FFI Norwegian Defence Research Establishment

21/01706

FFI-RAPPORT

Nuclear weapons

– worldwide situation 2021

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Norwegian Defence Research Establishment (FFI) 14 September 2021

Keywords
Kjernevåpen

FFI report
21/01706

Project number
1541

Electronic ISBN
978-82-464-3365-3

Approvers
Hanne Breivik, *Research Manager*
Janet Martha Blatny, *Research Director*

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Summary

This report is based on open sources and provides an overview of the current status and recent developments in the nuclear weapons arsenals of the world's nine nuclear-weapon possessing states. The brief sections on each state discusses stockpile sizes, key delivery vehicles, doctrinal and technological developments and other relevant indicators and aspects. This is followed by an analysis of select subjects and key trends.

All nuclear-weapon possessors invest significant amounts of money and prestige in their nuclear-weapon programmes. Some of the recent developments increase the flexibility of the state's nuclear posture, and some can be explained as attempts of retaining mutual vulnerability by overcoming current and future missile defence systems.

It is a concern that most, if not all, nuclear-weapon possessors appear to increase the emphasis they place on their nuclear weapons. There are ambitious modernisation programmes in the works, and some states are increasing their stockpiles of nuclear weapons.

It is also of concern that several states contribute to a blurring of the distinctions between nuclear and conventional delivery vehicles and command and control systems, thereby increasing the risk of miscalculation and inadvertent escalation.

Sammendrag

Rapporten gir en oversikt over dagens status og utviklingstrender for kjernevåpenarsenalene i de ni statene som har slike våpen. Rapporten omtaler kort hver enkelt stat med hensyn til antall våpen, leveringsmidler, doktriner, teknologiutvikling og andre relevante aspekter. Dette følges av en analyse av noen utvalgte temaer og trender. Rapporten er i sin helhet basert på åpne kilder.

Alle stater med kjernevåpen investerer mye penger og mye prestisje i kjernevåpenprogrammene sine. Noe av utviklingen i senere år tilskrives forsøk på å justere for mange års asymmetri mellom konvensjonelle og kjernefysiske våpen. Andre endringer antas å skulle gi et mer fleksibelt kjernevåpenarsenal, og noen bidrar til å opprettholde gjensidig sårbarhet ved å lage systemer som skal kunne omgå dagens og framtidige missilforsvarssystemer.

Det er bekymringsfullt at de fleste, kanskje alle, statene med kjernevåpen ser ut til å legge stadig større vekt på betydningen av disse våpnene. Ambisiøse moderniseringsprogrammer er iverksatt, og flere stater ser ut til å øke antall kjernevåpen i arsenalene sine.

Det er også bekymringsfullt at flere stater bidrar til å viske ut forskjellen mellom kjernefysiske og konvensjonelle våpensystemer og med det øker risikoen for feilvurderinger og utilsiktet eskalering av en konflikt.

Contents

1 Introduction

The goal of this report is not only to provide estimates of the nuclear weapons inventories in the states that possess such weapons, but also to look behind the numbers and attempt to understand why these very different states have chosen their particular nuclear postures. All numerical estimates in the report are based on open, unclassified sources such as the *Nuclear Notebook* series published in the *Bulletin of the Atomic Scientists* and reflected in the *SIPRI Yearbook*, or derived by the authors based on assessments of fissile materials production capacities, nuclear-weapon stockpiles and fissile material consumption per weapon.

The current chapter introduces some concepts and provides an overview of the states possessing nuclear weapons as well as their total number of weapons. Chapter 2 provides more details about each of the nuclear-weapon possessors both regarding their nuclear-weapon stockpiles and their security concerns, including what is known about their doctrines for possible use of their nuclear weapons. Chapter 3 contains more detailed discussions on six current nuclear-weapon issues, and the short Chapter 4 presents summaries and final remarks from the authors.

1.1 Terminology

The terminology and the definitions of many items and concepts in the field of nuclear weapons have changed over time and also varies from author to author. A *nuclear weapon* can be seen as one or more *nuclear warheads* mounted in a *delivery vehicle* such as a *missile* or a *bomb shell*, and it may be launched from a *platform* such as a *ship*, a *submarine*, an *aircraft* or a *silo*. Missile-based nuclear weapons may contain several nuclear warheads in separate *re-entry vehicles* mounted on a *bus*, cf. Figure 1.1. Tables and overviews in this and other publications generally present the number of warheads, not the number of weapons even though this distinction only applies to missiles.

The explosive power of these weapons comes as a result of nuclear physics processes. The term *nuclear weapon* is used for all such weapons from the smallest to the biggest. Basic nuclear physics describes two different ways of releasing energy from atomic nuclei: *fission* (splitting) of heavy nuclei and *fusion* (merging) of light nuclei. The early nuclear weapons were all *fission weapons* in which the fissile material, that is, *uranium* and/or *plutonium* of suitable quality and sufficient quantity, undergoes a very rapid fission *chain reaction*. There are two different types of fission weapons, known as *gun-type weapons* and *implosion weapons*. How they work – in principle – is well known and publicly available from many sources.

Weapons-quality fissile material originates from uranium ore which is mined in a number of countries. Uranium ore contains two kinds of uranium atoms (two *isotopes*), referred to as uranium-235 and uranium-238. Natural uranium contains about 0.7 percent uranium-235. For use in weapons, uranium must be *enriched* in large industrial facilities to around 90 percent uranium-235. The often-used terms *low enriched uranium (LEU)* and *high enriched uranium (HEU)* refer to uranium enriched to less than 20 percent or at least 20 percent uranium-235, respectively. Plutonium is produced as a by-product when uranium is used as fuel in a nuclear reactor.

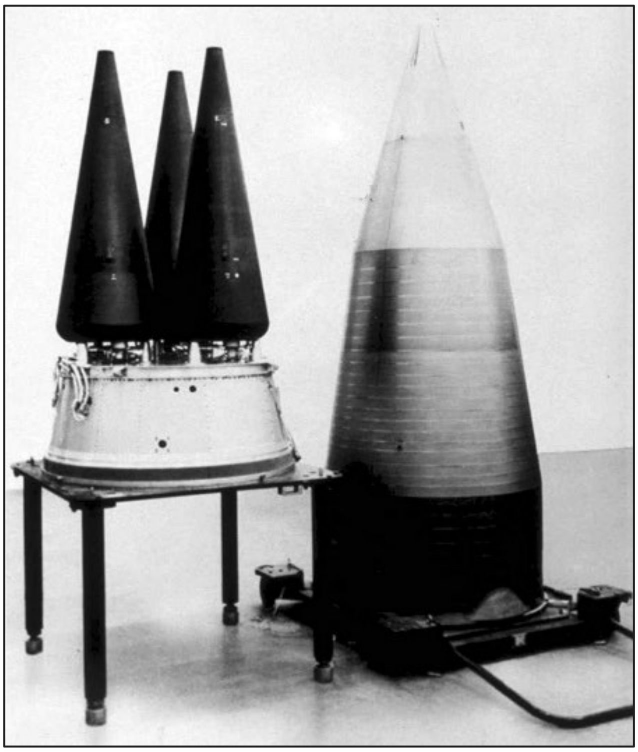

Figure 1.1 U.S. W78 warheads inside MK12A re-entry vehicles on an LGM-30 Minuteman III bus next to the front end of the missile. In 2020, the United States had 200 such missiles in service, not all necessarily equipped with three warheads [1]. (Photo from Wikimedia Commons, U.S. Government work, Public Domain.)

Fusion weapons are also known as *thermonuclear weapons*. Fusion processes require large amounts of energy to get started. In a fusion weapon, this energy is provided by first setting off a fission charge. Fusion weapons are therefore often referred to as *two-stage weapons*, each weapon containing two charges, a *primary* (fission) stage and a *secondary* (fusion) stage.[1] A *boosted* nuclear weapon is a fission weapon which is made more powerful by adding small amounts of fusion materials (hydrogen isotopes known as *deuterium* and *tritium*) to the fissile materials in order to increase the number of atomic nuclei actually undergoing fission. Nuclear physics limits the *yield* (the released energy) of a fission weapon (boosted or not), while in principle the yield of a fusion weapon is limited only by the available amount of fusion materials.

Any nuclear weapon is either a *strategic nuclear weapon* or a *non-strategic nuclear weapon*, but the dividing line between these categories is rather fuzzy. As the names imply, strategic weapons are intended to play a role in the bigger picture with deterrence and power balance, while non-strategic weapons may play a more operative role and are often referred to by a

[1] It is even possible to include additional fusion stages to further increase the total yield of the weapon.

number of other names such as *tactical nuclear weapons*, *sub-strategic nuclear weapons*, *battlefield nuclear weapons* or *theatre nuclear weapons*. Depending on their deployment, the same weapon systems could in many cases have either a strategic or a non-strategic function. Furthermore, for one state, strategic balance may be measured relative to its neighbour, while for another state, global balance may be the most important.

Most nuclear warheads are designed to be dropped from an aircraft as bombs or transported by a missile. Missiles generally fall into one of two groups: *ballistic missiles*, which after launch and a short boost phase until engine burn-out follow an aerodynamic trajectory determined by their velocity and inclination, air resistance and gravity; and *cruise missiles*, which have wings and operate more like aircraft throughout their flight (typically moving at much lower altitudes than ballistic missiles).

Many different types of ballistic missiles have been developed for different purposes. They have been designed to carry different loads over different ranges, and they use different propellants. They are often categorised according to range, for example as shown in Table 1.1. Some ballistic re-entry vehicles may be somewhat manoeuvrable as they approach their target.

Table 1.1 *Ballistic missiles categorised according to range. Different authors and various treaty texts may associate slightly different ranges to the same category. For example, the 1987 Intermediate-Range Nuclear Forces Treaty (INF Treaty)*[2] *defines an* intermediate-range missile *to have a range of 1000–5500 km and a* shorter-range missile *to have a range of 500–1000 km.*

<table>
<tr><th>Missile category</th><th>Acronym</th><th>Range</th></tr>
<tr><td>Close-range ballistic missile</td><td>CRBM</td><td>Less than 300 km</td></tr>
<tr><td>Short-range ballistic missile</td><td>SRBM</td><td>300–1000 km</td></tr>
<tr><td>Medium-range ballistic missile</td><td>MRBM</td><td>1000–3000 km</td></tr>
<tr><td>Intermediate-range ballistic missile</td><td>IRBM</td><td rowspan="2">3000–5500 km</td></tr>
<tr><td>Long-range ballistic missile</td><td>LRBM</td></tr>
<tr><td>Intercontinental ballistic missile</td><td>ICBM</td><td>Greater than 5500 km</td></tr>
</table>

1.2 The strategic picture and the perceived need for deterrence

Nuclear weapons were first developed in the United States during World War II, and the first nuclear test explosion in the world (named *Trinity*) was carried out in New Mexico on 16 July 1945. The United States then dropped a nuclear bomb on the Japanese cities of Hiroshima and Nagasaki on 6 August and 9 August 1945, respectively, thereby ending the war. [2]

[2] Formally known as the *Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles*; https://www.state.gov/t/isn/trty/18432.htm.

Nuclear weapons did not disappear with World War II, however. Further development took place in the United States, and many other states were also interested in studying and acquiring such powerful weapons. Could you stand up against other states if you did not have them? Would you be taken seriously? Even today, it is complicated and costly to produce uranium and plutonium for weapons use, and in the 1940s, the states also had to figure out for themselves how to do this. As it turned out, the great powers from World War II were to become the next nuclear-weapon states. The Soviet Union conducted its first test explosion in 1949, the United Kingdom in 1952 and France in 1960. China followed suit in 1964.

The main reason for acquiring nuclear weapons, in addition to the sheer projection of power, is presumably strategic, to deter other states from attacking. During the Cold War from the late 1940s to about 1990, the United States and the Soviet Union, which became known as *superpowers*, strived to keep up with each other to maintain their capability of *Mutually Assured Destruction* (also referred to as MAD). They manufactured very large numbers of nuclear weapons for all conceivable purposes, from large, strategic bombs and missiles releasing hundreds or even thousands of times the energy of the first nuclear bombs, to small bombs and artillery shells for battlefield use with a fraction of the destructive energy of those first bombs. The number of nuclear weapons in the United Kingdom and France has generally been on the order of about one percent of the number of weapons in the two superpowers. China, with the largest population in the world, probably saw nuclear weapons as a way to demonstrate and maintain its status as one of the most powerful states in the world. From there, it is easy to speculate that India saw a “need” for nuclear weapons to protect itself from attacks by China with which it has had numerous conflicts over the years, and similarly from Pakistan, with which it has also had many conflicts. And then, of course, Pakistan “needed” nuclear weapons to deter India.

In 2021, nine states are believed to possess nuclear weapons: the United States, Russia, the United Kingdom, France, China, Israel, India, Pakistan and North Korea. Furthermore, a number of other states have a well-developed nuclear-power related industrial infrastructure and would likely be able to develop their own nuclear weapons within a few years if they so desired.

1.3 The nuclear-weapon possessors and their arsenals

The total number of nuclear warheads in the world since 1945 is shown in Figure 1.2. Note that the number of warheads has decreased substantially since the end of the Cold War around 1990. Also, observe that the vast majority of the warheads have always belonged to the United States and the Soviet Union/Russia. When the Soviet Union collapsed in 1991, most of its nuclear weapons were located in Russia, but there were Soviet nuclear weapons also in Belarus, Kazakhstan and Ukraine. All Soviet nuclear weapons were eventually transferred to Russia.

