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Nuclear Non-Proliferation

1.1. Introduction

Nuclear weapons pose an immense risk to human beings, as well as to all living beings and to the environment. For this reason, many individuals and organizations have been working to limit the number of states capable of manufacturing this type of weapon.

UN efforts to prevent, or at least limit, nuclear proliferation are significant and ongoing. For example, the UN Security Council Resolution 1540 (April 28, 2004) echoes the terms of the UN Security Council's statement from January 31, 1992 by stating that "the proliferation of nuclear, chemical and biological weapons, as well as their means of delivery constitutes a threat to international peace and security". However, in this resolution, it is the risks associated with the acquisition of such weapons by "non-state actors" that are specifically targeted. Some analysts consider that this resolution may justify the use of force to combat proliferation [IRS 19b].

Unfortunately, and in spite of its efforts for 35 years, it is obvious that the UN's policy of nuclear disarmament has been a failure. The traditional vision of security that seems to be shared by the actors involved in the process of arms control and nuclear disarmament limits their capacity and willingness to abolish this type of armament [LAZ 06]. Hence, France and the United States are exerting strong pressure on the French-speaking states and on Japan to not sign the treaty on the Prohibition of Nuclear Weapons (TPNW).

In an interview with the IRIS (*Institut de Relations Internationales et Stratégiques*, the French Institute for International and Strategic Affairs), Jean-Marie Collin [COL 18b], expert and spokesman for ICAN FRANCE, an organization

awarded the Nobel Peace Prize in 2017, noted that nuclear weapons constitute a permanent and very real danger for the international community; otherwise, no treaty would have been signed at the UN, and the nuclear deterrent would be null and void. The International Committee of the Red Cross (ICRC) has stressed that no international plan or actor will be able to adequately address the needs of victims in the event of the use of nuclear weapons.

Nuclear weapons operate on the balance of terror. However, the problem with balance is that the risk of falling is always great. This "balance" is undesirable to an overwhelming majority of the world, because their security is directly at stake [COL 18b].

1.2. The first countries to acquire the atomic bomb

Five states have carried out their first atomic tests: the United States on July 16, 1945, the Soviet Union on August 29, 1949, the United Kingdom on October 3, 1952, France on February 13, 1960 and China on October 16, 1964.

In order to prevent the number of states possessing nuclear weapons from becoming too large, the United Nations has been concerned with nuclear disarmament from the outset, and four UN structures are particularly responsible for this task: the Security Council, the Disarmament Commission, the Conference on Disarmament and the Office for Disarmament Affairs [GIL 18].

The Security Council has primary responsibility under the UN Charter for the maintenance of international peace and security. It is composed of five permanent members (China, France, the Russian Federation, the United Kingdom and the United States) and 10 non-permanent members elected by the General Assembly for a period of two years. The general organization of the UN is shown in Figure 1.1.

The United Nations Disarmament Commission (UNDC) was established in 1952, within the framework of the Security Council, by General Assembly Resolution 502 (VI), to deal with disarmament issues. However, it only met occasionally after 1959. In 1978, the first special session of the General Assembly devoted to disarmament established a new Disarmament Commission as a subsidiary organ of the Assembly, composed of all UN member states of the Organization. It was established as a deliberative body to consider various disarmament issues and monitor the implementation of the relevant decisions and recommendations adopted

at the special session. It sits in New York for three weeks each year (usually in early spring). It considers a limited number of agenda items on a three-year cycle and submits an annual report to the General Assembly [GIL 18].

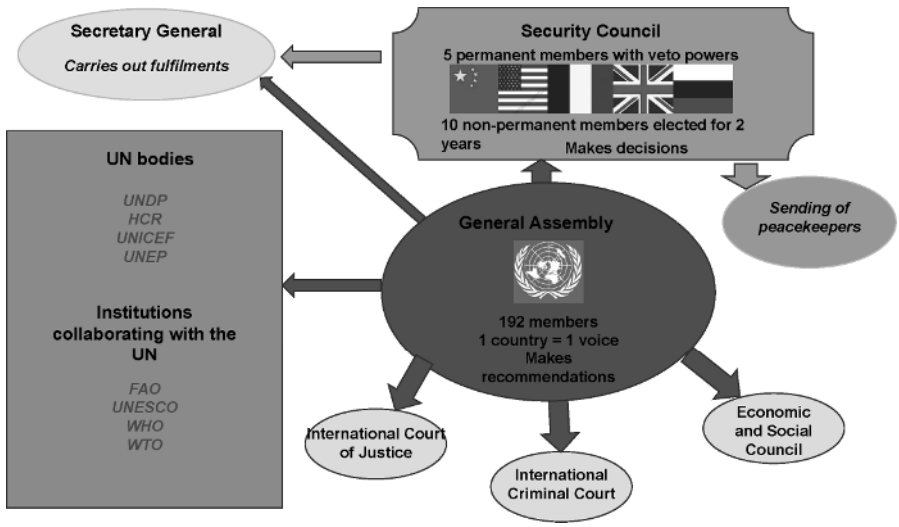

Figure 1.1. *The United Nations organization. For a color version of this figure, see www.iste.co.uk/amiard/disarmament.zip*

The Conference on Disarmament is the only multilateral forum for negotiating disarmament agreements. It is composed of 65 permanent members who hold three sessions a year in Geneva (usually January to March, May to June and August to September). It operates on the basis of consensus to ensure full support for the agreements reached. It has completed negotiations on the Comprehensive Nuclear-Test-Ban Treaty, but has not yet entered into force [GIL 18].

