] Korean Central News Agency, 'Third Plenary Meeting of Seventh CC, WPK held in presence of Kim Jong Un', 21 Apr. 2018. North Korea conducted underground nuclear test explosions in Oct. 2006, May 2009, Feb. 2013, Jan. and Sep. 2016, and Sep. 2017. The estimated explosive yields of the tests progressively increased.

[3] 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', Center for International Security and Cooperation, Stanford University, 11 Feb. 2019, p. 3.

[4] International Atomic Energy Agency, 'Application of safeguards in the Democratic People's Republic of Korea', Report to the Board of Governors by the Acting Director General, GOV/2019/33-GC(63)/20, 19 Aug. 2019, p. 4; and Pabian, F. V., Liu, J. and Makowsky, P., 'North Korea's Yongbyon Nuclear Complex: No sign of operations', 38 North, 15 Mar. 2019.

the 5-MW(e) reactor's spent fuel rods.[5] In November 2019 commercial satellite imagery analysed by non-governmental experts indicated that the Experimental Light Water Reactor (ELWR) under construction at Yongbyon, which is also capable of producing plutonium for nuclear weapons, was undergoing system tests but had not yet commenced operation.[6]

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 2019 satellite imagery analysis indicated that North Korea continued to operate the gas centrifuge enrichment plant located at the Yongbyon complex that it had declared in 2010.[7] 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.[8] However, analysts cautioned that without access to the plant it was not possible to confirm the nature and purpose of the activities being conducted there.[9] A US intelligence assessment 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.[10]

Land-based ballistic missiles

North Korea is expanding and modernizing its ballistic missile force, which consists of indigenously produced short-, medium- and long-range missile systems that are either deployed or under development.[11] In recent years it has pursued the serial development of several missile systems with progressively longer ranges and increasingly sophisticated delivery capabilities.[12]

[5] International Atomic Energy Agency (note 4). The plutonium separated from the reactor's spent fuel can be used for the production of nuclear weapons.

[6] Serbin, E. and Puccioni, A., 'North Korea's Experimental Light Water Reactor: Possible testing of cooling system', 38 North, 6 Dec. 2019.

[7] Pabian, F. V. and Liu, J., 'North Korea's Yongbyon nuclear facilities: Well-maintained but showing limited operations', 38 North, 9 Jan. 2019; and Hecker, Carlin and Serbin (note 3), pp. 3–4.

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

[9] Hecker, Carlin and Serbin (note 3), p. 4; and Madden, M., 'Much ado about Kangson', 38 North, 3 Aug. 2018.

[10] 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*, 30 June 2018.

[11] Center for Strategic and International Studies Missile Defence Project, 'Missiles of North Korea', Missile Threat, accessed Jan. 2020.

[12] James Martin Center for Nonproliferation Studies (CNS), CNS North Korea Missile Test Database, accessed Jan. 2020. North Korea conducted 20 known tests of such missiles in 2017.

Table 10.10. North Korean forces with potential nuclear capability, January 2020

Type[a]	Range (km)	Payload (kg)	Status	No. of warheads
Land-based ballistic missiles				. .
Hwasong-7 (Nodong)	>1 200	1 000	Single-stage, liquid-fuel missile. Fewer than 100 launchers; first deployed in 1990.	
Hwasong-9 (Scud-ER)	1 000	500	Scud missile variant, lengthened to carry additional fuel.	
Bukkeukseong-2 (KN-15)	1 000	. .	Single-stage, solid-fuel missile under development launched from canister TEL. Land-based version of Bukkeukseong-1 SLBM; test launched in 2017.	
Hwasong-10 (BM-25, Musudan)	>3 000	[1 000]	Single-stage, liquid-fuel missile under development; several failed tests in 2016.	
Hwasong-12 (KN-17)	>3 000	1 000	Single-stage, liquid-fuel missile under development.	
Hwasong-13 (KN-08)[b]	>5 500	. .	Three-stage, liquid-fuel missile with potential intercontinental range under development; no known test launches.	
Hwasong-14 (KN-20)	6 700–10 400	500–1 000	Two-stage, liquid-fuel missile under development; tested in 2017.	
Hwasong-15 (KN-22)	13 000	1 000–1 500	Two-stage, liquid-fuel missile under development; two tests in 2017.	
Taepodong-2[c]	12 000	. .	Under development; three-stage space launch vehicle variant placed satellites in orbit in Dec. 2012 and Feb. 2016.	
Submarine-launched ballistic missiles				. .
Bukkeukseong-3	[1 900]	. .	Two-stage, solid-fuel SLBM under development, replacing earlier Bukkeukseong-1 version. First flight tested in Oct. 2019.	
Total				**[30–40]**[d]