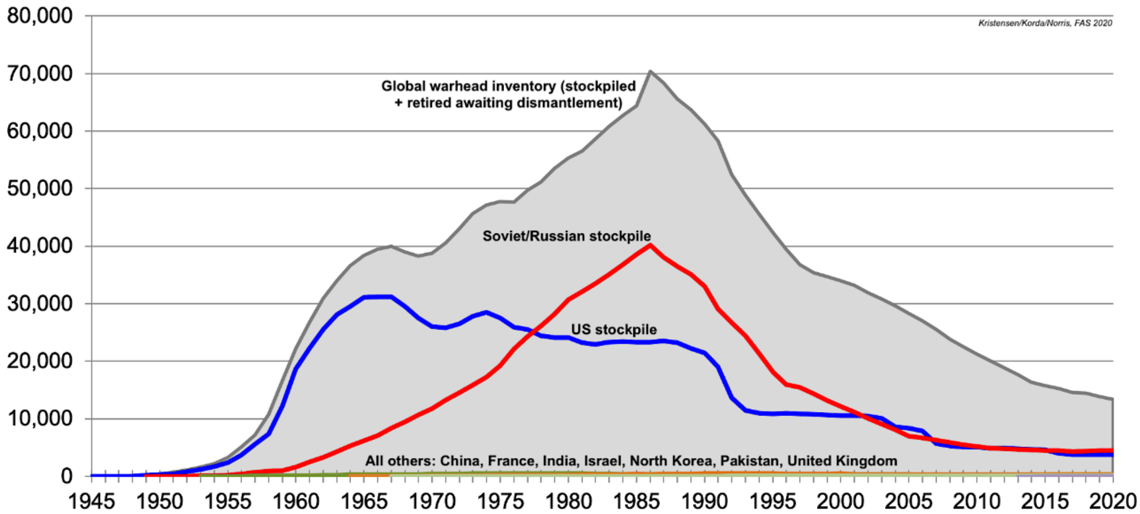

Figure 1.2 Estimated global nuclear warhead inventories 1945–2020. The illustration was made by the Federation of American Scientists [3].

Eight of the nine states mentioned above have publicly acknowledged possessing nuclear weapons and are known to have carried out nuclear test explosions. Israel, however, has so far maintained a policy of neither confirming nor denying possession of nuclear weapons. The stockpiles as of September 2020 are illustrated in Figure 1.3 and further specified in Table 1.2. The figures show that two states, Russia and the United States, are responsible for about 90 percent of all nuclear warheads in the world.

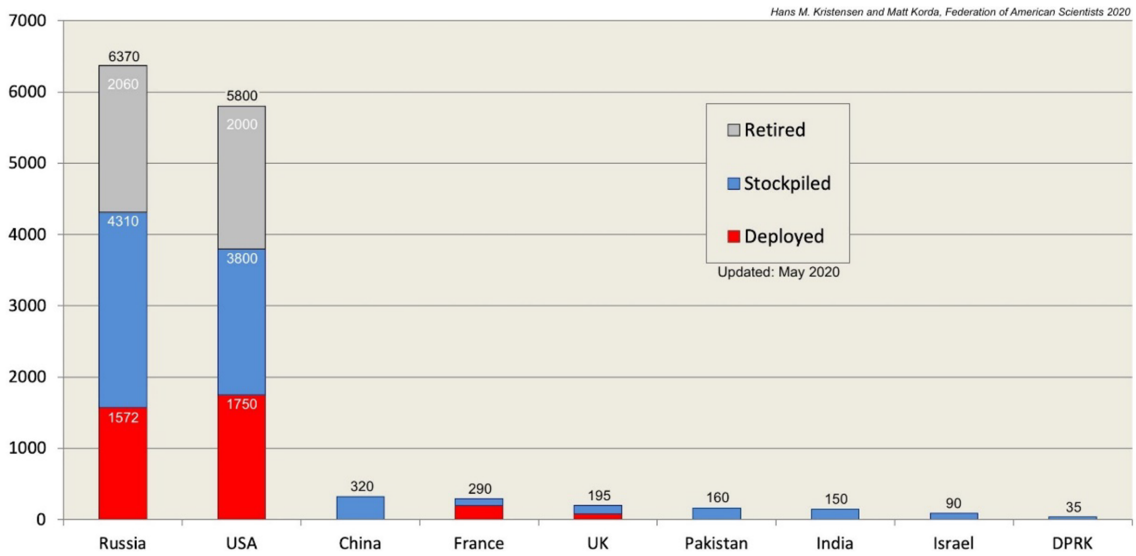

Figure 1.3 Estimated global nuclear warhead inventories as of September 2020 [3]. DPRK is short for the Democratic People's Republic of Korea, more commonly referred to as North Korea.

Table 1.2 Estimated global nuclear warhead inventory as of September 2020 [3]. "Military stockpile" is the sum of all deployed and non-deployed warheads in the custody of the military, while "Total inventory" also includes retired, but still intact, warheads awaiting dismantlement. Some of the numbers are well known, others are quite uncertain. For further details, see the original article [3].

Country	Deployed strategic	Deployed non-strategic	Reserve/ non-deployed	Military stockpile	Total inventory
Russia	1572	0	2740	4312	6372
United States	1600	150	2050	3800	5800
France	280	—	10	290	290
China	0	?	320	320	320
United Kingdom	120	—	75	195	195
Israel	—	—	90	90	90
Pakistan	—	—	160	160	160
India	—	—	150	150	150
North Korea	—	—	35	35	35
Total	**3720**	**150**	**5630**	**9320**	**13410**

In 1970, the *Treaty on the Non-Proliferation of Nuclear Weapons* (commonly referred to as the Non-Proliferation Treaty or the NPT) entered into force. This treaty recognises those states that carried out nuclear tests before the end of 1966 as *nuclear-weapon states* and requires all other states joining the treaty do so as *non-nuclear-weapon states*. In short, the nuclear-weapon states get to keep nuclear weapons against a promise of eventual disarmament, while the non-nuclear-weapon states must refrain from nuclear weapons against a promise of international assistance with peaceful uses of nuclear technology. Most states in the world are members of the NPT with the notable exceptions of India, Israel, North Korea and Pakistan. Five states are recognised as nuclear-weapon states: the United States, Russia, the United Kingdom, France and China. They happen to be the same as the five permanent members of the United Nations Security Council, generally referred to as the P5. India, Israel, North Korea and Pakistan are often called *de facto nuclear-weapon states*, while the term *nuclear-weapon possessors* (or N9) may be used to include all nine nuclear-weapon-armed states.

2 The nuclear-weapon stockpiles

2.1 The United States

After the end of World War II, the United States continued its development of nuclear weapons, and the next two nuclear test explosions took place already in June 1946 at the Bikini Atoll in what is now the Republic of the Marshall Islands [2]. Figure 1.2 shows that the stockpile of U.S. nuclear weapons peaked as early as in the mid to late 1960s. It reached more than 31 000 warheads in 1965 to 1967 [4].

The United States has long had a full triad of nuclear weapons, that is, its nuclear weapons may be launched from either the ground (missile launchers), the sea (submarines) or the air (aircraft).

An overview of the different categories of U.S. nuclear weapons is provided in Table 2.1. In 2020, the total estimated stockpile for military use was 3800 warheads. An estimated 1750 warheads were deployed while the remaining estimated 2050 warheads were in reserve. In addition, the United States had an estimated 2000 retired warheads awaiting dismantlement. The U.S. stockpile of nuclear weapons is matched in numbers only by Russia. [1]

Table 2.1 Estimated number of U.S. nuclear warheads in 2020. [1]

Type	Warheads	Total
Intercontinental ballistic missiles (ICBMs)	800	
Submarine-launched ballistic missiles (SLBMs)	1920	
Bombers	850	
Subtotal strategic weapons		***3570***
Fighter-plane delivered	230	
Subtotal non-strategic weapons		***230***
Total estimated stockpile		**3800**
Retired warheads awaiting dismantlement		***2000***
Total estimated inventory		**5800**

Significant changes to the nuclear-weapon stockpile, as well as the doctrines for possible use of it, take place slowly over the years as the nation's leadership changes. This is summarised in the *Nuclear Posture Review* typically issued by every new administration. The administration of former President Donald J. Trump presented its Nuclear Posture Review in 2018. It was more confrontational than that of the previous Obama administration, which already set out to modernise the entire nuclear weapons arsenal. The new review recommended to increase the types and role of U.S. nuclear weapons. These weapons should deter and prevail against both nuclear attacks and "non-nuclear strategic attacks." As a consequence, new low-yield weapons will be required. Some of these long-term plans and goals may again be modified by the current administration of President Joseph R. Biden, Jr. [1]

The United States has had, and to a lesser extent still has, a large number of different types and models of nuclear weapons. In the beginning, they were all aircraft-delivered gravity bombs. Later came a wide range of nuclear weapons spanning from artillery shells to intercontinental ballistic missiles launched from the ground and the sea. The composition of the nuclear weapons arsenal at any given time reflects the strategic and operational thinking at that time. For the United States, which has been the largest military power throughout the entire nuclear weapons era so far, this led to a race with the Soviet Union during the Cold War to be able to meet any perceived nuclear weapons threat with a nuclear counter-threat, both strategically and on the battlefield.

Today, the vast majority of U.S. nuclear weapons are strategic. Its triad of weapons constitutes an overwhelming deterrence including both first-strike and counter-strike capabilities. Land-based missiles are vulnerable during an attack and are therefore in general first-strike weapons. Aircraft are vulnerable on the ground, but somewhat less in the air and could be used for both purposes, while submarines hiding in the oceans ensure counter-strike capabilities (cf. Figure 2.1 showing a Trident II D5 missile launched from a strategic submarine).

Figure 2.1   Test launch of a Trident II intercontinental ballistic missile from the Ohio class strategic submarine USS West Virginia. All U.S. SLBMs are of this type. (Photo from Wikimedia Commons, U.S. Navy work, Public Domain.)

2.2 Russia

The Soviet Union carried out its first nuclear test at the Semipalatinsk test site in what is now Kazakhstan 29 August 1949 and thereby became the second nuclear-weapon state four years after the United States [2]. After the collapse of the Soviet Union in 1991, all Soviet nuclear weapons were eventually transferred to the Russian Federation which inherited all treaty-bound nuclear-weapon rights and obligations that were originally acquired by the Soviet Union. Belarus, Kazakhstan and Ukraine, which had a large number of nuclear weapons on their territories for a while, subsequently joined the NPT as non-nuclear-weapon states.

The Soviet Union/Russia has over the years kept a stockpile of nuclear weapons comparable in size to that of the United States. As is evident from Figure 1.3, no other nuclear-weapon possessors today come close to matching the capabilities of these two states. The Soviet stockpile peaked at a little above 40 000 warheads in 1986 [4].

Russia has a full nuclear triad, that is, it has nuclear weapons that may be launched from the ground, the sea and the air. Most of its strategic weapons are deployed, while all its non-strategic weapons are claimed to be in central storage [5], a claim that cannot be easily verified. An estimate of the different types of nuclear weapons in Russia is provided in Table 2.2. The total estimated stockpile for military use is 4310 warheads. An estimated 1570 warheads are deployed while the remaining 2740 warheads are in reserve. In addition, Russia has an estimated 2060 retired warheads awaiting dismantlement. [6]

Table 2.2 Estimated number of Russian nuclear warheads in 2020. As the figures are estimates only, sums are rounded. [6]

Type	Warheads	Total
Intercontinental ballistic missiles (ICBMs)	1136	
Submarine-launched ballistic missiles (SLBMs)	720	
Bombers	580	
Subtotal strategic weapons		***2440***
Antiballistic missiles / Air and coastal defence	382	
Land-based air	500	
Ground-based	90	
Naval	900	
Subtotal non-strategic weapons		***1870***
Total estimated stockpile		**4310**
Retired warheads awaiting dismantlement		***2060***
Total estimated inventory		**6370**

The official Russian document *Basic Principles of State Policy of the Russian Federation on Nuclear Deterrence*, which was published in 2020 [7], declares that the purpose of Russia's nuclear weapons is to deter other states from attacking. The published military doctrine from 2014 states the following about possible use of nuclear weapons [8]:

> *The Russian Federation shall reserve the right to use nuclear weapons in response to the use of nuclear and other types of weapons of mass destruction against it and/or its allies, as well as in the event of aggression against the Russian Federation with the use of conventional weapons when the very existence of the state is in jeopardy.*
>
> *The decision to use nuclear weapons shall be taken by the President of the Russian Federation.*

Russia's current stockpile of strategic nuclear weapons has a lot in common with the U.S. stockpile, to a large degree as a result of various arms control and disarmament treaties over the years. The only treaty in force in 2021 is New START from 2011 which sets a maximum limit for the total number of deployed, strategic missiles and heavy bombers, the number of nuclear warheads on these platforms and the total number of deployed and non-deployed, strategic missiles and heavy bombers. An example of a strategic, ground-launched missile is shown in Figure 2.2. As of March 2021 (the most recently published data [9]), both states had been consistently meeting the goals of New START, which expires in 2026.

Figure 2.2 A so-called transporter-erector-launcher (TEL) for a Russian intercontinental ballistic missile photographed in a Moscow street in 2008. The launcher may or may not contain its designated missile, referred to as Topol in Russia and SS-25 Sickle in NATO. It carries only one nuclear warhead, weighs about 45 metric tons at launch, is 20.5 m long and has a range of 11 000 km [10]. (Photo from Wikimedia Commons, CC BY-SA 3.0.)

The Soviet Union/Russia has over the years had access to a large number of non-strategic weapons of many kinds, such as various missiles, torpedoes, mines and more. Table 2.2 shows that the current estimates still include a large number of such weapons, but the actual status is much less transparent than it is for strategic weapons. Non-strategic nuclear weapons are not covered by any current arms control treaties. Indeed, one may argue that the best definition of Russian and U.S. non-strategic nuclear weapons are those weapons that are *not* covered by strategic arms control treaties.

Since 2008, Russia has allocated large resources into an ambitious modernisation of its military forces. Within this programme, modernisation of the nuclear forces is a priority. Many new missiles have been deployed, replacing old, Soviet-era nuclear weapons. More worrisome is the effort to manufacture new types of nuclear weapons as presented by President Vladimir V. Putin in his annual speech in March 2018. A common feature of these weapons is their increased ability to circumvent any missile defence systems. More details about this can be found in Section 3.1 and also, for example, in *Nuclear Notebook* [6] or in an earlier FFI Report [10] (in Norwegian).

2.3 The United Kingdom

The United Kingdom became the third country to test a nuclear device when it conducted the *Hurricane* test at the Monte Bello Islands in Western Australia 3 October 1952 [2]. Since then, the United Kingdom has been a nuclear-weapon possessor, but with a much smaller nuclear-weapons stockpile than the Soviet Union/Russia and the United States.