The Office for Disarmament Affairs, established in 1982, works to promote disarmament and non-proliferation and to strengthen disarmament regimes. Part of its work focuses on nuclear weapons [GIL 18] (Figure 1.2).

The first treaty limiting the use of weapons (particularly nuclear weapons), the Antarctic Treaty, signed in Washington, entered into force on June 23, 1961. This treaty stipulates that the Antarctic is an area exclusively reserved for peaceful purposes and prohibits all activities of a military nature, such as military maneuvers and the testing of any kind of weapon.

Figure 1.2. *The various UN bodies working on non-proliferation and disarmament. UNODA: United Nations Office for Disarmament Affairs. For a color version of this figure, see www.iste.co.uk/amiard/disarmament.zip*

1.3. The NPT

The International Treaty on the Non-Proliferation of Nuclear Weapons (NPT) was developed within the UN by the Eighteen-Power Committee on Disarmament. Concrete negotiations lasted three years, from 1965 to 1968. The text was mainly drawn up by the United States and the Soviet Union. On July 1, 1968, the treaty was opened for signature in Moscow, Washington and London. It entered into force on March 5, 1970 after ratification by the three depositary Powers and 40 other signatory states [AIE 70].

For the treaty itself, the parties had to decide on its extension 25 years after its entry into force. Despite the reluctance of some non-aligned countries (Mexico and Indonesia) and Arab countries (because of Israel's absence from the treaty), the NPT was extended indefinitely on May 11, 1995 [IRS 19a].

The NPT is now close to universality, with 191 states as members. Only four states have not joined: India, Israel, Pakistan and Southern Sudan. However, in January 2003, North Korea initiated a procedure to withdraw from the treaty [FRA 19b].

1.3.1. *The functioning of the Treaty*

In the operation of the NPT, states are divided into two categories. The first category consists of the nuclear-weapon states (NWS). These are the five official nuclear powers (United States, Russia, United Kingdom, France, China), which according to Article IX "*had manufactured and detonated a nuclear explosive device prior to 1 January 1967*" and are entitled to possess such weapons. The second category includes all non-nuclear weapon states (NNWS), which make up the rest of the NPT membership. For the purpose of control or safeguarding, this last category is divided into two sub-categories depending on whether or not the states have access to nuclear facilities (see section 4.1.1).

For many years, this NPT has not been functioning well. This is mainly due to non-compliance with two clauses. The first clause is the non-implementation of a process to create a zone free of nuclear weapons and weapons of mass destruction in the Middle East. The second clause is related to the hypocrisy of the five weapon states, who do not respect the spirit and letter of the NPT. Indeed, while no one can deny that the nuclear arsenals of these states, with the exception of China, have indeed decreased since the Cold War, it must also be noted that all of these states have undertaken processes of modernizing nuclear weapons and delivery systems.

This treaty seems to have reached its maximum effectiveness with regard to the two pillars of non-proliferation and the peaceful use of nuclear energy, but it seems limited in effectively forcing the NWS to implement the third pillar, that of a real disarmament policy [COL 15].

1.3.2. *Revision of the NPT*

This treaty is subject to a Review Conference (RevCom) every five years: the next one was due to take place in 2020, interspersed with three so-called Preparatory Conferences (PrepCom). The RevCom is an opportunity to take stock of the progress made in the past and the future of the treaty in a roadmap, which is called the Final Document [COL 15].

1.3.3. *Successes of the NPT*

The main success of the treaty is South Africa's renunciation of nuclear weapons. The first, and only South African nuclear research reactor is the SAFARI-1 (South African Fundamental Atomic Research Installation 1), built between 1961 and 1965 on the Pelindaba site. This site also housed a reprocessing plant (Plant Y). The country also had a secret military program for the South African Defence Force, abandoned by the ratification of the Treaty on the Non-Proliferation of Nuclear Weapons before the African National Congress came to power. The six aerial atomic bombs with a power of 15 to 20 kt, built between 1982 and 1989, and a seventh, which was under construction, were dismantled before 1993 [TOU 13].

Historically, the AEC (Atomic Energy Corporation) had two sites – Valindaba, for the production of highly enriched uranium (HEU) and Pelindaba, for research. The ARMSCOR (Armaments Corporation of South Africa) depended on the Ministry of Defense with two sites – Kentron and Naschem. The production of highly enriched uranium by the South African enrichment plant Y in 1994 was 993 kg (enriched on average to 68% in ^{235}U), of which 515 kg were enriched to 85% in ^{235}U [ALB 16].