. . = not available or not applicable; [ ] = uncertain figure; 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 intercontinental-range ballistic missile.

[b] A two-stage variant, the KN-14, is under development but has yet to be test launched.

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

[d] SIPRI's estimate is that North Korea may have enough fissile material to build between 30 and 40 nuclear warheads. It is unknown how many warheads may have been assembled.

Sources: US Department of Defense (DOD), Office of the Secretary of Defense, *Missile Defense Review 2019* (DOD: Arlington, VA, 2019); US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat* (NASIC: Wright-Patterson Air Force Base, OH, July 2017); *IHS Jane's Strategic Weapon Systems*, various issues; *Bulletin of the Atomic Scientists*, 'Nuclear notebook', various issues; and authors' estimates.

However, the flight tests were stopped in 2018, and the United States' Department of Defense (DOD) reported in January 2019 that none of the new longer-range ballistic missiles (Hwasong-10/12/13/14/15 or Bukkeokseong-1/2) had been deployed.[13]

In December 2019 North Korea conducted two sustained static firings of rocket engines at the Sohae Vertical Engine Test Stand.[14] Some analysts suggested that North Korea had ground tested a large, solid-fuel rocket motor designed for a new long-range ballistic missile.[15] However, others suggested that it was more likely that the test involved either a new, unknown liquid-fuel engine or an existing one.[16]

Short-range ballistic missiles

In 2019 North Korea conducted the initial launches of at least three new types of solid-fuelled SRBM.[17] One missile, designated by the US DOD as the KN-23, externally resembles the Russian Iskander-M SRBM.[18] The missile has an estimated maximum range exceeding 600 kilometres and was flight tested four times in 2019.[19] A second missile, designated by the US DOD as the KN-25, uses a large-calibre, multiple-launch rocket system and has a demonstrated range of 380 km.[20] A third missile, the KN-24, resembles an enlarged version of the US Army Tactical Missile System (ATACMS).[21] It was tested twice in 2019 and has an estimated range of 400 km.[22]

There is very little open-source information about the technical dimensions of the new SRBMs, including their ranges, accuracy and missile defence penetration capabilities. In 2019 some analysts speculated that the

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

[14] Warrick, J., 'North Korea never halted efforts to build powerful new weapons, experts say', *Washington Post*, 24 Dec. 2019.

[15] Ankit Panda (@nktpnd), 'Also, given the "very important" test that's set to improve their "strategic position"—and now Kim Yong Chol talking about surprises—we have more reason to expect the demonstration of a *qualitatively new* capability that we haven't seen before. Solid-fuel ICBM/IRBM looks likely', Twitter, 9 Dec. 2019.

[16] Elleman, M., 'North Korea's rocket engine test: What we know and don't know', 38 North, 10 Dec. 2019.

[17] Center for Strategic and International Studies Missile Defence Project, 'North Korean missile launches & nuclear tests: 1984-present', Missile Threat, 25 Mar. 2020.

[18] Lewis, J., 'Preliminary analysis: KN-23 SRBM', Middlebury Institute of International Studies at Monterey, James Martin Center for Nonproliferation Studies, 5 June 2019.