The British stockpile peaked at 500 nuclear warheads between 1973 and 1981 [4], and in 2020 it consisted of 195 warheads, cf. Table 1.2. Currently, all British nuclear weapons are U.S. Trident II D5 submarine-launched ballistic missiles with thermonuclear warheads designed and manufactured in the United Kingdom. The United Kingdom is the only recognised nuclear-weapon state which has reduced its nuclear deterrent capability to a single weapon system. At any given time, no more than 120 warheads are deployed. The remaining warheads (at least 75) are in reserve. For completeness, the British nuclear stockpile is detailed in Table 2.3. [11]

Table 2.3 Estimated number of British nuclear warheads in 2020, cf. Table 1.2.

Type	Warheads	Total
Intercontinental ballistic missiles (ICBMs)	0	
Submarine-launched ballistic missiles (SLBMs)	195	
Bombers	0	
Subtotal strategic weapons		***195***
Subtotal non-strategic weapons		***0***
Total estimated stockpile		**195**
Retired warheads awaiting dismantlement		***0***
Total estimated inventory		**195**

Note that the United Kingdom has retained only one leg of the triad, relying on its nuclear submarines for deterrence and counter-strike capability. Under what is known as *Operation Relentless*, the United Kingdom has since 1969 kept at least one of its four strategic nuclear submarines on patrol at any time (cf. Figure 2.3). This is known as "continuous at sea deterrence." The operational alert status is such that a submarine on patrol will need several days' notice to fire any of its nuclear weapons. Under ordinary circumstances, the missiles are not targeted at any particular state. [11]

Figure 2.3 The British strategic, nuclear-propelled submarine HMS Vengeance. The United Kingdom has four such submarines, each capable of carrying up to 16 Trident II D5 missiles, each with up to five nuclear warheads. The British government has limited the total number of warheads on a given submarine to 40. [12] (Photo from Wikimedia Commons, courtesy of the Royal Navy, OGL v1.0.)

Only the prime minister can authorise the launch of British nuclear weapons. As far as potential use of these weapons is concerned, official policy is that the state "will not use, or threaten to use, nuclear weapons against any Non-Nuclear Weapons State party to the Treaty on the Non-Proliferation of Nuclear Weapons," but the "assurance does not apply to any state in material breach of those non-proliferation obligations." Furthermore, the United Kingdom upholds about its nuclear weapons that "we will remain deliberately ambiguous about precisely when, how and at what scale we would contemplate their use, in order not to simplify the calculations of any potential aggressor." Its nuclear force structure, however, is ideal for ensured retaliation (not ruling out other uses). [11;13]

In March 2021, the British government published a review of its *Security, Defence, Development and Foreign Policy* in which it announced substantial changes to its nuclear posture [14]. Most dramatically, its long-established goal of disarming to 180 warheads by

2025 was changed to limiting the overall nuclear-weapon stockpile to "no more than 260 warheads," in other words, changing from disarming to re-arming. The policy of "deliberate ambiguity" is expanded to include that the United Kingdom will "no longer give public figures for our operational stockpile, deployed warhead or deployed missile numbers." The document contains further changes to established nuclear-weapon policy as well.

2.4 France

France was the next state to carry out a nuclear test explosion, more than seven years after the United Kingdom. The first French test, named *Gerboise Bleue* ("blue jerboa"), took place in Reggane in Algeria on 13 February 1960 [2].

Over the years, the size of the French nuclear-weapon stockpile has been similar to the size of the British stockpile. It peaked later, however, at 540 warheads in 1991 and 1992 [4]. In 2020, the stockpile was estimated to 290 operationally available warheads plus a few more in maintenance or kept in reserve. The French president Emmanuel Macron confirmed in February 2020 that the total stockpile was "currently under 300 nuclear weapons" [15;16].

Table 2.4 Estimated number of French nuclear warheads in 2020 [15;16]. France does not distinguish between strategic and non-strategic nuclear weapons.

Type	Warheads	Total
Intercontinental ballistic missiles (ICBMs)	0	
Submarine-launched ballistic missiles (SLBMs)	240	
Bombers	50	
Total estimated stockpile		**290**
Retired warheads awaiting dismantlement		***0***
Total estimated inventory		**290**

The French nuclear doctrine appear to have some major features in common with the British doctrine. Only the president of France can authorise the firing of French nuclear weapons, and, like the United Kingdom, France does not have a no-first-use policy. In particular, France stresses the possible need to issue a "final warning" to an attacking state by responding with a limited nuclear retaliatory strike (such as, for example, a high-altitude detonation generating an electromagnetic pulse) in order to demonstrate that any further aggression will have terrible consequences. France is a member of NATO, but unlike the United Kingdom, its nuclear forces are not part of NATO's integrated military command structure. [15;17]

Like the United States, France has been very transparent about the size and composition of its nuclear forces. Being capable of launching nuclear weapons from submarines and aircraft, France has two legs of the triad. Its bombers are either land-based (*Rafale B*) or carrier-based

(*Rafale M*), cf. Figure 2.4. Just like the United Kingdom, France has four strategic nuclear submarines, at least one of which is always on patrol. France has maintained a "continuous at sea deterrence" since 1972 [15]. Since 1996, all French nuclear weapons have been considered "strategic" based on the logic that any use of nuclear weapons would indicate a change in the nature of the conflict [17].

Figure 2.4 The French Air Force bomber Rafale B photographed in 2009. France has 40 of these land-based aircraft in addition to ten similar Rafale M based on its aircraft carrier Charles de Gaulle [15]. *(Photo from Wikimedia Commons, courtesy of Tim Felce, CC BY-SA 2.0.)*

2.5 China

China has been a nuclear-weapon state since it conducted its first nuclear test explosion 16 October 1964 at the Lop Nur test site in the Xinjiang province [2]. China has so far refrained from building up a very large arsenal of nuclear weapons and has instead relied on a policy of quantitative and geographic ambiguity, keeping all information about the number of weapons and their location strictly secret. China today appears to have a relatively small, technically advanced stockpile of about 320 nuclear weapons, cf. Table 2.5. This is the largest Chinese stockpile ever.

Very little information about the Chinese nuclear programme has been made available to the public. China has always maintained that it follows a policy of minimal credible deterrence, and that it will adhere to a strict no-first-use policy under all circumstances.

Assumptions about Chinese nuclear weapons are to a large extent based on estimates of the production of nuclear materials, which in themselves are uncertain. More is known about the delivery vehicles, however, since information about them can be gathered from knowledge of missile forces and test launches.

Table 2.5 Estimated number of Chinese warheads in 2020 [18]. There are large uncertainties in these numbers, mainly due to secrecy and production of new warheads.

Type	Warheads	Total
Intercontinental ballistic missiles (ICBMs)	150–200	
Shorter-range land-based ballistic missiles	60	
Submarine-launched ballistic missiles (SLBMs)	48–72	
Bombers	20	
Total estimated stockpile		**~ 320**
Retired warheads awaiting dismantlement		***0***
Total estimated inventory		**~ 320**

China possesses several types of nuclear-capable missiles, including intercontinental ballistic missiles, submarine-launched ballistic missiles and possibly cruise missiles, and it is currently believed to be in the process of developing multiple, independently targetable re-entry vehicles (MIRV). According to SIPRI [16], China has modified an older missile, DF-5A,[3] to carry up to five MIRVed warheads, and a newer missile that is still not ready for deployment, DF-41, will also have MIRV capability.

Another interesting missile is the DF-26, which is shown in Figure 2.5. An open U.S. intelligence report from 2020 [19] describes the DF-26 missile in this way: *Official Chinese media commentary has described the DF-26 IRBM[4] as "one carrier, many warheads." Chinese media has stated that the DF-26 can carry a conventional or nuclear payload and that it can launch conventional and long-range precision strikes against important targets on land and large ships at sea*. The DF-26 has an estimated range of 4000 km, not enough to classify it as an intercontinental missile (cf. Section 0), but enough to reach the eastern parts of Europe and parts of Alaska.

DF-31 and DF-31A are recognized as the most advanced, fully operational, nuclear-capable Chinese missiles. They are both solid-fuel, intercontinental ballistic missiles, with ranges of at least 7200 km and 11 200 km, respectively. The new DF-41 missile is expected to have a range of 12 000 km and become operational in 2021. [18]

[3] DF is short for Dong Feng or "East Wind."
[4] IRBM is an acronym for Intermediate-Range Ballistic Missile, cf. Table 1.1.

Figure 2.5 The TEL for the DF-26 intermediate-range ballistic missile as seen after the 2015 military parade in Beijing to commemorate the 70th anniversary of the end of WWII. This was the first public display of the DF-26 [20]. China may have up to about 100 operational DF-26 launchers, most of them presumably having a non-nuclear mission [18]. (Photo from Wikimedia Commons, CC BY-SA 4.0.)

In June 2021, the *Washington Post* first reported that commercial satellite images indicated a large number of missiles launch silos being under construction in remote areas of China [21]. It is assumed that these silos are primarily meant for the new DF-41 missile. The satellite images seem to be showing at least 100 silos at each of two different locations, Yumen in Gansu province and Hami in Xinjiang province [22]. The large number of silos does not necessarily mean that China will be building the same number of missiles. As assessments of Chinese stocks of fissile materials generally limit the number of nuclear warheads to around 400 or less, and as the DF-41 is designed to have a MIRV capability, it seems likely that some of the silos will be kept empty. There is simply not enough weapons-grade uranium and plutonium to deploy nuclear armed DF-41s (MIRVed or not) in all these silos in the foreseeable future. It seems more reasonable that China will deploy missiles in only some of the silos, and possibly move these missiles between silos from time to time. This will still leave a potential adversary with a very large counter-force target list without Beijing having to produce a corresponding number of costly ICBMs and warheads. China's existing stockpiles and production capacity of fissile materials remain the bottleneck for a vast expansion of China's nuclear forces.

Previous to this recent development, China had just a few launch silos and relied instead mainly on portable missile launchers hidden in mountain tunnels. The new silo development combined with the new missiles suggest that the Chinese nuclear strategy may be changing from keeping both the size and the position of the nuclear arsenal hidden to focusing on strength and numbers.

2.6 India

India conducted its first nuclear test, often referred to as "Smiling Buddha," 18 May 1974 at its Pohkran test site in Rajasthan [2]. The Indian government at the time claimed this was a test of a device for "Peaceful Nuclear Explosions." Later on, five nuclear devices were exploded in May 1998.

It is generally assumed that India has enough plutonium for 150–200 nuclear warheads [23]. This is based on the estimated production in two research reactors, CIRUS and Dhruva, which are the only reactors that are known to have produced plutonium for military purposes in India. The number of warheads is likely to be lower, however. Table 1.2 reports a current estimate of about 150 nuclear warheads. Further details are provided in Table 2.6. In a report from 2004 [24], FFI estimated the Indian accumulated stockpile of weapons-grade plutonium to be between 360 kg and 680 kg, with a continued production of between 23 kg and 36 kg a year. One of the two reactors known to produce plutonium for the weapons programme in India, CIRUS, has since been closed down, but the larger one, Dhruva, is continuing its operations. The above estimate is consistent with other independent estimates, for instance from the International Panel on Fissile Materials (IPFM), which estimated that India had a stockpile of 600±150 kg of weapons-grade plutonium in 2020 [25].

The official nuclear doctrine from 2003 states that India will not be the first to use nuclear weapons in a conflict. Even though there has been some ambiguity regarding a possible response to attacks with other weapons of mass destruction, this official policy still stands [26;27].

Table 2.6 Estimated number of Indian nuclear warheads in 2020 [23]. India has no missiles of intercontinental range. The numbers are uncertain, particularly because warheads are under production for new Agni missiles and new submarines.

Type	Warheads	Total
Land-based ballistic missiles	70+	
Ship and submarine-launched ballistic missiles	16+	
Fighter-plane delivered	48	
Total estimated stockpile		**~ 150**
Retired warheads awaiting dismantlement		***0***
Total estimated inventory		**~ 150**

India has a domestic missile development programme and is developing more advanced ballistic missiles. The newest, Agni IV and Agni V, are expected to a have a range of 3500 km and 5000 km respectively. Both missiles have been tested extensively, but neither of them appear to be operational yet. The missiles Agni II (2000 km) and Agni III (3200 km, cf. Figure 2.6) are the only operational Indian missiles that can be classified as medium and intermediate range, respectively. An American unclassified intelligence report from 2020 [28] states that India has less than ten of each of these missiles in service. The rest of India's nuclear warheads are on short-range missiles or in the form of air-drop bombs.

Figure 2.6 An Agni III IRBM paraded in New Delhi in 2008. (Photo from Wikimedia Commons, courtesy of the Ministry of Defence, Government of India, OGDL.)

India has one type of submarine-launched missile that might be nuclear capable, known as *Sagarika* or K-15. This missile has been covered in secrecy, but the latest news reports [29] indicate that it is indeed a nuclear-capable submarine-launched ballistic missile. The missile, which can also be fitted with conventional warheads, is deployed on India's *Arihant* class nuclear powered submarines, and has a range of 700 km [23].

The new Indian missiles include, *inter alia*, land-mobile, intercontinental ballistic missiles and submarine-launched ballistic missiles with sufficient ranges to reach deep into China. India has recently also acquired modern, French *Rafale* fighter planes, which may be adapted to carry nuclear weapons. Additionally, the state is building up to six nuclear-propelled, strategic submarines of the Arihant class, the first of which (and the only one so far) was commissioned in 2018 [30]. The submarine-launched ballistic missiles will bolster the credibility of India's second-strike capability once they enter into service. That harmonises with the official no-first-use doctrine. Still, the realities of this doctrine are sometimes debated, not least on the grounds that India faces a conventionally superior adversary (China) [23].

2.7 Pakistan

Pakistan carried out its first nuclear test 28 May 1998 at its Chagai test site in Baluchistan [2]. This followed the Indian test explosions earlier in the same month. In total, Pakistan exploded six nuclear devices in May 1998, making its total number of tested devices the same as India's.

Pakistan has a small nuclear weapons arsenal, with an estimated 160 warheads distributed between airplane-delivered bombs, ballistic missiles and cruise missiles (cf. Table 1.2 and Table 2.7). The stockpile has been steadily increasing and is comparable in size with India's nuclear arsenal.