South Africa's only nuclear test likely occurred in 1979. On the night of September 22, 1979, a double flash was spotted off the Prince Edward Islands by the American satellite Vela 6911. The double flash of light is the signature of an atmospheric atomic explosion. The initial flash burst at the start of the explosion and corresponded to a fireball. Then, the glow was obscured for a fraction of a second by the shock wave, which made the atmosphere opaque. Then, when the cloud dissipated, the second flash appeared. Since South Africa was the only power in the region with the means to enrich uranium, it was immediately suspected, but foreign support, possibly Israeli, was also envisaged [BAT 18].

South Africa's disarmament program was complicated by its division State into two countries (South Africa and Namibia) [DZI 17].

The program to dismantle South Africa's nuclear program began with the dismantling of the six nuclear weapon devices and the seventh, which was in production. The highly enriched uranium was returned to the AEC to be kept under secure surveillance. The second stage was the complete decontamination of the Armscor installations (1990–1991) and the return of highly contaminated equipment, such as melting furnaces, to the AEC. Advena/Circle's facilities were converted into commercial civil or military activities, but with conventional weapons: the destruction and disposal of non-nuclear components, as well as engineering design and manufacturing information provisions. South African nuclear officials informed the de Klerk government of an appropriate timetable for

the state's accession to the NPT, the signing of a comprehensive safeguards agreement with the IAEA (International Atomic Energy Agency), and the submission of a complete national inventory of nuclear materials and facilities, as required by the safeguards agreement. Finally, the closure of plant Y was to take place as soon as possible [ALB 16].

Other countries have developed nuclear programs in the past: Brazil, Algeria, Libya, Ukraine, Sweden, Belarus and Kazakhstan, but have abandoned nuclear deterrence.

1.3.4. *Failures of the NPT*

Despite the NPT's entry into force, four countries have since acquired atomic weapons (Israel, India, Pakistan and North Korea).

Israel has always used deliberately ambiguous language with respect to nuclear weapons and has refused to sign the NPT. The only public revelation of Israel's nuclear capabilities was made by a former Dimona nuclear power plant technician, Mordechai Vanunu, in the Sunday Times on October 5, 1986 [COH 05].

Historically, Israel benefited from French aid, between 1956 and 1961, for scientific advice for the construction of the Dimona reactor, as well as the supply of many nuclear materials by the British between 1950 and 1960. Between 1961 and 1969, American experts visited Israeli installations, but with advanced notice of their arrival. This made it possible to camouflage the real activities of the installations. In 1969, President Richard Nixon agreed to allow Israel to possess nuclear weapons, on the condition that it would not conduct nuclear tests or display its nuclear warheads [COH 98, BIA 09, COH 10, TÉN 10].

No nuclear tests have been officially recognized. However, it is possible that an underground test took place in 1963 in the Negev desert, as well as a 3 kt atmospheric test in 1979 in South African waters, in collaboration with South Africa (double Vela flash). Indeed, on September 22, 1979, the American satellite Vela 6911 detected an optical signal characteristic of an atmospheric nuclear explosion over the southern Indian or Atlantic Ocean. Weiss believes that the flash was an Israeli nuclear test assisted by South Africa [WEI 11]. In a new analysis of radionuclide and hydroacoustic data, it was concluded that the double flash resulted from a low-yield nuclear weapon test [DEG 18]. Among the evidence put forward by these authors, the concentration of iodine-131 found in the thyroids of some Australian sheep could suggest that they had grazed grass in the path of a potential radioactive fallout plume from this test.

In September 1996, when the Comprehensive Test Ban Treaty was signed, it was reasonable to believe that this would become a general rule of behavior accepted by all states. However, in May 1998, India and Pakistan defied the international community by conducting nuclear tests. Faced with the new risk of a regional nuclear conflict involving Kashmir in particular, the Western powers needed to integrate these two states into the nuclear non-proliferation regime. There were only two ways to do this: sanctions or dialogue. However, India and Pakistan were no longer ordinary states that could be dictated to. They had become nuclear powers with all that this implies in terms of prestige and political weight on the international scene [CAP 98].

India developed a nuclear program as soon as it gained independence in 1948, with the adoption of the Atomic Energy Act, aimed at developing nuclear energy for peaceful purposes. Today, India is not a signatory to the Nuclear Non-Proliferation Treaty (NPT), but has more than 20 nuclear reactors, mainly Canadian-designed CANDU pressurized heavy water reactors.

India's Atomic Energy Commission detonated its first underground nuclear weapon, the Smiling Buddha, at a depth of 100 meters in Pokharan on May 18, 1974. This led to the cessation of all forms of international cooperation in favor of India's civilian program and exclusion from the Nuclear Non-Proliferation Treaty (NPT). Subsequent nuclear tests took place underground on May 11 and 13, 1998. India conducted three tests on May 11, testing an A-bomb and an H-bomb, and two more tests on May 13, using small charges [CAP 98]. In 2018, the Indian Nuclear Deterrent Air Force had 48 nuclear warhead-launching aircrafts, 60 ground-based ballistic missiles, and about 18 cruise missiles for a total of 130–140 nuclear bombs [KRI 18a].