[19] Center for Strategic and International Studies Missile Defence Project, 'KN-23', Missile Threat, accessed Jan. 2020.

[20] Center for Strategic and International Studies Missile Defence Project, 'KN-25', Missile Threat, accessed Jan. 2020; and Byrne, L., 'North Korea tests "super-large" multiple rocket launch system: KCNA', NK News, 24 Aug. 2019.

[21] Elleman, M., 'North Korea's new short-range missiles: A technical evaluation', 38 North, 9 Oct. 2019; and Panda, A., 'North Korea tests new type of short-range ballistic missile', The Diplomat, 12 Aug. 2019.

[22] Center for Strategic and International Studies Missile Defence Project, 'KN-24', Missile Threat, accessed Jan. 2020.

KN-23 and perhaps the KN-24 missiles might be so-called dual-capable systems—that is, assigned delivery roles for both conventional and nuclear warheads.[23] They raised concerns that such a capability could create a 'new level of unpredictability' in military decision making because neither the USA nor South Korea would be able to ascertain whether an incoming missile of one of these types was nuclear armed and they might therefore respond disproportionately.[24] However, 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 more accurate KN-23 (or KN-24).[25]

Medium- and intermediate-range ballistic missiles

Assuming that North Korea is able to produce a sufficiently compact warhead, some observers assess that the size, range and operational status of the Hwasong-7 or Nodong (also transliterated as Rodong) medium-range missile make it the system most likely to be given a nuclear delivery role.[26] Based on a Soviet-era Scud missile design, the Nodong 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 or Scud-ER (extended-range), which may also be a nuclear-capable delivery system. Based on the Hwasong-6 (Scud C variant) missile with a lengthened fuselage to carry additional fuel, the Scud-ER has an estimated range of 1000 km.[27]

The Hwasong-10 missile, also designated the Musudan or BM-25, is a single-stage, liquid-fuelled missile with an estimated range exceeding 3000 km. The Musudan was first unveiled at a military parade in 2010. Flight testing began in 2016, with multiple failures.[28] No flight tests of the Musudan are known to have been conducted since 2016–17, and the status of the missile development programme is unclear.

The Hwasong-12 (also referred to by the US DOD designation KN-17) is a single-stage, intermediate-range missile that is believed to have a new

[23] Denyer, S., 'Fast, low and hard to stop: North Korea's missile tests crank up the threat level', *Washington Post*, 15 Aug. 2019; and Lewis (note 18).

[24] Kim, D. and Hanham, M., 'North Korean missiles: Size does not matter', *Bulletin of the Atomic Scientists*, 15 May 2019.

[25] For an unofficial technical assessment that did not assign nuclear capability to the KN-23 see Elleman (note 21).

[26] See e.g. Fitzpatrick, M., 'North Korea nuclear test on hold?', Shangri-La Voices, International Institute for Strategic Studies, 27 May 2014; and Albright, D., 'North Korean miniaturization', 38 North, 13 Feb. 2013.

[27] US Air Force, National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat* (NASIC: Wright-Patterson Air Force Base, OH, July 2017), pp. 18, 25.

[28] Savelsberg, R. and Kiessling, J., 'North Korea's Musudan missile: A performance assessment', 38 North, 20 Dec. 2016. In 2016 North Korea conducted 8 flight tests of the Musudan system. Only 1 of the tests was judged to have been successful. In the other tests, the missiles exploded on launch or shortly thereafter.

liquid-propellant booster engine as well as design features that may serve as a technology test bed for a future intercontinental-range ballistic missile (ICBM).[29] 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.[30] The missile, which has an estimated range of more than 3000 km, was last test launched in 2017 but has not been deployed.[31]

North Korea is developing the Bukkeukseong-2 missile (US DOD designation, KN-15), which is a land-based variant of the Bukkeukseong-1 SLBM. The two-stage, solid-fuelled missile has an estimated range of approximately 1000 km.[32] It was flight tested twice in 2017. Some analysts have noted that North Korea's development of the Bukkeukseong-2 was 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.[33]

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, there has remained considerable uncertainty in assessments of North Korea's current long-range missile capabilities.[34]

The Hwasong-13 (US DOD designation, KN-08) was first presented by North Korea as a road-mobile, three-stage missile with intercontinental range at a military parade in April 2012, although some non-governmental analysts have argued that the missiles displayed were only mock-ups.[35] Estimates of the range and payload capabilities of the missile are highly speculative. As of 2019, it had not been flight tested.