Table 2.7 Estimated number of Pakistani nuclear warheads in 2020 [31]. Note that the estimates in the "Warhead" column are from 2018 while the total is an updated estimate from 2020.

Type	Warheads	Total
Land-based ballistic missiles	~ 102	
Fighter-plane delivered	~ 36	
Ground and air-launched cruise missiles	~ 12	
Total estimated stockpile		**~ 160**
Retired warheads awaiting dismantlement		***0***
Total estimated inventory		**~ 160**

Pakistan still produces both enriched uranium and plutonium, and there are indications that the production facilities are being expanded. There are two known enrichment plants, the Kahuta enrichment plant east of Islamabad and the Gadwell enrichment plant north of Islamabad [31], and construction work at the Kahuta plant suggests that a whole new enrichment plant is being constructed there. Pakistan has four heavy-water plutonium producing reactors located in the Khushab complex, three of which have been constructed after 2008, and it appears to have two reprocessing plants, New Labs Reprocessing plant in Nilore east of Islamabad and an additional new plant located in Chashma in the Punjab province [31;32].

Pakistan has no intercontinental missiles and no submarine-launched missiles. Its strike power is therefore limited in comparison to that of the major nuclear powers, but not relative to its neighbouring nuclear-weapon possessing rival, India. Furthermore, Pakistan has developed sophisticated weapon systems such as the nuclear cruise missiles shown in Figure 2.7, something India does not have.

U.S. intelligence services and others have expressed concern that Pakistan's fielding of tactical nuclear delivery systems will lower the threshold for nuclear escalation in a potential conflict with India [33]. It is common to assess the Pakistani development of nuclear-capable air-launched and sea-launched cruise missiles, as well as the very precise, short-range ballistic missile *Nasr* (Hatf-9), as an effort to off-set India's conventional superiority [34]. Moreover, some claim that India's so-called *cold start doctrine*, in which the state aims to respond militarily to a Pakistani provocation within 48 hours, has been an important driver and motivation for the development of tactical nuclear weapons in Pakistan [35].

Figure 2.7 The launcher for the Pakistani Babur *(Hatf-7) ground-launched nuclear cruise missile photographed in 2008. The launcher carries four missiles with wings unfolding after launch as shown on the sketch in front of the vehicle. (Photo from Wikimedia Commons, CC BY-SA 3.0.)*

2.8 North Korea

North Korea conducted its first nuclear test 9 October 2006. The yield was very low, suggesting that the test was not completely successful. [36]

North Korea has produced weapons-grade plutonium since the late 1980s, but almost exclusively from one production reactor in its main nuclear centre in Yongbyon. Pyongyang's long-suspected uranium enrichment programme was first properly revealed to a group of U.S. visitors in late 2010. Most analysts doubt the Yongbyon-based facility is the only one in the country. Indeed, media and independent analysts have identified a couple of sites suspected of housing covert enrichment plants in North Korea during the last twenty-or-so years. The latest such site is in Kangson [37]. None of these sites have been independently confirmed to be enrichment related, but the one in Kangson has so far not been dismissed either.

Pyongyang has never declared the size of its nuclear-weapon stockpile, but assessments of available stocks of fissile materials help narrow down independent estimates of the possible number of weapons. Estimates of North Korea's available stocks of weapons-usable fissile materials depend in particular on the following:

- Total production minus process losses
    - Reasonable estimates for plutonium, but huge uncertainties for uranium

- Consumption in each tested weapon
    - Probably only plutonium in the first two or three tests, but potentially several tens of kilograms of uranium in the only likely thermonuclear test to date

- Distribution of produced weapon types
    - That is, the number of pure fission, boosted fission and thermonuclear devices, and whether plutonium and/or uranium is used

In 2013, FFI estimated the available stock of plutonium in North Korea to be 51–71 kg before subtracting the amounts consumed in the weapons tests [38]. In 2015, Institute for Science and International Security estimated that 30–34 kg of plutonium was available when accounting for the consumption from the first two tests (estimated as 6–8 kg in total) [39]. Pyongyang, on the other hand, declared a total plutonium separation of 31 kg in the context of the last round of Six-Party Talks in 2008 (the first round of which took place in 2003) [40]. There has not been any conclusive evidence that more plutonium has been separated in Yongbyon since the reprocessing campaign following the breakdown of the Six-Party Talks in 2009, but some geospatial imagery indicated that such a campaign took place in 2016 and possibly in 2018 [41-43]. That could potentially add another 5–12 kg of plutonium, estimated on the basis of past operations and the intermittent, low-power nature of the later years' reactor operations.

While Pyongyang has never declared any nuclear-weapon production numbers, they did claim to use only 2 kg of plutonium in the first underground nuclear test in 2006 [44]. It is reasonable to assume that North Korea, as other nuclear-weapon possessors, prefer using plutonium in any thermonuclear primaries (presumably boosted such). That is because a uranium-based primary would be larger and heavier than one based on plutonium. Keeping in mind the varying yields and official descriptions of Pyongyang's six underground nuclear tests by early 2021, we assume the range of 2–5 kg of plutonium per such test. One or more of the tests may have been with a pure or boosted uranium device, but the lack of evidence of this makes us keep the lower average amount of 2 kg of plutonium per test. This leads to an estimated plutonium consumption of 12–30 kg from the six underground tests, corresponding to a residual stock of approximately 20–70 kg available for weapons (based on the 2013 estimate and taking the possible, but unconfirmed later years' addition of plutonium into account only in the upper boundary). Maintaining the estimate of 2–5 kg of plutonium per weapon, including pure fission, boosted fission, and thermonuclear devices, we arrive at possibly 4–35 nuclear weapons containing plutonium.

North Korea possesses ample uranium ore deposits, mines, and mills to sustain a substantial nuclear-weapon programme, both in terms of producing natural uranium fuel for plutonium producing reactors, and in terms of producing high enriched uranium (HEU) for weapons. Kurbanbekov *et al.* estimated in 2019 that Pyongyang's uranium ore reserve probably exceeded 4 million tons [45]. That is sufficient for several hundred pure HEU weapons or HEU secondaries in thermonuclear warheads, depending on usage per weapon and enrichment strategy (in particular process losses and uranium-235 concentration in the tails). Thus, uranium ore is not likely a constraint on Pyongyang's nuclear arms build-up for the foreseeable future.

As pointed out in our 2013 report and elsewhere, North Korean officials stated in 2010 that the Yongbyon enrichment plant had a capacity of 8000 SWU[5] per year. Furthermore, Albright [39] notes a doubling of the floor space of the facility from 2013, possibly doubling the plant's capacity already by late 2014. Having in mind reports of some start-up problems, we assess that in the period of late 2010 through late 2014, the plant had no more than 8000 SWU of annual enrichment capacity, while in the period from late 2014 until the time of this writing (March 2021), it possibly had an annual capacity of as much as 16 000 SWU. This adds up to not more than 130 000 SWU of total enrichment effort. This is sufficient to produce about 650 kg of weapons-grade (90 percent enriched) uranium in an ideal cascade configuration and with a typical tails assay of 0.3 percent uranium-235. Assuming this is the only facility producing weapons-grade uranium in North Korea, Pyongyang may have produced as many as 32 to 43 uranium-based fission or boosted fission warheads by the winter of 2021, assuming 15 kg to 20 kg of uranium per warhead, and that no uranium has been consumed by other applications (such as for instance prototype fuel for the experimental light water reactor in Yongbyon). Furthermore, a handful of thermonuclear warheads, including the probably thermonuclear test in September 2017, may have consumed a few tens of kilograms of HEU as well, which may add weight to the lower figures of the estimate of warhead numbers. With the uncertainty of the fission vs. thermonuclear weapons distribution, and the possibility that one or two of the other nuclear tests were uranium-based (except for the first test in 2006, which was confirmed to be a plutonium device [46]), one arrives at a rough estimate of 30 to 40 possible uranium-based nuclear warheads.

Any additional enrichment plants may add unknown amounts of weapons-grade uranium and increase warhead numbers in unquantifiable ways. Leaving such unknown, but not unlikely, facilities aside, we assess that the lower segments of our estimates are more likely than the upper ones, as one can more readily estimate maximum and nominal capacities than a realistic operational history with all the snags and losses that typically occur. Combining the plutonium and uranium oriented estimates, then, North Korea may possess as many as 35 to 75 nuclear warheads. A presumption here is that Pyongyang's nuclear weapon engineers continuously weaponise all available fissile material, which is not obvious. Again, the lower part of the estimate is the more likely. Note that the lower figure coincides with the conspicuously precise number in Table 1.2. This may be regarded a pure coincidence, as there are many ways of arriving at these estimates under varying sets of assumptions.

The reason for the somewhat lengthy assessment of possible warhead numbers is not mainly to arrive at a very precise estimate, but rather to illustrate the basis for our assessment, and the nature of the huge uncertainties associated with performing such numerical estimates. The estimates are summarised in Table 2.8 in a form comparable to the sections addressing other states' nuclear arsenals.

[5] *Separative Work Units*, a measure of enrichment work/effort or enrichment capacity (if reported per time unit).

Table 2.8 Estimated number of nuclear warheads in North Korea, categorised as in the other sections.

Type	Warheads	Total
Land-based ballistic missiles	?	
Submarine-launched ballistic missiles	?	
Bombers	probably 0	
Total estimated stockpile		**35–75**
Retired warheads awaiting dismantlement		***0***
Total estimated inventory		**35–75**

In 2019, FFI published a report that discussed at length Pyongyang's declaratory nuclear doctrine, and the degree to which it had the force structure to back it up [47]. Despite a period of voluntary moratoria on nuclear and long-range missile testing, summits and détente between Pyongyang and Washington, there is little to suggest that the nuclear doctrine has changed since the 2019 report was published. Rather, North Korea has kept up the pace in both the nuclear and missile sectors, introducing several new delivery vehicles, both strategic (in particular a new, liquid-fuelled, land-mobile ICBM, cf. Figure 2.8) and non-strategic (in particular short-range, solid-fuelled, ballistic missiles). Pyongyang seeks to bolster its ability to perform nuclear attacks on a range of military targets in the region, as well as holding at risk major U.S. population centres with thermonuclear warheads mounted on ICBMs. In its declaratory doctrine, as interpreted in the 2019 FFI report, Pyongyang envisions deploying nuclear weapons against a U.S. military build-up in the region to prevent a strategic attack on its own soil. Furthermore, the mere possibility that even one or two thermonuclear warheads may be successfully delivered to a large U.S. city in response to U.S. military action against Pyongyang, may serve to "decouple" the U.S. alliance commitment towards its regional allies (South Korea, Japan and Taiwan). This issue is revisited in Section 3.3.

For decades, North Korea has produced, deployed and even exported ballistic missiles with short and medium ranges. Most of these are based on *Scud* and other 1960s vintage Soviet liquid-fuel technology. However, in recent years, North Korea has made huge strides in developing road-mobile and submarine-launched ballistic missiles with solid fuel, and with short and medium ranges. Furthermore, the North Korean missile engineers have mastered more advanced, liquid-fuelled rocket engines (also of Soviet origin), that are key to their successful development and flight testing of one IRBM and two ICBMs. This is discussed in more detail in the FFI report from 2019 [47].

Figure 2.8 A road-mobile ICBM, tentatively called Hwasong-16*, debuting in the public during a parade in Pyongyang in October 2020. (Photo from Wikimedia Commons, screenshot from KCTV.)*

Based on the doctrine, presumed operational requirements, and reasonable assumptions about warhead and missile types and numbers, most of North Korea's nuclear warheads are probably fission and/or boosted fission weapons to be mounted on (mostly land-based, but a few submarine-launched) medium and perhaps intermediate-range ballistic missiles. Any thermonuclear warheads are probably fewer in numbers and likely reserved for a numerically small fleet of ICBMs as a true last resort.

Projecting into the future, one cannot rule out the possibility of Pyongyang successfully developing and deploying road-mobile ICBMs with solid fuel and throw-weights sufficient to carry missile defence counter measures along with multiple warheads (independently manoeuvrable or not). Conversely, and based on the already disproportionately comprehensive fleet of strategic delivery vehicles, Pyongyang may even pursue solid-fuel SLBMs with intercontinental ranges. Success in either or both of these areas may constitute a more credible second-strike capability, which in Pyongyang's eyes would amount to a strengthened nuclear deterrence. In any case, such a dramatic development may come with the benefit of reduced escalation pressure in the region, as Pyongyang and its foes may trust its ability to retaliate even after a surprise nuclear counter-force attack. Having stated that, the most effective way to curb this eventuality is probably to negotiate a renewed moratorium on strategic delivery vehicle flight testing, as Pyongyang may very well be comfortable with its existing nuclear weapons designs, but will likely hesitate to deploy untested, strategic missiles (although it has done so in the past with the medium-to-intermediate-range *Hwasong-10*, which was later abandoned). [47]

2.9 Israel

The official stance of the Israeli government is one of *nuclear opacity*, which means that its nuclear-weapon capabilities are neither confirmed nor denied, but still sufficiently recognised to affect other states' situational awareness and actions [48]. Tel Aviv has never signed the NPT, and it is widely assumed internationally that Israel is indeed a nuclear-weapon possessor [3;38]. The size of its presumed nuclear arsenal has never been publicly disclosed, however, and its policy of opacity in combination with various incidents and anecdotes over the years has led to much international speculation.