Pakistan (Islamic Republic) began its nuclear program in January 1972. This program was originally a response to India's development of nuclear weapons. The military nuclear program began in 1987. Pakistan's first underground nuclear test was conducted on May 28, 1998, codename Chagai-I (Chagai district, Balochistan province). This test was a series of five low-power nuclear tests. The second test (Chagai-II), took place in the Kharan desert two days later. The power was equivalent to 12 kt of TNT. Of the six tests, one used plutonium and the others used enriched uranium. Pakistan, which is not a signatory of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), thus became the seventh country in the world to develop and test nuclear weapons and is also the only Muslim country to possess nuclear weapons.

Its capacities have not been made public, leading to estimates. Thus, in 2013, one source indicated that the Pakistani armed forces possessed 300 to 350 nuclear

warheads (Le Monde, June 3, 2013), compared to around 50 in 2007, while SIPRI estimated Pakistan's arsenal to be 250 to 300 warheads in 2017, much higher than India [GAI 17, SIP 18].

The Indian and Pakistani nuclear programs can be explained by the exacerbated rivalry between the two states. In addition, the Pakistani nuclear physicist A.Q. Khan, has established strong nuclear proliferation ties with Iran, North Korea and Libya because of his personal motivations, religious orientation and anti-Western worldview [ABB 18]. The Pakistani people were overcome with fever dreams for the future and were very proud after the first atomic tests. However, in India, the population was more reserved about the Indian tests and regretted the practice of secrecy in this field [ABR 09].

The third failure of the NPT is that of North Korea, which after signing the treaty withdrew from it. In October 2006, North Korea announced that it had detonated its first nuclear bomb. Other tests were carried out in 2009, 2013, 2016 and 2017. The best estimate of the stocks of highly enriched uranium (HEU) in the Yongbyon nuclear complex at the end of 2015 were between 75 and 320 kg [BRA 18].

In order to stop this North Korean nuclear program, in the early 1990s, successive American presidents tried to negotiate with the North Korean government. American decision-makers were left asking themselves about the usefulness of such a negotiation, the timeframe and the objectives of these diplomatic talks with Pyongyang.

The United States began four major rounds of formal nuclear and missile negotiations with North Korea. These were the bilateral framework (1994–2002), bilateral missile negotiations (1996–2000), multilateral Six-Party Talks (2003–2009) and bilateral Leap Day Deal negotiations (2012). In general, North Korea agreed, ostensibly, to end, or even deactivate its nuclear and/or missile programs in return for economic and diplomatic incentives. But despite some progress in some negotiations, North Korea has continued to advance its nuclear and missile programs [NIK 17].

In April 2018, Pyongyang announced the end of its nuclear tests, and in June 2018, an official meeting between Donald Trump and Kim Jong-un took place in Singapore. On June 30, 2019, another historic meeting between the US and North Korean presidents took place on the border between North Korea and South Korea. However, no specific agreement has been reached.

1.3.5. *Future nuclear-weapon states*

Alongside these four states that have acquired nuclear weapons, nuclear proliferation has been observed in several countries. This is developed in section 4.1.3.

The fact that Israel is the only state in the Middle East that possesses nuclear weapons, and that this state enjoys privileges at the UN and the IAEA, since no control is exercised over its production of fissile material, nor over these nuclear weapons, inevitably leads to strong tension in this region. Also, there are many candidates to acquire nuclear weapons. The first candidate is Iran, which has begun to enrich uranium and has a missile program. Among the other postulants is Saudi Arabia, which is anxious to thwart Iran's influence in the Near East. This state is supported by the United States in this desire. This is obvious and by issuing authorizations for the transfer of American nuclear technology to Saudi Arabia, without any guarantee of non-proliferation, the American president at the time (Donald Trump) was provoking Iran [TIS 19].

1.4. Other nuclear non-proliferation treaties

Three international treaties and several regional treaties restrict the use of nuclear weapons.

1.4.1. *The CTBT Treaty*

In January 1946, the first General Assembly resolution specifically called for the elimination of all nuclear and other similar weapons "capable of being used for purposes of mass destruction", including biological and chemical weapons.

Among the solutions available to the UN, a nuclear test ban can be a very effective way to prevent horizontal proliferation (to states) and vertical proliferation (improvement of nuclear weapons). This solution is not a panacea but could help to limit the number of nuclear weapons.

According to Duarte, a test ban has three advantages. First, it makes it possible to prevent certain forms of "vertical proliferation", in particular, the development of new generations of nuclear weapons or the modernization of existing arsenals. Second, it helps to begin the process of dismantling the complex institutional infrastructures that have been put in place to develop and maintain these arsenals. Third, a ban also contributes to the process of delegitimizing nuclear weapons

themselves, in the eyes of the world, and thus makes it more difficult for policy makers to support the need for nuclear deterrence [DUA 19].