North Korea has developed the Hwasong-14 (US DOD designation, KN-20), a prototype ICBM that first appeared in 2015 at a military parade in Pyongyang.[36] The two-stage missile appears to use the same high-energy

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

[31] Panda, A., 'North Korea shows increased operational confidence in the Hwasong-12 IRBM', The Diplomat, 17 Sep. 2017; and US Department of Defense (note 13).

[32] US Air Force, National Air and Space Intelligence Center (note 27), p. 25.

[33] 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.

[34] Albert, E., 'North Korea's military capabilities', Council on Foreign Relations, updated 20 Dec. 2019.

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

[36] Schiller and Kelley (note 35).

liquid-propellant booster engine as the single-stage Hwasong-12.[37] Based on a flight test conducted in 2017, analysts have estimated that the missile's range was unlikely to exceed 8000 km when carrying a 500 kilogram payload, which is thought to be around the weight of a nuclear warhead. This meant that the missile could not reach targets in the USA beyond the West Coast when launched from North Korea.[38]

North Korea is developing a new two-stage ICBM, the Hwasong-15 (US DOD designation, KN-22), 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. One estimate put the theoretical maximum range of the Hwasong-15 on a normal trajectory at up to 13 000 km—sufficient to reach Washington, DC, and other targets on the East Coast of the USA.[39] The missile was assessed to be carrying a light payload, however, and the range would be significantly reduced if it were carrying a heavier payload such as a nuclear warhead.[40]

While North Korea has made important progress towards building a nuclear-armed ICBM capable of credibly threatening the USA, it has yet to validate the performance and reliability of the missile systems under development.[41] In particular, defence analysts have pointed out that North Korea has not demonstrated a mastery of the technology for building a reliable atmospheric re-entry vehicle or for terminal-stage guidance and warhead activation.[42] The US DOD's 2019 *Missile Defense Review* indicated that North Korea had deployed one ICBM, the Taepodong-2.[43] However, other official US sources list the missile as a space-launch vehicle that would need reconfiguration to be used as an ICBM.[44]

Submarine-launched ballistic missiles

North Korea continues to pursue the development of an SLBM system as part of an effort to improve the survivability of its nuclear-capable ballistic missile

[37] 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', IISS Voices blog, International Institute for Strategic Studies, 14 Aug. 2017.

[38] Elleman, M., 'North Korea's Hwasong-14 ICBM: New data indicates shorter range than many thought', 38 North, 29 Nov. 2018.

[39] Wright, D., 'Re-entry of North Korea's Hwasong-15 missile', All Things Nuclear blog, Union of Concerned Scientists, 7 Dec. 2017.

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

[41] Acton, J., 'Assessing North Korea's progress in developing a nuclear-armed ICBM', Carnegie Endowment for International Peace, 4 May 2018.

[42] Wright (note 39); and Elleman (note 40). See also Ali, I., 'US general says North Korea not demonstrated all components of ICBM', Reuters, 30 Jan. 2018.

[43] US Department of Defense (note 13), p. 7.