Among the incidents, some seemingly lifted from cheap spy novels, is the disappearance of a cargo load of 200 metric tons of yellowcake (a range of uranium oxides which constitute the starting point for the purification and enrichment of uranium for use in nuclear reactors and nuclear weapons) *en route* from Antwerp to Genova in 1968. The vessel *Scheersberg* disappeared for two weeks and then instead of Genova, turned up in Iskenderun, Turkey – without the cargo. The uranium may have found use in Israel's Dimona nuclear reactor. [49]

As a second example, the whistle-blower Mordechai Vanunu revealed details of the Israeli nuclear-weapon programme in 1986. In particular, he claimed an annual plutonium production from the Dimona reactor of 40 kg, which – assuming a mass of 4 kg of plutonium per nuclear warhead, the figure that was used in the original *Sunday Times* article (reproduced in [50]) – would be sufficient for up to ten warheads per year. This implied that by the end of the 1980s, Israel might have already been in possession of material sufficient for 100 to 150 warheads. However, using the amount of available material to estimate the number of deployed weapons is, of course, overly alarmist. Furthermore, pictures taken by Vanunu more than suggest that Israel also sought thermonuclear weapons in the 1980s. [51;52]

The third example is the so-called "Vela incident," in which an American Vela satellite, specifically designed to monitor the ban on atmospheric nuclear testing, registered signs of a nuclear explosion over the ocean south of South Africa on 22 September 1979. It is still unclear if the signs actually did indicate a nuclear test explosion and, if so, which country might have carried out the test, but many international experts have stated over the years that this most likely was an Israeli nuclear test, possibly in cooperation with South Africa. [53]

When it comes to inventory and yield of the current stockpile of nuclear weapons, almost everything is up to speculation, and the conclusions of different authors vary widely, typically from less than a hundred warheads to more than four hundred. From the point of view of Israeli infrastructure, the nuclear arsenal is most likely plutonium-based. This follows from the fact that the Dimona reactor is suitable for the production of weapons-grade plutonium. Various rumours of Israeli uranium enrichment efforts exist, however [54]. Furthermore, assuming that Israel has at most carried out one nuclear test explosion, one would assume that Israeli nuclear weapons are of few and not very sophisticated designs.

The most recent *Nuclear Notebook* article about Israeli nuclear weapons date back to 2014 [55]. The authors then made a good case for the existence of some 80 nuclear warheads of rather conventional build suitable for use with only a few types of nuclear weapons, dismissing the rumours of more exotic weapon designs. The most relevant question in this context is probably whether Israel has developed a boosted fission weapon or a thermonuclear weapon. The *Nuclear Notebook* authors have recently revised their best estimate to 90 warheads constituting a full triad as reflected in Table 1.2 and Table 2.9 [3].

Table 2.9 Estimated number of Israeli nuclear warheads in 2020 [3;55].

Type	Warheads	Total
Intermediate-range ballistic missiles (IRBMs)		✓
Submarine-launched cruise missiles (SLCMs)		✓
Fighter-plane carried bombs		✓
Total estimated stockpile		**~ 90**
Retired warheads awaiting dismantlement		***0***
Total estimated inventory		**~ 90**

Israel has since its foundation in 1948 experienced serious threats to its existence from other states in the Middle East. The Israeli interest in nuclear weapons is therefore most likely due to a perceived need to deter these states from attacking, as well as to maintain the ability to always strike back under any circumstance. The policy of nuclear opacity fits well into this picture. If Israel should officially declare possession of nuclear weapons, this would put the state's Western allies in an awkward position potentially forcing them to openly criticise Israel and reduce their support. Furthermore, an openly nuclear-armed Israel might "force" its Middle Eastern rivals to develop their own nuclear weapons, a pressure nuclear opacity today makes it easier to ignore. The obvious disadvantage of nuclear opacity is that it seriously complicates any other form of disarmament than quietly removing the nuclear weapons and the associated infrastructure (as South Africa did around 1990). Israel cannot use items the state does not admit to possessing, as negotiating cards to gain concessions from its adversaries.

The number of possible delivery vehicles for Israeli nuclear weapons is limited. The IRBMs referred to in Table 2.9 are Israeli *Jericho* missiles. *Jericho I* was a short-range (500 km) missile, maybe with a 450 kg nuclear payload, which came into service in 1973 and is no longer in service. It was replaced in the 1990s by *Jericho II* with larger range (estimated at 1500–3500 km) and larger payload, maybe a 1500 kg nuclear warhead. Jericho II is apparently in the process of being retired and replaced with *Jericho III*, which entered service in 2011. Its precise specifications are somewhat uncertain, but estimates give a range of up to about 4800 km with a 750 kg nuclear payload. Jericho missiles may be launched from land-mobile platforms or train cars. In principle, they could also be launched from silos, but the 2014 *Nuclear Notebook* article argues against this having been implemented. The number of Jericho II and Jericho III missiles currently in service is unknown, but most likely a few tens, and they may also be carrying conventional warheads. [55;56]

The Israeli Navy has five submarines (and one more under construction) of the German-built *Dolphin* class, partially subsidised by Germany. The first three submarines (the *Dolphin I* class) have conventional diesel-electric propulsion, while the two (three) newer submarines (the *Dolphin II* class) also have air-independent propulsion powered by a fuel cell. Four of the ten torpedo tubes have a larger diameter of 650 mm. The purpose of these tubes is likely to launch cruise missiles. Little is known about these SLCMs, but there are rumours about possible nuclear warheads and a range of 1500 km. *Jane's Fighting Ships* states, however, that "while Israel probably has the expertise and technology to deploy SLCMs, little information exists to confirm or deny such a programme." [55;57;58]

The Israeli Air Force has a large number of fighter planes, mostly in special versions modified for Israeli use. In early 2021, there were 25 F-15s, 219 F-16s and 20 F-35s in service [59-61]. In the U.S. Air Force, these aircraft may be equipped for a nuclear role; therefore, it is possible that some of them have a similar role in the Israeli Air Force. [55]

In summary, *Nuclear Notebook* estimated in 2014 that Israel had "a stockpile of approximately 80 nuclear warheads for delivery by two dozen missiles, a couple of squadrons of aircraft, and perhaps a small number of sea-launched cruise missiles." In 2020, the estimate was updated to about 90 nuclear warheads. [3;55]

3 The global picture – selected developments

The global nuclear arsenals have been reduced to about one fifth of their maximum numbers during the Cold War, and the *Treaty on the Prohibition of Nuclear Weapons* (TPNW) entered into force on 22 January 2021. Still, there is little to suggest that the nine nuclear-weapon possessors will lessen their emphasis on nuclear weapons in the years to come. As shown in Table 1.2, *Nuclear Notebook*/SIPRI estimated that there were about 13 400 nuclear warheads in the world in 2020, of which 3870 were deployed. The strategic stability between NATO and Russia is threatened by the demise of arms-control treaties and a reduced mutual vulnerability. Russia and to some degree China strive to maintain their ability to hold North America and European NATO members at risk when these states are shielded by NATO and U.S. missile defence systems. India and Pakistan are currently developing new nuclear weapon systems that enhance the risk of nuclear escalation by increasing the likelihood of miscalculation in the case of dual-use delivery systems, or by deploying lower-yield and more precise weapons that may lower the threshold for nuclear use. China and North Korea develop delivery systems that are more usable, precise and robust against adversarial first strikes. Iran's nuclear future is uncertain. These are some key development features in today's nuclear weapons landscape.

3.1 A premise under pressure and reduced transparency

The first major success in strategic arms control during the Cold War was the *Anti-Ballistic Missile Treaty* (the *ABM Treaty*) from 1972 [62]. This treaty limited the Soviet Union and the United States each to deploy missile defence systems in only two locations in their respective territories. In practical terms, that meant around the capital and one missile base of their choice. The purpose was to avoid having the nuclear arms race getting out of control. Had both countries developed and deployed missile defences on several locations, it would have generated a perceived need to compensate with the addition of more offensive nuclear arms in order to retain the ability to successfully strike the other part. This *mutual vulnerability* was a key premise for the strategic stability that the Soviet Union and the United States succeeded in establishing during the Cold War, and that Russia and the United States have since maintained. The emergence of the ABM Treaty was not sufficient to halt further arms build-up on both sides, however. Only around 1990 did the operational arsenals begin to shrink significantly (cf. Figure 1.2). That was in large part due to the *INF Treaty*[6] from 1987, which led to the elimination of Soviet and U.S. land-based, medium-range ballistic and cruise missiles. These weapons were perceived as particularly destabilising, as they enabled destruction of major population centres with only a few minutes of warning. Strategic weapons usually have longer flight times, and thus longer warning times. False warnings about a strategic attack are therefore more readily identified as such before the world as we know it ends due to inadvertent nuclear escalation.

[6] INF is short for "Intermediate-range Nuclear Forces." Its full name is *Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles*, and it includes missiles with non-nuclear payloads.

Lacking insight into the other side's forces was probably one of several reasons why the arms race kept its pace, despite years of attempts to achieve binding limitations of the strategic arsenals through the SALT I and SALT II talks from 1969 to 1979 [63]. Human intelligence (HUMINT), signals intelligence (SIGINT, "wiretapping"), and image intelligence (IMINT, acquired from satellites and spy planes such as the U2) provided a certain overview and understanding of the other side's nuclear weapons capabilities, but it still left room for exaggerations and overly pessimistic estimates. Not until the *START I Treaty*,[7] signed in 1991, did the two nuclear superpowers get the tools they needed to convince each other that the scope of deployed, strategic nuclear weapons was as declared and agreed upon, namely *declarations* and *on-site inspections* [64]. Both parties sent inspectors to each other's missile bases, bases for strategic bombers and strategic submarine bases. The inspectors visually observed the numbers of deployed missiles and bombers and then stipulated the total numbers of deployed warheads and compared those to the declared numbers. The parties also exchanged flight measurement data from missile tests, so-called *telemetry*. The process of information exchange and mutual inspections is called *verification* and is widely attributed to having reduced the risk of misinformed assessments leading to further arms racing. Verification in the context of other treaties are also regarded as conducive for building trust, as long as the parties to the treaties comply with them, and neither party is accused of cheating. Examples include the INF Treaty, the *Open Skies Treaty* (allowing parties to perform airborne reconnaissance missions over each other's territories) [65], the *Treaty on Conventional Armed Forces in Europe* (the *CFE Treaty*) [66], and the Iran nuclear agreement (*Joint Comprehensive Plan of Action, JCPOA*) [67].

The United States withdrew from the ABM Treaty in 2002, from the JCPOA in 2018, from the INF Treaty in 2019, and from the Open Skies Treaty in 2020. The latter two withdrawals were justified by claims of Russian non-compliance. Russia, on the other hand, withdrew from the CFE Treaty in 2007 following allegations that NATO member states had been cheating. Fortunately, Moscow and Washington agreed to extend the *New START Treaty* in early 2021 [68]. The extension entails a continuation of the constraints on deployed, strategic arsenals (warheads and bombers) with ample verification. The allowed numbers of deployed warheads and bombers are significantly smaller than they were under START I and the *Strategic Offensive Reductions Treaty (SORT*, also called the *Treaty of Moscow*) [69]. The latter was a successor to START I when signed in 2002, but it was trust-based and included no verification regime.

The Trump administration planned to deploy missiles that would have been prohibited under the INF Treaty, but it remains to be seen if the current Biden administration will uphold these plans [70]. Nonetheless, today's bigger picture is characterised by less mutual transparency, significantly weakened arms control and lingering doubts about the future, mutual vulnerability. Without future vulnerability, the result may be a new strategic arms race. In 2020, Kristensen and Korda estimated that the United States had about 3800 warheads, of which 1750 were deployed (mostly on strategic platforms), while Russia had an estimated 4310 warheads, of which 1570 were deployed on strategic platforms and the rest resided in storage (cf. Table 1.2).

[7] In this context, START stands for *Strategic Arms Reduction Treaty*.

The U.S. withdrawal from the ABM Treaty in 2002 has served as a justification, and likely as a driver, for the development of a series of spectacular nuclear delivery vehicles in Russia. These are all designed to be able to penetrate or bypass (through blind sectors) all known concepts of missile defence. President Putin presented the novel weapon systems in a speech to the Russian people in 2018 [10;71]. The weapons included a *hypersonic* (that is, moving at least five times faster than the local speed of sound) *boost-glide vehicle*, delivered by ICBMs and able to outmanoeuvre interceptors in the terminal phase of the flight;[8] a huge, *autonomous torpedo with nuclear propulsion* and a high-yield, thermonuclear warhead (to hold coastal cities at risk); a *hypersonic cruise missile* carried by heavy bombers; and a land-based *cruise missile with nuclear propulsion* and practically unlimited range. These systems are meant to secure Russia's ability to hold at risk the continental United States in the event that the latter's missile defence systems prove capable of effectively protecting against today's ICBMs and their re-entry vehicles (which is so far not the case).

The United States has announced its intent to develop new silo-based ICBMs [72], new warheads with reduced yield for its submarine-launched ballistic missiles [73] and new air-launched, nuclear-tipped cruise missiles [74]. Washington has justified the fielding of new, reduced-yield warheads with a conceived need to counter what the U.S. government claims is a concept in Russia's actual (in contrast to the declared) nuclear weapons doctrine, known as *escalate to de-escalate*. The United States fears Russia may respond to conventional aggression with limited nuclear use to force the adversary to back down, and thus assert escalation dominance. To re-establish perceived escalation parity, the United States thus seeks the ability to respond to this kind of nuclear use in a proportional manner (that is, with reduced-yield weapons). Russia firmly rejects this interpretation of its declaratory nuclear weapons doctrine. In earlier years, U.S. nuclear strategists have largely not subscribed to the idea that it should be possible to control escalation once the nuclear threshold has been crossed. In any case, the U.S. nuclear posture may very well be adjusted once the Biden administration has completed its expected *Nuclear Posture Review*, which is a tradition for newly elected presidents.

3.2 China's late offset and regional power projection

About forty years ago, China assumed a version of minimal deterrence called *first strike uncertainty* [75]. With a lack of delivery vehicles that could provide an assured retaliatory capability, they instead opted to create ambiguities by establishing a set of both genuine and false missile bases. The land-based, strategic missiles were eventually placed in tunnels with rails leading to the outside launch pads. The idea was to instil doubt in the minds of adversaries contemplating a disarming, nuclear first strike. Beijing hoped that the prospect of a Chinese retaliation with only a fraction of its nuclear forces would be sufficient to deter a nuclear first strike. One could argue that remnants of this obfuscation strategy are manifest in China's posture even today. Some of its operational, ballistic missile brigades are both conventional and nuclear capable (probably the medium-range DF-17 and the intermediate-range DF-26

[8] Note that every RV delivered by ICBMs are hypersonic. The real issue is this RV's ability to glide and manoeuver in the terminal phase.

brigades). A lacking distinction between nuclear and conventional weapons and combat units may increase the risk of miscalculations, and thus be destabilising [76]. An attack on presumably conventional forces may suddenly turn out to be an attack on China's nuclear forces, which may prompt a very different and unexpected response.