Prior to the Comprehensive Nuclear-Test-Ban Treaty (CTBT), five other anti-nuclear test treaties had been signed. The first Partial Test-Ban Treaty, signed on August 5, 1963, prohibited nuclear explosions in the atmosphere, under the seas and in outer space. Its main purpose was to stop radioactive substances from contaminating the environment. The second treaty signed on January 27, 1967 prohibited the placement of nuclear weapons or weapons of mass destruction in space. It entered into force on October 10, 1967. The third treaty, signed on February 11, 1971, prohibited the introduction and placement of nuclear weapons or other weapons of mass destruction on the seabed and ocean floor and in the subsoil. It entered into force on May 18, 1972. The fourth treaty concerned the limitation of underground testing, and was signed on July 3, 1974. The fifth treaty, signed on May 28, 1976, prohibited underground explosions for peaceful purposes. Finally, on September 24, 1996, the CTBT Treaty was signed [COL 19b, IRS 19b].

The Comprehensive Nuclear-Test-Ban Treaty (CTBT), along with the Non-Proliferation Treaty (NPT), is now one of the pillars of the global nuclear non-proliferation structure.

Negotiations took place between 1994 and 1996 and the treaty was opened for signature on September 24, 1996. As of May 1, 2019, only 184 states have signed the CTBT and it has only been ratified by 168 of them. In order for the treaty to enter into force, the negotiators defined, among other things, a list of nuclear-capable countries whose ratification was indispensable (regardless of the number of states that had ratified the treaty elsewhere). These were the 44 so-called Annex 2 states. As of May 1, 2019, eight Annex 2 states had not yet ratified the treaty: Iran, the United States, China, Israel, Egypt, India, Pakistan and North Korea, the last three of which were also expected to sign [RÉP 19].

1.4.2. *The TPNW*

Faced with the non-compliance of one of the pillars of the NPT, effective nuclear disarmament, the non-nuclear weapon states decided to start drafting a new treaty at the level of the UN General Assembly. This made it possible to bypass the undertakings of the five nuclear powers that were hindering this disarmament.

The International Treaty on the Prohibition of Nuclear Weapons (TPNW) was the first multilateral treaty on nuclear disarmament, open for signature in 1996, and is supported by a very large majority of UN member states. It was written by diplomats whose ambition was to both respect the mosaic of treaties that codify

nuclear weapons (NPT, CTBT and the future FMCT), in accordance with the safeguarding system currently being formulated by the IAEA, and to move the international community towards a world without nuclear weapons [COL 18a].

In the last decade or so, nuclear weapons have been reclassified, thanks to the humanitarian initiative, as weapons with catastrophic humanitarian consequences. This has led to a change in consciousness. The illegality of nuclear weapons, as well as the illegality of the policy of threatening to use them, appears shocking to the states that possess them because they have not yet made their "moral revolution". The rest of the world is now aware that the presence of these weapons is no longer acceptable and that they are generating growing insecurity, particularly because of their potential humanitarian, environmental and climatic impact at the global level [COL 18a].

On July 7, 2017, an International Nuclear Weapons Ban Treaty was adopted at the UN. Approved by 122 states and ratified by 50 nations on October 24, 2020, it entered into force on January 22, 2021. Historically, this text will prohibit signatory countries from manufacturing, stockpiling or using nuclear weapons. Will the threat to use these weapons, i.e. the policy of deterrence, also become prohibited [SOR 18]?

It should be noted that many states are revising their policy on nuclear weapons. This is the case for the Vatican, for example. For many years, this state accepted nuclear deterrence as a "tragic illusion" (Paul VI, June 7, 1978), as "a step on the road to progressive disarmament, can still be considered morally acceptable" (John Paul II, June 7, 1982) or as "the prospect [of deterrence based on balance], apart from being fatal, is utterly fallacious" (Benedict XVI, January 1, 2006). Pope Francis, on the contrary, has a much stronger stance on rejecting the use of atomic weapons and balanced nuclear deterrence.

States that possess nuclear weapons, or support a policy of deterrence, can no longer afford to question their understanding of nuclear disarmament. The Nuclear Weapons Treaty offers them this opportunity. This norm of international law exists and is likely to enter into force around the 10th NPT Review Conference (scheduled for May 2020, although it has been postponed). The (non-exhaustive) proposals set out in Annex 1 offer some ideas on how to overcome some of the misunderstandings and demonstrate a common will among states to move forward together and create a world free of nuclear weapons [COL 18a].

1.4.3. *The Fissile Material Cut-Off Treaty (FMCT)*

The treaty banning the production of fissile material or other nuclear explosive devices (FMCT or " Cut-off ") is an old draft of the UN General Assembly. It was

on December 16, 1993 that this Assembly adopted a resolution (A/RES/48/75L) that called for the opening of negotiations to elaborate such a treaty. The reasoning was simple: stopping the production of fissile materials (military plutonium or ^{239}Pu and highly enriched uranium) constitutes one of the essential locks of nuclear proliferation.

For more than 20 years, the Disarmament Conference (DC) has been working on the text of this treaty. Several drafts have been submitted by France and Canada. However, the impasse in which the DC still finds itself today is due to the abuse of the consensus rule, which allows any state to block the progress of work for any reason whatsoever.