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

systems. In October 2019 North Korea announced that it had test launched 'a new type' of SLBM called the Bukkeukseong-3 (also transliterated as Pukguk-song-3).[45] The test was conducted from a towed underwater platform in the waters off North Korea's east coast. The missile was a two-stage, solid-fuelled design, but it was unclear whether it used the same booster engine as the Bukkeukseong-1 SLBM that preceded it. With an estimated maximum range of 1900 km, the Bukkeukseong-3 would be the longest-range, solid-fuelled missile in the North Korean inventory.[46]

During 2019, North Korea demonstrated that it had made progress towards achieving its goal of designing, building and eventually deploying an operational ballistic missile submarine. Currently, North Korea has one Sinpo class experimental submarine in service, which can hold and launch one SLBM. A visit by North Korean leader Kim Jong Un to the Sinpo South Shipyard in July 2019 revealed circumstantial evidence that North Korea was building a new ballistic missile submarine.[47] The vessel appeared to be based on a modified Romeo class diesel-electric submarine and fitted with three missile-launch canisters.[48] According to the state-run Korean Central News Agency, the submarine's operational deployment was 'near at hand'.[49]

[45] Korean Central News Agency, 'DPRK succeeds in test-firing new-type submarine-launched ballistic missile', 2 Oct. 2019; Lee, J., 'North Korea says it successfully tested new submarine-launched ballistic missile', Reuters, 2 Oct. 2019; and Ji, D., 'Pukguksong-3 SLBM test-launch is "powerful blow" to hostile forces: Rodong Sinmun', NK News, 4 Oct. 2019.

[46] Panda, A., 'North Korea finally unveils the Pukguksong-3 SLBM: First takeaways', The Diplomat, 3 Oct. 2019; and Center for Strategic and International Studies Missile Defence Project (note 11).

[47] Bermudez, J. and Cha, V., 'Sinpo South Shipyard: Construction of a new ballistic missile submarine?', Beyond Parallel, Centre for Strategic and International Studies, 28 Aug. 2019.

[48] Liu, J. and Town, J., 'North Korea's Sinpo South shipyard: Recent activity', 38 North, 26 Sep. 2019; and Hotham, O., 'New North Korean submarine capable of carrying three SLBMs: South Korean MND', NK News, 31 July 2019.

[49] 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, 2019

MORITZ KÜTT, ZIA MIAN AND PAVEL PODVIG
INTERNATIONAL PANEL ON FISSILE MATERIALS

Materials that can sustain an explosive fission chain reaction are essential for all types of nuclear explosives, 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 2019, of HEU (table 10.11) and separated plutonium (table 10.12), including in weapons, and details of the current capacity to produce these materials (tables 10.13 and 10.14, respectively). The 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) were released in 2019 and give data for 31 December 2018, and so are taken here to be applicable for the start of 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, however, 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 with a civil nuclear industry have some capability to produce fissile materials that could be used for weapons.

Table 10.11. Global stocks of highly enriched uranium, 2019

State	National stockpile (tonnes)[a]	Production status	Comments
China	14 ± 3	Stopped 1987–89	
France[b]	30 ± 6	Stopped 1996	Includes 5.1 tonnes declared civilian[c]
India[d]	4.4 ± 1.6	Continuing	Includes HEU in naval reactor cores
Israel[e]	0.3	–	
Korea, North[f]	Uncertain	Uncertain	
Pakistan	3.7 ± 0.4	Continuing	
Russia[g]	679 ± 120	Stopped 1987–88	Includes about 6 tonnes in use in research applications
UK[h]	22.6	Stopped 1962	Includes 0.7 tonnes declared civilian[c]
USA[i]	565 (85 not available for military purposes)	Stopped 1992	Includes HEU in a naval reserve
Other states[j]	~15		
Total[k]	**~1 335**		

HEU = highly enriched uranium.

[a] Most of this material is 90–93% enriched uranium-235 (U-235), which is typically considered weapon-grade. The estimates are for the end of 2018 and treated as applicable for the start of 2019. Important exceptions are noted.

[b] The uncertainty in the estimate applies only to the military stockpile of about 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] INFCIRC/549 declaration to the International Atomic Energy Agency (IAEA) for the end of 2018 and treated as applicable for the start of 2019.