China never strived to keep up with the Soviet Union and the United States in the Cold War nuclear arms race. Kristensen and Korda estimated that China possessed only around 320 nuclear warheads in 2020 (cf. Table 1.2), a number expected to grow in the coming years [18]. However, China's rise to economic superpower status in the last couple of decades, as well as its increased military assertiveness and overall modernisation in the last decade or so, would indicate that the state by now should be almost on par with Russia and the United States in terms of technological quality of warheads and delivery systems. Furthermore, Beijing possesses the world's largest arsenal of ballistic missiles (some of them carrying hypersonic glide vehicles), which more than anything underlines their stronger emphasis on conventionally armed missiles compared to their nuclear rivals. In concert with an increasingly more modern and comprehensive navy, precise and long-reaching ballistic and cruise missiles enable Chinese power projection and war fighting hundreds of kilometres from its coastal population centres, bearing some resemblance to the Russian *bastion concept* [77].[9]

Nevertheless, one might question why China only in the later years reportedly have performed long-range patrols with one of its *Jin class* strategic submarines, whereas the other nuclear-weapon states under the NPT have done so on a continuous basis for decades as a key element of their active deterrence posture [18]. Ballistic missile submarines constitute a reliable second-strike capability, adding credibility to Beijing's declaratory, no-first-use nuclear doctrine. Still, some analysts question the realities of the declaratory doctrine, including the contention that nuclear warheads are not mated with their delivery vehicles in peacetime. More precise and robust missiles (with regard to pre-emptive strikes and missile defence) may hold an adversary's nuclear-weapon systems in the region at risk [78]. Additionally, Beijing is developing strategic early-warning capabilities, leading some observers to suspect that they are inching towards a *launch-on-warning strategy*, such as Russia and the United States [79]. In that case, China's strategic weapons would be ready for launch few minutes after the detection and warning of an incoming nuclear strike. This obviously would require mating warheads and delivery systems in peacetime.

The United States has unsuccessfully attempted to make China a party to the INF, and to include China in talks of a successor treaty to New START. Chinese compliance with the INF would have eradicated about 80 percent of the country's ballistic missiles (with all types of payloads), and as long as no warheads are officially mounted on missiles in peacetime, a strategic arms control treaty such as START I, SORT, and New START would not have imposed any real constraints on the Chinese nuclear arsenal [80]. The way to include China in

[9] A bastion is defined as "a projecting part of a fortification built at an angle to the line of a wall, so as to allow defensive fire in several directions," Lexico, https://www.lexico.com/en/definition/bastion.

strategic arms control may instead lie in a treaty that includes a wider range of delivery vehicles and weapon readiness levels, not just deployed, strategic systems.

3.3 North Korea's breakthrough

As discussed in Section 2.8, North Korea has produced plutonium and nuclear-capable ballistic missiles for decades. In at least the last decade, the state has also produced enriched uranium. For years, however, experts have questioned Pyongyang's ability to produce reliable nuclear warheads and deliver them to regional targets. After six underground nuclear tests from 2006 through 2017, with yields spanning from a fraction of a kiloton to a couple of hundred kilotons, there is little doubt North Korea now possesses at least two functioning nuclear weapons designs, of which one is most likely a full-fledged thermonuclear design. Furthermore, the state has developed a plethora of new, nuclear-capable ballistic missiles. These include submarine-launched ballistic missiles with regional ranges, and land-mobile ballistic missiles with regional and even intercontinental ranges. In January 2021, North Korea paraded non-strategic (tactical) delivery systems with a potential nuclear role [81]. This was also reflected in President Kim Jong-un's speech to the eighth party congress the same month [82], in which he claimed that North Korea is developing

> *... "ultramodern tactical nuclear weapons," "hypersonic gliding-flight warheads," "multi-warhead" missiles, military reconnaissance satellites, a nuclear-powered submarine, and land- and submarine-launched intercontinental ballistic missiles that use solid fuel.*

These stated ambitions stand in stark contrast to the previously discussed, severe limitations in production and stocks of plutonium (cf. Section 2.8) – and probably tritium as well.

In 2017, Pyongyang successfully flight tested three ballistic missiles capable of striking parts of the continental United States (*Hwasong-14*, two tests) or all of the United States (*Hwasong-15*, one test) with warheads powerful enough to destroy a medium-sized city [47]. Furthermore, in October 2020, they paraded the largest road-mobile ballistic missile ever known (assumed to be designated *Hwasong-16*), which by February 2021 has not yet been flight tested. The summit and love letter diplomacy between presidents Kim Jong-un and Donald Trump in 2018 provided but a hiatus in the North Korean nuclear and long-range missile testing. The development and production seem to have continued at full pace in both sectors. As discussed in Section 2.8, Pyongyang possibly possesses up to a few tens of nuclear warheads, some of which may be thermonuclear. The key bottleneck for increasing the number of warheads is plutonium (and possibly tritium) production. There are also some questions regarding the ability of North Korea's warheads to survive the mechanical and thermal loads associated with intercontinental flight and atmospheric re-entry. This has simply not been clearly proven, but the sheer throw-weights of the two largest ICBMs allow for "over-engineering" of structural elements (such as flanges, pylons, and shock absorbers) and thermal protection (such as ablative heat shields, insulation, and heat sinks), increasing the likelihood of warhead survival.

North Korea is consolidating a regional, nuclear first-strike capability with enhanced mobility and diversity, augmented by the uncertainty associated with the fact that only a small fraction of its hundreds of ballistic missiles may be assumed to carry a nuclear payload. That surely represents a very tough target prioritisation challenge for the operators of regional missile defence systems in Japan and South Korea and at Guam. In addition, Pyongyang's potential for thermonuclear retaliation against the continental United States constitutes a first-strike uncertainty of sorts, as long as even one thermonuclear warhead would impose an unacceptable threat if detonated above a U.S. city.

It seems obvious that a North Korean nuclear attack on its arch enemy, the United States, would be tantamount to suicide. Still, one could argue that the balance of power has already somewhat shifted by the prospect of a North Korean thermonuclear strike on a U.S. population centre. Will the United States in the future hesitate to honour its commitments to its Northeast Asian allies if it means risking the lives of hundreds of thousands of its own civilians? This effect is called *alliance decoupling*, and was relevant also in Europe during the Cold War [83]. Charles De Gaulle justified downplaying France's NATO participation and its development of a national, independent nuclear force by questioning whether the United States was actually willing to sacrifice New York City to save Paris [84]. What will it take for Japan and South Korea to reach a similar conclusion?

3.4 Will a nuclear arms race in the Middle East finally emerge?

Israel is the sole nuclear-weapon possessor in the Middle East. However, the state has not officially declared its status as such, but rather practiced a so-called *opacity doctrine*, cf. Section 2.9, implying that Tel Aviv neither confirms nor denies the possession of nuclear weapons. That precludes adopting a declaratory doctrine with clearly communicated nuclear rules of engagement. However, as reported in Section 2.9, most observers assess that Israel is able to strike targets across the Middle East with at least about 50 warheads, and maybe as many as around 400, distributed between ballistic missiles, warplanes, and possibly submarine-launched cruise missiles. In their estimate of 90 warheads, Kristensen and Norris assume that Israel has not yet produced thermonuclear weapons, but probably have boosted fission weapons [55]. It is particularly demanding to develop reliable thermonuclear weapons without nuclear testing.

A regional nuclear arms race in the Middle East has been feared for decades. And several of Israel's foes have indeed pursued clandestine nuclear-weapon programmes in the past. In line with its preventive *Begin doctrine* [85], Israel has performed air strikes against reactors in Iraq (1981) and Syria (2007) [86;87], and the state is widely assumed to be associated with a series of sabotages, cyberattacks and assassinations targeting the Iranian nuclear programme [88]. Libya abandoned its half-hearted nuclear-weapon programme in 2003 as a result of British and U.S. pressure and negotiations [89].

Iran is much closer to a nuclear weapons capability than Libya and Syria ever were, but does not possess such weapons today. Tehran came a long way in developing necessary components for a uranium implosion weapon, deliverable by medium-range ballistic missiles, before a series of inadvertent disclosures in 2002 and 2003. Years of international investigations and diplomatic efforts ensued, leading to a series of sanctions based on national decisions as well as United Nations Security Council resolutions, in attempts to strong-arm Tehran into shutting down its most sensitive nuclear dual-use activities and admit to past attempts at developing a nuclear weapons capability. The JCPOA, as previously mentioned, was supposed to provide sanctions relief to Iran. In exchange for that, Iran would, *inter alia*, scale down its uranium enrichment capacity, reduce its stocks of enriched uranium, limit the enrichment level of its uranium, and accept even more intrusive international inspections than stipulated in its safeguards agreement with the IAEA. Tehran's reciprocal steps following the U.S. withdrawal from the JCPOA in 2018 have yielded an enrichment capacity and stocks of low enriched uranium that exceed the limits stipulated in the treaty. Low enriched uranium is used to fuel nuclear power reactors, but may also be enriched further to weapons-grade uranium much faster than if one uses natural uranium as feed material. Fortunately, the inspection regime under the JCPOA is still more or less intact by late February 2021, despite recent Iranian legislation demanding a roll-back of that aspect as well [90].

Will President Biden's diplomats succeed in preventing Iran from withdrawing from the JCPOA entirely after the June 2021 presidential election? The late November 2020 assassination of Iran's head of the covert, military part of its nuclear programme, Mohsen Fakhrizadeh, probably did not improve the odds [91]. And it certainly did not eliminate Iran's future ability to produce nuclear weapons, should that option be chosen. Furthermore, the timing, shortly after JCPOA supporter Joe Biden won the U.S. presidential election, suggests that the JCPOA might in fact have been the strategic goal of the elimination. The treaty is highly unpopular among actors who simply do not accept any kind of nuclear technology in Iran, and who criticises the JCPOA for not resolving any and all disagreements between the West and Tehran. Should the JCPOA become history, Iran will still be bound by the NPT and thus remain prohibited from acquiring nuclear weapons.

Although the widely anticipated nuclear power renaissance has yet to fully materialise across the globe, it has manifested itself to a certain degree in the Middle East. Iran had the only operational nuclear power plant in the region from 2011 until The United Arab Emirates (UAE) followed suit in August 2020 [92]. Saudi Arabia is likely to become the next nuclear power state in the Middle East [93]. Some observers warn that Riyadh may opt for a nuclear weapons option in the process, but the Saudis are far from having that capability in the short term. While the UAE practices the highest standards of international transparency in its nuclear efforts, Saudi Arabia has been dragging its feet in negotiating and implementing a comprehensive safeguards agreement with the IAEA [94].

3.5 France and the United Kingdom emphasise retaliatory capability and status quo

France has a declared stockpile of less than 300 nuclear warheads on submarine-launched ballistic missiles (approximately 240 warheads) and air-launched cruise missiles (about

50 warheads), cf. Section 2.4. Thus, France possesses two legs of a nuclear triad, with the missing leg being ground-based weapons. In contrast to France, the United Kingdom (Section 2.3) is satisfied with only one leg of the triad: submarine-launched ballistic missiles. The British have no more than 120 deployed warheads at any given time (up to 40 warheads on each of three strategic submarines) out of a total stockpile of 195 nuclear warheads, which is the lowest number among the five NPT nuclear-weapon states (even if these numbers increase in the coming years, as mentioned in Section 2.3). Another significant difference between the two nuclear arsenals is the fact that the British weapons are included in NATO's nuclear weapons planning, while the French are not.

Both France and the United Kingdom have an assured retaliatory capability through their *continuous at sea deterrence* manifested by submarine-launched ballistic missiles with thermonuclear warheads of intercontinental range. Their respective doctrines deviate on one significant point, however: While the United Kingdom *solely* operates strategic retaliatory weapons, France still retains the option of performing a limited nuclear attack on military targets as a stark warning that its nuclear threshold has been reached, without the adversary having employed nuclear weapons first [17]. By forgoing ambitions of a massive, nuclear first-strike capability against enemy nuclear forces ("counter force"), and by maintaining a significant and practically invulnerable strategic retaliatory capability against soft targets ("counter value," that is, targeting population centres), both states do without a launch-on-warning strategy. Such a strategy requires a large degree of *positive control*, meaning that a decision of nuclear use will be successfully executed before one's own weapons are taken out. As such, a launch-on-warning strategy implies an almost inhumane pressure on decision makers to decide the fate of perhaps millions of people in an emergency situation if the incoming attack alarm sounds. History includes at least a handful of examples of false alarms that have temporarily put Russians and Americans in such a situation [95].

3.6 Increased risk of escalation in South and East Asia

Pakistan considers India its main strategic competitor and nemesis. Both India and Pakistan remain outside the NPT together with Israel and North Korea. Table 1.2 shows that Pakistan possessed an estimated 160 nuclear warheads in 2020, a number which has increased significantly in recent years and may continue to increase [31]. Islamabad seems to further scale up its capacity to separate plutonium from irradiated fuel from its four heavy-water reactors in Khushab [96].

The Pakistani emphasis on non-strategic nuclear weapons in the context of India's conventional superiority on the subcontinent was discussed in Section 2.7. India, on the other hand, focuses more on China in its strategic considerations after a few decades with a primary focus on Pakistan in its nuclear war planning. Kristensen and Korda estimated that India possessed about 150 nuclear warheads in 2020 (cf. Table 1.2), even though its stocks of plutonium could give rise to more. Just as Islamabad, New Delhi is increasing its plutonium production. The reason is probably to meet the warhead requirements for several new types of missiles under development, as mentioned in Section 2.6. New, so-called "breeder reactors" will in a few years enable the expected increase in plutonium production, although the reactors are purposed for electricity production.

It is worth noting that there has been several armed conflicts between India and Pakistan over the years following their nuclear weapons tests in 1998. Furthermore, China and India were on the brink of armed conflict during a border dispute in Doklam in 2017. The absence of escalation to an all-out war between especially India and Pakistan is by some pundits accredited to the effect of nuclear deterrence. Other analysts conclude oppositely based on the same observations, namely that nuclear deterrence did not preclude the breakout of armed conflict with the inherent risk of major escalation.