The main causes of divergence on this treaty concern the delimitation of the scope for negotiating this prohibition. Egypt and Pakistan want the stockpiles of nuclear-weapon states (NWS) to be taken into account, which the five strongly reject. China wants to increase its stockpile in the face of India's expanding stockpile. The same is true for Pakistan with regard to India. France has always been favorable and actively supports the process of creating this treaty, but its stockpile (30.6 tons of highly enriched uranium and 6 tons of plutonium 239) would allow it to produce several thousand nuclear weapons [COL 15]. For nearly 15 years, France has been strongly committed to the negotiation of a treaty banning the production of fissile material for nuclear weapons, known as the Cut-Off Treaty. This is one of the French proposals for disarmament, announced by the President of France in his speech in Istres on February 19, 2015 [FRA 15, FRA 19a].

In spite of this lack of progress, there is hope, however, with the shifting of discussions to the level of the General Assembly. In October 2012, the UN General Assembly voted in favor of a Canadian-sponsored resolution that established a Group of Governmental Experts (GGE) on TIPMF. In 2016, the UN General Assembly adopted another resolution introduced by Canada, and co-sponsored by Germany and the Netherlands, establishing a 25-member High-Level Preparatory Group of Experts (Preparatory Group) to build on the work of the GGE and make recommendations on the substantive elements of a treaty being prepared for negotiation [UN 17a, UN 17b].

At its last meeting in June 2018, the Preparatory Group successfully negotiated a consensus report recommending the elements of a future treaty. The UN Secretary General transmitted this report to the DC in the hope that they will begin formal negotiations on a treaty that will help end the global nuclear arms race [GOU 18].

1.4.4. *Regional disarmament treaties*

Nuclear-Weapon-Free Zone Treaties represent a regional approach to strengthening international norms for nuclear non-proliferation and disarmament, coupled with the promotion of international peace and security.

In 2016, there were five nuclear-weapon-free zones established under different treaties: (a) Latin America and the Caribbean, under the Treaty of Tlatelolco; (b) the South Pacific, under the Treaty of Rarotonga; (c) Southeast Asia, under the Treaty of Bangkok; (d) Africa, under the Treaty of Pelindaba; and (e) Central Asia, under the Treaty of Semipalatinsk.

The Treaty of Tlatelolco was the first international instrument establishing a nuclear-weapon-free zone in a densely populated part of the world.

In addition to these regional zones, the UN recognized Mongolia's self-proclaimed nuclear-weapon-free status by adopting the biennial General Assembly resolution entitled "Mongolia's international security and nuclear-weapon-free status".

In 2018, the treaties of Tlateloko and Ranotonga were signed and ratified by the five nuclear powers. The treaties of Pelindaba and Central Asia have been signed by all five powers, but the United States (alone) has not ratified them. The Treaty of Bangkok is in the process of being signed. The text of these treaties and the list of countries that have acceded to them are available at: http://disarmament.un.org/treaties/ [ONU 18]. The geographic scope of these regional treaties is shown in Figure 1.3.

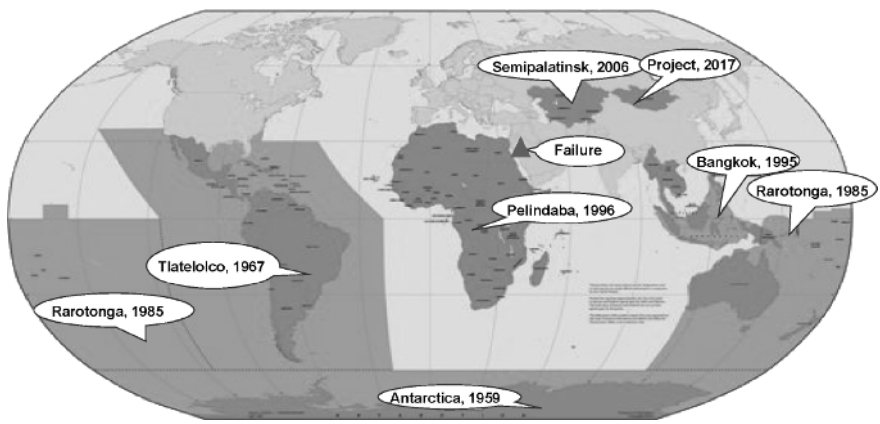

Figure 1.3. *The various regional treaties banning nuclear weapons. For a color version of this figure, see www.iste.co.uk/amiard/disarmament.zip*

1.5. Disarmament controls

The best treaty in the world is worthless if it is not respected and if all parties cannot verify its application. All confidence lies in the effective verification of nuclear disarmament. The main role of a verification system is the same for all arms control treaties, namely, to deter cheating [GOL 07]. Depending on the treaties, verification can be carried out at the international level or bilaterally. International controls mainly concern the NPT and CTBT.

1.5.1. *Principle and practice of disarmament controls*

Disarmament controls are not easy because a large number of factors interfere with them. However, the technologies that serve these controls are increasingly effective.