[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 about 300 kg of weapon-grade HEU from the USA in or before 1965.

[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 2018 suggest an accumulated HEU stockpile range of 180–850 kg.

[g] This estimate may understate the amount of HEU in Russia since it assumes that it ceased production of all HEU in 1988. However, Russia may have continued producing HEU for civilian and non-weapon military uses after that date. 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.

[h] The estimate reflects a UK 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 about 500 kg of HEU from the UK were transferred to the USA for downblending into low-enriched uranium.

[i] 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 Sep. 2018, another 17 tonnes had been downblended or shipped for blending down. The amount available for use had been reduced to about 480 tonnes, mostly by consumption in naval reactors. The 85 tonnes declared excess includes the remaining about 69 tonnes as well as 16 tonnes of the 20 tonnes originally reserved for HEU fuel for research reactors.

[j] The 2018 IAEA Annual Report lists 160 significant quantities of HEU under comprehensive safeguards in non-nuclear weapon states as of the end of 2018. 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 Norway has reported under this scheme. At the end of 2018, it held less than 4 kg of HEU for civilian purposes.

[k] 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, Dec. 2015). China: Zhang, H., *China's Fissile Material Production and Stockpile* (IPFM: Princeton, NJ, Dec. 2017). France: International Atomic Energy Agency (IAEA), Communication Received from France Concerning its Policies Regarding the Management of Plutonium, INFCIRC/549/Add.5-21, 29 Sep. 2017; 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, Sep. 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.8-22, 23 Oct. 2019. USA: US Department of Energy (DOE), *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, 2001); Personal communication, US DOE, Office of Fissile Material Disposition, National Nuclear Security Administration; White House, Office of the Press Secretary, 'Fact sheet: Transparency in the US highly enriched uranium inventory', 31 Mar. 2016; US DOE, *FY 2019 Congressional Budget Request* (DOE: Washington, DC, Mar. 2018), p. 474; and US DOE, *Tritium and Enriched Uranium Management Plan through 2060*, Report to Congress (DOE: Washington, DC, Oct. 2015). Non-nuclear weapon states: IAEA, *IAEA Annual Report 2018* (IAEA: Vienna, 2018), Annex, Table A4, p. 129.

Table 10.12. Global stocks of separated plutonium, 2019

State	Military stocks (tonnes)	Military production status	Civilian stocks (tonnes)[a]
China	2.9 ± 0.6	Stopped in 1991	0.04[b]
France	6 ± 1.0	Stopped in 1992	67.7 (excludes foreign owned)
India[c]	0.6 ± 0.15	Continuing	6.9 ± 3.7 (includes 0.4 under safeguards)
Israel[d]	0.96 ± 0.13	Continuing	–
Japan	–	–	45.7 (includes 36.7 in France and UK)
Korea, North[e]	0.04	Continuing	–
Pakistan[f]	0.37 ± 0.1	Continuing	–
Russia[g]	128 ± 8 (40 not available for weapons)	Stopped in 2010	61.3
UK	3.2	Stopped in 1995	115.8 (excludes 23.1 foreign owned)[b]
USA[h]	79.7 (41.3 not available for weapons)	Stopped in 1988	8[i]
Other states[j]	–	–	1.9
Totals[k]	**~220 (81 not available for weapons)**		**~300**

– = nil or negligible figure.

[a] The data for France, Japan, Russia, the UK and the USA is for the end of 2018, reflecting their most recent INFCIRC/549 declaration. Some countries with civilian plutonium stocks do not submit an INFCIRC/549 declaration to the International Atomic Energy Agency (IAEA). Of these countries, Italy, the Netherlands, Spain and Sweden store their plutonium abroad.

[b] As of Mar. 2020, China had not submitted IAEA INFCIRC/549 declarations for the end of 2017, nor for the end of 2018. The number is based on the 2016 declaration.

[c] 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 IAEA INFCIRC/549 declaration.