4 Final remarks

This report present an overview of the current arsenals of nuclear weapons in the world as well as some more recent developments in these arsenals. Some of the developments increase the flexibility of the state's nuclear posture, and some can be explained as attempts of retaining mutual vulnerability by overcoming current and future missile defence systems.

Several states contribute to a blurring of the distinctions between nuclear and conventional delivery vehicles and command and control systems, thereby increasing the risk of miscalculation and inadvertent escalation. One reason is that some conventionally armed ballistic missiles now are sufficiently precise to be effective against hardened military targets at quite long ranges, thereby eliminating the earlier need to use a nuclear weapon.

It is of concern that most, if not all, nuclear-weapon possessors appear to increase their emphasis on the importance of nuclear weapons. Ambitious modernisation programmes are ongoing, and some states are increasing their stockpiles of nuclear weapons. This is in contrast to Article VI of the NPT which claims an obligation for all states to work towards disarmament.

With regard to the two states that have posed the most severe challenges to the international non-proliferation regime in the last couple of decades, North Korea is now established as a nuclear-weapon possessor, while Iran so far is not. On the positive side, no other states seem particularly close to breaking out from the NPT.

Should New START be succeeded by yet another bilateral strategic arms control treaty, the Russian and U.S. stockpiles will expectedly approach the Chinese, French and British stockpiles in numerical terms. Perhaps, then, future nuclear arms control agreements will no longer be limited to deployed, strategic weapons in only two nuclear-weapon states.

The *Treaty on the Prohibition of Nuclear Weapons* (TPNW), which bans all nuclear weapons, entered into force 22 January 2021 upon ratification by 50 states. At the moment, no nuclear-weapon possessors have signed the treaty and neither have any states covered by their "nuclear umbrellas" (such as the NATO member states). The impact of the TPNW on the future nuclear weapon arsenals is yet unclear, but the treaty will most likely over time contribute to strengthening the norm of global nuclear disarmament.

References

[1] Kristensen H. M., Korda M.: *United States nuclear forces, 2020*. Bulletin of the Atomic Scientists 2020;76(1):46-60. Available at https://doi.org/10.1080/00963402.2019.1701286 (dated 2020-01-13, accessed 2021-01-29).

[2] Mikhailov V. N., Ed., Andryushin I. A., Voloshin N. P., Ilkaev R. I., Matushchenko A. M., Ryabev L. D., Strukov V. G.*, et al.*: *Catalog of Worldwide Nuclear Testing*. New York: Begell-Atom, LLC, 1999.

[3] Kristensen H. M., Korda M.: *Status of World Nuclear Forces*. Federation of American Scientists, 2020. Available at https://fas.org/issues/nuclear-weapons/status-world-nuclear-forces/ (dated 2020-09, accessed 2021-01-29).

[4] Kristensen H. M., Norris R. S.: *Global nuclear weapons inventories, 1945–2013*. Bulletin of the Atomic Scientists 2013;69(5):75-81. Available at https://doi.org/10.1177/0096340213501363 (dated 2015-11-27, accessed 2021-02-01).

[5] Russian Federation: *Practical Steps of the Russian Federation towards Nuclear Disarmament*. 2015. Available at http://geneva.mid.ru/documents/2964536/92210e8b-4b62-4158-a741-a26acfa74624 (accessed 2017-05-11).

[6] Kristensen H. M., Korda M.: *Russian nuclear forces, 2020*. Bulletin of the Atomic Scientists 2020;76(2):102-117. Available at https://doi.org/10.1080/00963402.2020.1728985 (dated 2020-03-09, accessed 2021-01-29).

[7] *Basic Principles of State Policy of the Russian Federation on Nuclear Deterrence*. 2020. Available at https://www.mid.ru/en/web/guest/foreign_policy/international_safety/disarmament/-/asset_publisher/rp0fiUBmANaH/content/id/4152094 (dated 2020-06-08, accessed 2020-06-18).

[8] *The Military Doctrine of the Russian Federation, approved on 25 December 2014*. 2014. Available at http://rusemb.org.uk/press/2029 (dated 2015-06-29, accessed 2017-04-19).

[9] *New START Treaty Aggregate Numbers of Strategic Offensive Arms - Fact Sheet March 1, 2021*. USDepartment of State, 2021. Available at https://www.state.gov/wp-content/uploads/2021/04/04-01-2020-March-NST-FACTSHEET-Public-Release-of-Aggregate-Data_final.pdf (dated 2021-04-01, accessed 2021-05-04).

[10] Høibråten S., Kippe H.: *Russiske kjernefysiske styrker*. Forsvarets forskningsinstitutt, 2020. FFI-rapport 20/00131. Available at https://www.ffi.no/publikasjoner/arkiv/russiske-kjernefysiske-styrker (dated 2020-08-20).

[11] Ministry of Defence: *UK nuclear deterrent*. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/510878/Fact_sheet-nuclear_deterrent_FINAL_v15.pdf (dated 2016-03, accessed 2021-02-02).

[12] Kristensen H. M., Norris R. S.: *British nuclear forces, 2011*. Bulletin of the Atomic Scientists 2011;67(5):89-97. Available at https://doi.org/10.1177/0096340211421474 (dated 2015-11-27, accessed 2021-04-19).

[13] HM Government: *National Security Strategy and Strategic Defence and Security Review 2015 - A Secure and Prosperous United Kingdom*. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment

_data/file/478933/52309_Cm_9161_NSS_SD_Review_web_only.pdf (dated 2015-11, accessed 2021-03-15).
[14] HM Government: *Global Britain in a competitive age - The Integrated Review of Security, Defence, Development and Foreign Policy*. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/969402/The_Integrated_Review_of_Security__Defence__Development_and_Foreign_Policy.pdf (dated 2021-03, accessed 2021-03-17).
[15] Kristensen H. M., Korda M.: *French nuclear forces, 2019*. Bulletin of the Atomic Scientists 75(1):51-55. Available at https://doi.org/10.1080/00963402.2019.1556003 (dated 2019-01-07, accessed 2021-02-01).
[16] Stockholm International Peace Research Institute: *SIPRI Yearbook 2020: Armaments, Disarmament and International Security*: Oxford University Press, 2020.
[17] Tertrais B.: *French nuclear deterrence: policy, forces and future*. Fondation pour la Recherche Stratégique, 2019. Available at https://www.frstrategie.org/web/documents/publications/recherches-et-documents/2019/201901.pdf (dated 2019-01, accessed 2021-03-15).
[18] Kristensen H. M., Korda M.: *Chinese nuclear forces, 2020*. Bulletin of the Atomic Scientists 2020;76(6):443-457. Available at https://doi.org/10.1080/00963402.2020.1846432 (dated 2020-12-10, accessed 2021-01-29).
[19] *India Profile: Missile Chronology*. Nuclear Threat Initiative, 2010. Available at http://www.nti.org/e_research/profiles/India/Missile/chronology.html (dated 2010-06, accessed 2010-06-28).
[20] *Weapons: Strategic - DF-26*. Weapons: Strategic: Jane's, 2021. Available at https://customer.janes.com/Janes/Display/JSWSA399-JSWS (dated 2021-01-26, accessed 2021-06-29).
[21] Warrick J.: *China is building more than 100 new missile silos in its western desert, analysts say*. Washington Post. 2021-06-30. Available at https://www.washingtonpost.com/national-security/china-nuclear-missile-silos/2021/06/30/0fa8debc-d9c2-11eb-bb9e-70fda8c37057_story.html.
[22] Korda M., Kristensen H. *China Is Building A Second Nuclear Missile Silo Field*. Federation of American Scientists. Available at https://fas.org/blogs/security/2021/07/china-is-building-a-second-nuclear-missile-silo-field/ (dated 2021-07-26, accessed 2021-08-17).
[23] Kristensen H. M., Korda M.: *Indian nuclear forces, 2020*. Bulletin of the Atomic Scientists 76(4):217-225. Available at https://www.tandfonline.com/doi/full/10.1080/00963402.2020.1778378 (dated 2020-07-20, accessed 2021-03-11).
[24] Toft H. K.: *Indias kjernevåpenprogram*. Forsvarets forskningsinstitutt, 2004. FFI-rapport 2003/00460. Available at https://publications.ffi.no/nb/item/asset/dspace:2923/03-00460.pdf (dated 2004-09-28, accessed 2021-06-30).
[25] International Panel on Fissile Materials: *Countries: India*. International Panel on Fissile Material, 2021. Available at http://fissilematerials.org/countries/india.html (dated 2021-04-29, accessed 2021-06-30).
[26] Ministry of External Affairs - Government of India: *The Cabinet Committee on Security Reviews [o]perationalization of India's Nuclear Doctrine*. 2003. Available at https://www.mea.gov.in/press-

releases.htm?dtl/20131/The+Cabinet+Committee+on+Security+Reviews+perationalization+of+Indias+Nuclear+Doctrine (dated 2003-01-04, accessed 2021-06-19).
[27] Sundarem K., Ramana M. V.: *India and the Policy of No First Use of Nuclear Weapons*. Journal for Peace and Nuclear Disarmament 2018;1(1):152-168. Available at https://doi.org/10.1080/25751654.2018.1438737 (dated 2018-02-22, accessed 2021-06-30).
[28] *2020 Ballistic and Cruise Missile Threat*. Defense Intelligence Ballistic Missile Analysis Commitee, 2020. Available at https://media.defense.gov/2021/Jan/11/2002563190/-1/-1/1/2020%20BALLISTIC%20AND%20CRUISE%20MISSILE%20THREAT_FINAL_2OCT_REDUCEDFILE.PDF (dated 2020-07, accessed 2021-06-30).
[29] *Weapons: Strategic - Sagarika (K-15/B-05)*. Janes's, 2021. Available at https://customer.janes.com/Janes/Display/JSWS0007-JSWS (dated 2021-03-26, accessed 2021-04-12).
[30] *Arihant class (SSBN/SSGN)*. Jane's Fighting Ships, 2016. Available at https://janes.ihs.com/Janes/Display/1357885 (dated 2016-01-27, accessed 2016-03-30).
[31] Kristensen H. M., Norris R. S., Diamond J.: *Pakistani nuclear forces, 2018*. Bulletin of the Atomic Scientists 2018;74(5):348-358. Available at https://doi.org/10.1080/00963402.2018.1507796 (dated 2018-08-31, accessed 2021-03-25).
[32] Albright D., Brurkhard S., Pabian F.: *Pakistan's growing Unranium Enrichment Program*. 2018. Available at https://isis-online.org/isis-reports/detail/pakistans-growing-uranium-enrichment-program/12 (dated 2018-05-30, accessed 2021-06-23).
[33] Coats D. R.: *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community*. Director of National Intelligence, 2018. Available at https://www.armed-services.senate.gov/imo/media/doc/Coats_03-06-18.pdf (dated 2018-03-06, accessed 2021-06-30).
[34] Panda A.: *Pakistan Conducts Second Nasr Nuclear-Capable Ballistic Missile Test in a Week*. The Diplomat. 2019-02-04. Available at https://thediplomat.com/2019/02/pakistan-conducts-second-nasr-nuclear-capable-ballistic-missile-test-in-a-week/.
[35] Ahmed M.: *Pakistan's Tactical Nuclear Weapons and Their Impact on Stability*. Carnegie Endowment for International Peace, 2016. Regional Insight. Available at https://carnegieendowment.org/2016/06/30/pakistan-s-tactical-nuclear-weapons-and-their-impact-on-stability-pub-63911 (dated 2016-06-30, accessed 2021-06-30).
[36] Kristensen H. M., Norris R. S.: *North Korean nuclear capabilities, 2018*. Bulletin of the Atomic Scientists 2018;74(1):41-51. Available at https://doi.org/10.1080/00963402.2017.1413062 (dated 2018-01-08, accessed 2021-07-05).
[37] Panda A.: *Exclusive: Revealing Kangson, North Korea's First Covert Uranium Enrichment Site*. The Diplomat. 2018-07-13. Available at https://thediplomat.com/2018/07/exclusive-revealing-kangson-north-koreas-first-covert-uranium-enrichment-site/.
[38] Høibråten S., Breivik H., Enger E., Heireng H. S., Kippe H.: *Atomprogrammene i India, Pakistan, Nord-Korea, Israel, Iran og Syria*. Forsvarets forskningsinstitutt, 2013. FFI-rapport 2011/01603. Available at https://publications.ffi.no/nb/item/asset/dspace:6747/11-01603.pdf (dated 2013-01-23, accessed 2021-04-07).

[39] Albright D.: *North Korean Plutonium and Weapon-Grade Uranium Inventories*. Institute for Science and International Security, 2015. ISIS Reports. Available at https://isis-online.org/uploads/isis-reports/documents/North_Korean_Fissile_Material_Stocks_Jan_30_2015_revised_Oct_5_2015-Final.pdf (dated 2015-10-07).

[40] Nuclear Threat Initiative: *North Korea Declares 31 Kilograms of Plutonium*. Global Security Newswire. 2008-10-24. Available at https://www.nti.org/gsn/article/north-korea-declares-31-kilograms-of-plutonium/.

[41] Pabian F. V., Bermudez J. S., Jr., Liu J.: *North Korea's Yongbyon Nuclear Research Center; Possible Preparation for Reprocessing Campaign in Early May?* 38 North, 2018. Available at https://www.38north.org/2018/05/yongbyon053018/ (dated 2018-05-30).

[42] Albright D., Burkhard S.: *North Korean Reprocessing Campaign May Have Taken Place*. Institute for Science and International Security, 2018. ISIS Reports. Available at https://isis-online.org/isis-reports/detail/north-korean-reprocessing-campaign-may-have-taken-place/10 (dated 2018-06-05).

[43] Landay J., Brunnstrom D., Spetalnick M.: *Exclusive: North Korea restarts plutonium production for nuclear bombs - U.S. official*. Reuters. 2016-06-07. Available at https://www.reuters.com/article/us-northkorea-nuclear-usa-exclusive-idUSKCN0YT2I1.

[44] *N. Korea says used 2 kg of plutonium in 2006 nuke test: source*. Kyodo News. 2008-06-28.