1.5.1.1. *General*

The verification of nuclear disarmament is influenced by a multitude of factors. First, international politics and inter-state relations play an important role in the design of verification systems, determining which verification techniques can be used and how and when they can be applied. This leads to a compromise between different positions that may not necessarily represent the best technical solution to the various verification problems.

Even within a particular state, different national interest entities may disagree on interpretations and practical aspects of compliance. Some will view violations, or even ambiguities, as clear evidence of deliberate fraud, while others will interpret them as minor and unavoidable oversights or unintended consequences.

In the construction of nuclear verification systems, there is a necessary tension between the levels of intrusiveness and the need to prevent the disclosure of militarily or commercially sensitive information. In the early days of verification, this balance was oriented towards the protection of information, either through the use of national technical means alone, or through a limited number of on-site inspections. Subsequently, verification systems became more intrusive and on-site inspections have become an essential element of nuclear verification regimes, even at sensitive military facilities.

In the context of bilateral disarmament efforts undertaken by the United States and Russia, the potential benefit of fraud through misrepresentation is derisory since both sides have retained large arsenals of nuclear weapons. On the contrary, withholding weapons in small numbers during dismantlement could be a significant

strategic advantage for states with limited nuclear arsenals. The case of South Africa's total nuclear disarmament is a hopeful one [BOW 18].

The main issues that need to be considered when verifying the dismantlement of nuclear warheads, are counting and avoiding theft. To do this, it is necessary to ensure the chain of traceability and monitor the access portal to the storage site. Several technical solutions have been implemented (managed access, use of labels and seals, information barrier). During exercises between the United Kingdom and Norway (UKNI, United Kingdom–Norway Initiative), the unexpected result was that human factors could also have a decisive influence on the verification process and its results. This is likely due to the fact that the verification process is characterized by a constant tension between trust, perceived as an evidence-based judgment by informed actors, and confidence, perceived as the perception of intentions in a situation where evidence is lacking [BOW 18].

Some experimental simulations on disarmament verification have been carried out. The design of this simulation was the key element of the preparatory work that formed the basis of the research and required a considerable investment of time and resources. However, this approach offers a flexible way to recreate real-life challenges and problems in an artificial environment that can be, in part, controlled and targeted.

In these simulations, everything from the attitude of the host team, to the manner and speed with which information was provided, was a potential indicator of intentions and was incorporated into the research participants' interpretation scheme. This intellectually demanding cognitive process encompassed the more objective and scientific, evidence-based approach that all participants aspired to experience. Since trust is indeed a crucial influence on the results of verification, it would be simplistic, even dangerous, to only view verification in terms of a purely technical nature, based only on scientific evidence [BOW 18].

1.5.1.2. *Technologies at the service of disarmament*

Future nuclear arms reduction efforts will require technologies that can verify that the warheads to be dismantled are genuine, without revealing any sensitive warhead design information to international inspectors.

How can a claim be proved about an extremely sensitive object, a nuclear weapon, for example, without revealing information about it? This paradox has been challenging the control of nuclear weapons for more than five decades. A mechanism in the form of an interactive evidence system has been proposed, that can validate the structure and composition of an object, such as a nuclear warhead, with arbitrary precision, without revealing its structure and composition [KEM 16].

Confirming the authenticity of nuclear warheads and their components is at the heart of the challenge of verifying future reductions in nuclear arsenals. An overview of the development of verification systems and the challenges and opportunities highlighted for future research in this area are provided in [YAN 15].

For a long time, low-resolution gamma spectrometry (sodium iodide crystal probes) has been used in verification systems. Thus, the programs CIVET (Controlled Intrusiveness Verification Technology) from 1998 to 1991, TRIS (Trusted Radiation Identification System) from 1999 to 2001 and NG-TRIS (Next Generation Trusted Radiation Identification System) since 2007 have been successively used. Since 1984, the FNMIS (Fieldable, Nuclear Material Identification System) has used neutron activation. The parameters most frequently sought are the presence of plutonium, its various isotopes, its mass or its age, and sometimes the presence of uranium 235, its enrichment or its mass. Recently, some authors have proposed the use of intensities of nuclear resonance fluorescence (NRF) close to 2.2 MeV to distinguish between real computer objects and hoax objects, with great confidence and realistic measurement times [VAV 18].

A concept that exploits isotope-specific nuclear resonance phenomena in order to authenticate the fissile components of a warhead by comparing them to a previously authenticated model, has been submitted [HEC 18].

Most of the plutonium in the world resides inside the rods of spent fuel from nuclear reactors. Only the United States, France and Japan have isolated and stored plutonium. This high-activity radioactive waste is generally stored long term in large, heavily shielded casks. The measurements of the diffusion angles of cosmic muons that pass through a storage cask can be used to determine whether the radioactive waste in the casks is in the form of intact spent fuel assemblies, or whether the plutonium has been recovered by reprocessing, without opening the cask [DUR 18].

1.5.2. *NPT controls*

The NPT has been the subject of an impressive number of agreements between states and the IAEA to improve disarmament controls. While there have been some successes, there have unfortunately been some resounding failures.