[d] Israel is believed to still be operating the Dimona plutonium production reactor but may be using it primarily for tritium production. The estimate is for the end of 2018.

[e] North Korea reportedly declared a plutonium stock of 37 kg in June 2008. It resumed plutonium production in 2009 but has probably expended some material in the nuclear tests that were conducted since then. It is believed to have separated up to 8 kg of plutonium in 2016. An additional 10–14 kg of plutonium may be in irradiated fuel unloaded in Dec. 2018 and is not included here.

[f] As of the end of 2018, 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.

[g] The 40 tonnes of plutonium not available for weapons comprises 25 tonnes of weapon-origin plutonium stored at the Mayak Fissile Material Storage Facility and about 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 the US–Russian agreement on plutonium production reactors signed in 1997. Russia made a commitment to eliminate 34 tonnes of that material (including all 25 tonnes of plutonium stored at Mayak) as part of the US–Russian Plutonium Management and Disposition Agreement concluded in 2000.

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.

[h] In 2012 the USA declared a government-owned plutonium inventory of 95.4 tonnes as of 30 Sep. 2009. In its 2019 IAEA 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. 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 as declared excess to national security needs.

[i] The USA placed about 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.

[j] 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.

[k] 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, Dec. 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, Dec. 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, 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: Agreement Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation (Russian–US Plutonium Management and Disposition Agreement), signed 29 Aug. and 1 Sep. 2000, amended Apr. 2010, entered into force July 2011. USA: National Nuclear Security Administration (NNSA), *The United States Plutonium Balance, 1944–2009* (NNSA: Washington, DC, June 2012); and Gunter, A., 'US DOE, Office of Environmental Management, K-Area Overview/Update', 28 July 2015.

Table 10.13. Significant uranium enrichment facilities and capacity worldwide, 2019

State	Facility name or location	Type	Status	Enrichment process[a]	Capacity (thousands SWU/yr)[b]
Argentina[c]	Pilcaniyeu	Civilian	Uncertain	GD	20
Brazil	Resende Enrichment	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] SWU/yr = Separative work units per year, 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 resumption of production at 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 a Joint Comprehensive Plan of Action (JCPOA) that 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, '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* (International Panel on Fissile Materials, IPFM: Princeton, NJ, Dec. 2017); Hecker, S. S., Carlin, R. L. and Serbin, E. A., 'A comprehensive history of North Korea's nuclear program', Center for International Security and Cooperation, accessed Feb. 2019; 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, *Annual Report and Accounts 2018* (Urenco: Stoke Poges, 2018); and IPFM, *Global Fissile Material Report 2015: Nuclear Weapons and Fissile Material Stockpile and Production* (IPFM: Princeton, NJ, Dec. 2015).

Table 10.14. Significant reprocessing facilities worldwide, as of 2019

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 2021	800
Korea, North	Yongbyon	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	5
UK	BNFL B205 (Magnox fuel)	Civilian	To be shut down 2020	1 500
	BNFL Thorp, Sellafield	Civilian	Shut down in 2018	(was 1 200)
USA	H-canyon, Savannah River Site	Civilian	Operational	15

HWR = heavy water reactor.

[a] Design capacity refers to the highest amount of spent fuel the plant is designed to process and is measured in tonnes of heavy metal per year (tHM/yr), tHM being a measure of the amount of heavy metal—uranium in these cases—that is in the spent fuel. Actual throughput is often a small fraction of the design capacity. LWR spent fuel contains about 1% plutonium, and heavy water- and graphite-moderated reactor fuel about 0.4%.

[b] China is building a pilot reprocessing facility near Jinta in 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] A 250 tHM/yr Pilot Experimental Centre is under construction in Zheleznogorsk. A pilot reprocessing line with the capacity of 5 tHM/yr was launched in June 2018. A second pilot line is expected to be completed in 2020.

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], Rosatom, 29 May 2018 (in Russian). Data on design capacity is based on International Atomic Energy Agency (IAEA), 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, Dec. 2015).