[45] Kurbanbekov S. R., Seung M. W., Chirayath S. S.: *Analysis of the DPRK's Nuclear Weapons Capabilities by Estimating Its Highly Enriched Uranium Stockpile and Natural Uranium Reserves*. Science & Global Security 2019;27(2-3):113-123. Available at https://doi.org/10.1080/08929882.2019.1657608 (dated 2019-09-10, accessed 2021-07-01).

[46] Shanker T., Sanger D. E.: *North Korean Fuel Identified as Plutonium*. The New York Times. 2006-10-17. Available at https://www.nytimes.com/2006/10/17/world/asia/17diplo.html.

[47] Kippe H.: *Nuclear weapons capabilities and doctrines in North Korea*. Norwegian Defence Research Establishment (FFI), 2019. FFI-rapport 18/01830. Available at https://publications.ffi.no/nb/item/asset/dspace:4373/18-01830.pdf (dated 2019-02-18).

[48] Cohen A.: *Israel and the Bomb*: Columbia University Press, New York, 1998.

[49] *HIGH SEAS: Uranium: The Israeli Connection*. TIME Magazine, 1977. Available at http://www.time.com/time/magazine/article/0,9171,914952,00.html (dated 1977-05-30, accessed 2011-09-07).

[50] *Revealed: The Secrets of Israel's Nuclear Arsenal*. First published in the Sunday Times 1986-10-05. Available at https://peterhounam.com/revealed-the-secrets-of-israels-nuclear-arsenal/ (accessed 2021-08-16).

[51] The US Campaign to Free Mordechai Vanunu: *Vanunu's Photos of Dimona – 1985*. Available at https://www.vanunu.com/uscampaign/photos.html (accessed 2021-04-07).

[52] *Israel's Nuclear Weapons Program*. Nuclear Weapon Archive, 1997. Available at https://www.nuclearweaponarchive.org/Israel/index.html (dated 1997-12-10, accessed 2021-04-07).

[53] Normark M., Lindblad A., Norqvist A., Sandström B., Waldenström L.: *Israel and WMD: Incentives and Capabilities*. Totalförsvarets forskningsinstitut (FOI), 2005. FOI-R--1734--SE. Available at https://foi.se/rapportsammanfattning?reportNo=FOI-R--1734--SE (dated 2005-12, accessed 2021-04-07).

[54] Glaser A., Miller M. *Estimating Plutonium Production at Israel's Dimona Reactor*. 52nd Annual INMM Meeting; Palm Desert, CA, USA, 2011. Available at http://www.princeton.edu/~aglaser/PU056-Glaser-Miller-2011.pdf.

[55] Kristensen H., Norris R. S.: *Israeli nuclear weapons, 2014*. Bulletin of the Atomic Scientists 2014;70(6):97-115. Available at https://doi.org/10.1177/0096340214555409 (dated 2015-11-27, accessed 2021-02-15).

[56] *Weapons: Strategic - Jericho 1/2/3 (YA-1/YA-3/YA-4)*. Weapons: Strategic, 2020. Available at https://customer.janes.com/Janes/Display/JSWS0443-JSWS (dated 2020-06-23, accessed 2021-02-16).

[57] *Dolphin I (Type 800) class*. Jane's Fighting Ships, 2020. Available at https://customer.janes.com/Janes/Display/jfs_1570-jfs_ (dated 2020-03-15, accessed 2021-02-16).

[58] *Dolphin II class*. Jane's Fighting Ships, 2020. Available at https://customer.janes.com/Janes/Display/jfs_c354-jfs_ (dated 2020-06-02, accessed 2021-02-16).

[59] *Aircraft - Fixed-Wing - Military - Boeing F-15E Eagle*. All the World's Aircraft: Development & Production, 2021. Available at https://customer.janes.com/Janes/Display/JAWA1183-JAWA (dated 2021-02-01, accessed 2021-02-19).

[60] *Aircraft - Fixed-Wing - Military - Lockheed Martin F-16 Fighting Falcon*. All the World's Aircraft: Development & Production, 2021. Available at https://customer.janes.com/Janes/Display/JAWA1348-JAWA (dated 2021-02-04, accessed 2021-02-19).

[61] *Aircraft - Fixed-Wing - Military - Lockheed Martin F-35 Lightning II*. All the World's Aircraft: Development & Production, 2021. Available at https://customer.janes.com/Janes/Display/JAWA1347-JAWA (dated 2021-05-07, accessed 2021-02-19).

[62] *Treaty Between The United States of America and The Union of Soviet Socialist Republics on The Limitation of Anti-Ballistic Missile Systems (ABM Treaty)*. 1972. Available at https://2009-2017.state.gov/t/avc/trty/101888.htm.

[63] *Strategic Arms Limitations Talks/Treaty (SALT) I and II*. U.S. Department of State. Available at https://history.state.gov/milestones/1969-1976/salt.

[64] *Treaty Between The United States of America and The Union of Soviet Socialist Republics on the Reduction and Limitation of Strategic Offensive Arms*. 1991. Available at https://1997-2001.state.gov/www/global/arms/starthtm/start/start1.html.

[65] *Treaty on Open Skies*. Organization for Security and Co-operation in Europe (OSCE), 1992. Available at https://www.osce.org/files/f/documents/1/5/14127.pdf.

[66] *Treaty on Conventional Armed Forces in Europe*. Organization for Security and Co-operation in Europe (OSCE), 1990. Available at https://www.osce.org/library/14087.

[67] *Joint Comprehensive Plan of Action*. 2015. Available at https://2009-2017.state.gov/e/eb/tfs/spi/iran/jcpoa//index.htm.

[68] *New START: Treaty Text*. U.S. Department of State, 2010. Available at https://2009-2017.state.gov/t/avc/newstart/c44126.htm.

[69] *The Moscow Treaty*. 2002. Available at https://www.congress.gov/treaty-document/107th-congress/8/document-text.

[70] Reif K., Bugos S.: *U.S. Aims to Add INF-Range Missiles*. Arms Control Today. October 2020. Available at https://www.armscontrol.org/act/2020-10/news/us-aims-add-inf-range-missiles.

[71] Woolf A. F.: *Russia's Nuclear Weapons: Doctrine, Forces, and Modernization*. Congressional Research Service, 2020. CRS Report R45861. Available at https://crsreports.congress.gov/product/pdf/R/R45861 (dated 2020-07-20).

[72] Secretary of the Air Force Public Affairs: *Department of the Air Force awards contract for new ICBM system that enhances, strengthens US triad*. U.S. Air Force, 2020. Available at https://www.af.mil/News/Article-Display/Article/2340139/department-of-the-air-force-awards-contract-for-new-icbm-system-that-enhances-s/ (dated 2020-09-08).

[73] Rood J.: *Statement on the Fielding of the W76-2 Low-Yield Submarine Launched Ballistic Missile Warhead*. U.S. Department of Defense, 2020. Available at https://www.defense.gov/Newsroom/Releases/Release/Article/2073532/statement-on-the-fielding-of-the-w76-2-low-yield-submarine-launched-ballistic-m/ (accessed 2020-02-04).

[74] Insinna V.: *Lockheed, Raytheon nab contracts for nuclear cruise missile*. Defense News. 2017-08-23. Available at https://www.defensenews.com/air/2017/08/23/lockheed-raytheon-nab-contracts-for-nuclear-cruise-missile/.

[75] Ikenberry G. J., Trachtenberg M., Ed., Narang V.: *Nuclear Strategy in the Modern Era - Regional Powers and International Conflict*. Princeton, New Jersey, USA: Princeton University Press, 2014.

[76] Acton J.: *Is It a Nuke? – Pre-Launch Ambiguity and Inadvertent Escalation*. Carnegie Endowment for International Peace, 2020. Available at https://carnegieendowment.org/files/Acton_NukeorNot_final.pdf.

[77] Lacey J.: *Battle of the Bastions*. War on the Rocks. 2020-01-09. Available at https://warontherocks.com/2020/01/battle-of-the-bastions/.

[78] Senate Committee on Armed Services: *Statement of Charles A. Richard, Commander United States Strategic Command, Before the Senate Committee on Armed Services 13 February 2020*. 2020. Available at https://www.armed-services.senate.gov/imo/media/doc/Richard_02-13-20.pdf (dated 2020-02-13).

[79] Stefanovich D.: *Russia to Help China Develop an Early Warning System*. The Diplomat. 2019-10-25. Available at https://thediplomat.com/2019/10/russia-to-help-china-develop-an-early-warning-system/.

[80] Bodeen C.: *China Vows to Counter US Deployment of Midrange Missiles in Asia*. The Diplomat. 2019-08-07. Available at https://thediplomat.com/2019/08/china-vows-to-counter-us-deployment-of-midrange-missiles-in-asia/.

[81] Liang T. N.: *The Tactical Implications of North Korea's Military Modernization*. The Diplomat. 2021-01-27. Available at https://thediplomat.com/2021/01/the-tactical-implications-of-north-koreas-military-modernization/.

[82] Choe S.-H.: *Kim Jong-un Uses Party Congress to Double Down on Nuclear Program*. The New York Times. 2021-01-13. Available at https://www.nytimes.com/2021/01/13/world/asia/north-korea-kim-jong-un-nuclear.html.

[83] Panda A.: *Under Trump, A Looming North Korean ICBM Threat Brings Alliance 'Decoupling' Fears Back to East Asia*. The Diplomat. 2017-05-02. Available at https://thediplomat.com/2017/05/under-trump-a-looming-north-korean-icbm-threat-brings-alliance-decoupling-fears-back-to-east-asia/.

[84] *Memorandum of Conversation, US/MC/1, Paris, May 31, 1961, 12:30 p.m., President's Visit, Paris, May 31-June 2, 1961*. U.S. Department of State, 1961. Available at https://history.state.gov/historicaldocuments/frus1961-63v14/d30.

[85] Nuclear Threat Initiative: *Country Profiles: Israel*. Available at https://www.nti.org/learn/countries/israel/nuclear/.
[86] Correll J. T.: *Air Strike at Osirak*. Air Force Magazine. 2012-04-01. Available at https://www.airforcemag.com/article/0412osirak/.
[87] Follath E., Stark H.: *The Story of 'Operation Orchard' - How Israel Destroyed Syria's Al Kibar Nuclear Reactor*. Der Spiegel. 2009-11-02.
[88] Sanger D. E., Schmitt E., Bergman R.: *Long-Planned and Bigger Than Thought: Strike on Iran's Nuclear Program*. The New York Times. 2020-07-10. Available at https://www.nytimes.com/2020/07/10/world/middleeast/iran-nuclear-trump.html.
[89] Sanger D. E., Miller J.: *Libya To Give Up Arms Programs, Bush Announces*. The New York Times. 2003-12-20. Available at https://www.nytimes.com/2003/12/20/world/libya-to-give-up-arms-programs-bush-announces.html.
[90] International Atomic Energy Agency: *Joint statement by the Vice-President of the Islamic Republic of Iran and Head of the AEOI and the Director General of the IAEA*. Available at https://www.iaea.org/newscenter/pressreleases/joint-statement-by-the-vice-president-of-the-islamic-republic-of-iran-and-head-of-the-aeoi-and-the-director-general-of-the-iaea (dated 2021-02-25).
[91] Fassihi F., Sanger D. E., Schmitt E., Bergman R.: *Iran's Top Nuclear Scientist Killed in Ambush, State Media Say*. The New York Times. 2020-11-27. Available at https://www.nytimes.com/2020/11/27/world/middleeast/iran-nuclear-scientist-assassinated-mohsen-fakhrizadeh.html.
[92] *Nuclear Power in the United Arab Emirates*. Information Library, Country Profiles: World Nuclear Association, 2020. Available at https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates.aspx.
[93] *Nuclear Power in Saudi Arabia*. Information Library, Country Profiles: World Nuclear Association, 2020. Available at https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/saudi-arabia.aspx.
[94] International Atomic Energy Agency: *Safeguards Implementation Report 2019 – Summary*. Available at https://www.iaea.org/sites/default/files/20/06/statement-sir-2019.pdf.
[95] Schlosser E.: *Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Safety*: Penguin Group, 2013.
[96] *New satellite image of Chashma nuclear site in Pakistan*. ISIS Imagery Brief: Institute for Science and International Security, 2010. Available at https://isis-online.org/uploads/isis-reports/documents/Chashma_9July2010.pdf (dated 2010-07-09, accessed 2021-07-01).

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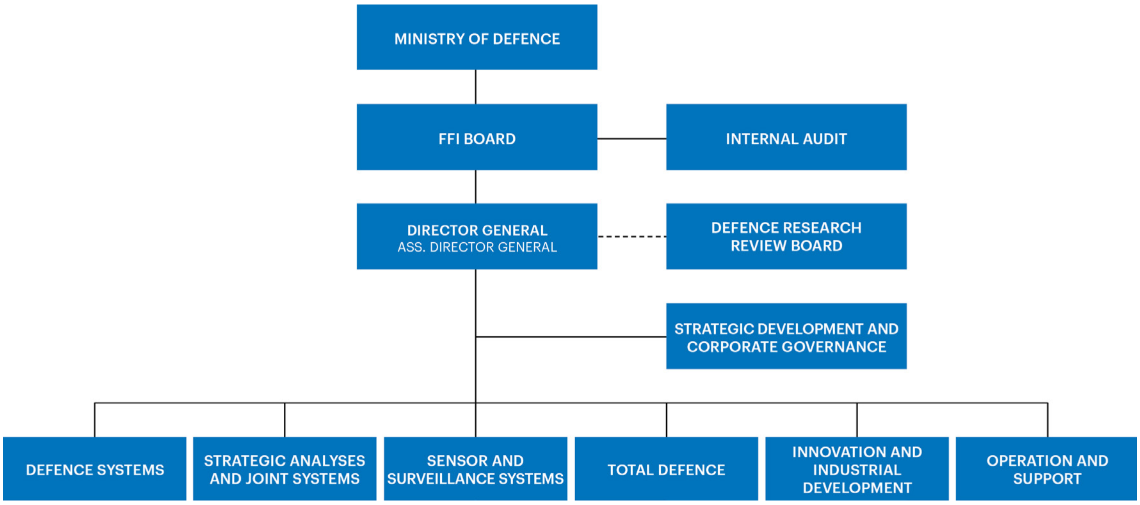

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