1.5.2.1. *NPT guarantees*

The UN has entrusted the IAEA with the task of monitoring the application of the NPT, known as safeguards. States are divided into three groups, the five nuclear-weapon states (NWS), the non-nuclear weapon states (NNWS) and the three states (India, Israel and Pakistan) that have not signed the NPT Treaty.

There are four main types of guarantee agreements: General Guarantee Agreements (GGAs), Limited Guarantee Agreements, Voluntary Submission Agreements (VSAs) and emergency measures.

The Generalized Guarantee Agreements concern all the NNWS and the text is the result of compromises, in order to encourage the NNWS to adhere to this new control regime. In order to provide an appropriate and identical legal framework for all signatories, a model Comprehensive Safeguards Agreement, INFCIRC/153 (corrected 1983), was developed in 1971 [AIE 75] by a committee of experts from IAEA Member States. This GGA is currently in progress with 174 NNWS. However, because of Iraq's clandestine military nuclear program, in 1997 it was decided to reinforce the verification standard by an Additional Protocol (AP, i.e. INFCIRC/540) [IEA 97]. This AP – which remains optional – ensures faster access to suspect sites for IAEA inspectors and better control of nuclear materials. As of December 2015, the IAEA had concluded five VSAs and APs, 173 GGAs, 121 APs and three Elemental Agreements. As of December 21, 2018, 134 states have adhered to the AP standard and 14 are in the process of implementation [COL 18].

Limited Warranty Agreements are reserved for certain states (India, Israel, Pakistan), which have not signed the NPT. They have concluded more limited safeguards agreements with the Agency (of the INFCIRC/66 type), which only apply to nuclear material, equipment, non-nuclear material and facilities specified by the agreement (thus designated by the state).

Voluntary Submission Agreements (VSAs) are reserved for NWS that are not required to enter into a safeguards agreement with the Agency. All five states have done so. France, for example, has signed a safeguards agreement modeled on the Comprehensive Safeguards Agreements concluded between the IAEA and the NNWS. Under this agreement (INFCIRC/290), signed on July 27, 1978, France subjects the nuclear material it designates in selected facilities, or parts of facilities, to IAEA safeguards. To take account of the safeguards exercised by the EURATOM, the safeguards agreement concluded by France is trilateral in nature, with EURATOM being a party to the agreement.

The emergency measures decreed by the IAEA concerned three points (declaring a new nuclear installation within 180 days; declaring international transfers and the production of uranium and thorium concentrates; effectively resorting to special inspections) [IRS 19a].

IAEA controls under the NPT Treaty are called "purpose" controls. Their objectives are to ensure that nuclear material in the agency's custody is not used for non-peaceful purposes. Since the Additional Protocols' entry into force, the agency's controls are no longer limited to nuclear material, but extend to the provision of information concerning the nuclear industry.

1.5.2.2. *The various types of collaboration between states to verify disarmament*

Article VI of the NPT states, among other things, that each party to the NPT must undertake effective measures in the field of arms control and disarmament of nuclear weapons.

As a result of the 1996–2002 joint project of the Russian Federation, the United States and the IAEA, called the "Trilateral Initiative", the partners proposed an innovative method for IAEA verification of fissile material in support of nuclear disarmament to the IAEA [SHE 15].

In early 2007, representatives from the UK Ministry of Defence, the Atomic Weapons Establishment, several Norwegian laboratories and the non-governmental organization VERTIC (Verification Research, Training and Information Centre) began work on the best techniques for the verification and control of the effective disarmament of nuclear weapons. This was the first time that a nuclear-weapon state, a non-nuclear weapon state and an independent NGO collaborated in this area of research. This work was presented at the 2009 NPT PrepCom [UKN 10b].

The results of three years of collaboration between experts from Norway and the United Kingdom, to study the technical and procedural problems associated with a possible nuclear disarmament verification regime, were presented in a report. The report encourages the international community as a whole to contribute to the ultimate goal of an effective verification regime for the dismantlement of nuclear weapons [UKN 10a].

In 2010 and 2011, the United States and the United Kingdom undertook a warhead monitored dismantlement (WMD) exercise to investigate the methods for two nuclear-weapon states to verify compliance with an arms reduction treaty. The two fictitious countries negotiated the use of NDA (non-destructive analysis) and CoC (chain-of-custody) measuring equipment [HAU 16].

1.5.2.3. *Practical implementation of NPT safeguards*

By having early detection of the theft of nuclear materials or the misuse of nuclear technology, the IAEA can alert the world to a proliferation risk [AMA 16]. Through safeguards, the IAEA provides credible assurance that states only use

nuclear material and technology for peaceful purposes in accordance with their international obligations.

In 2015, the IAEA conducted 2,118 field inspections, collected 967 environmental and nuclear material samples, observed 1,416 surveillance cameras and 407 satellite images through a network of 20 certified laboratories and 883 staff. This enabled it to provide safeguards at 1,286 nuclear facilities.

The implementation of the safeguards is carried out in four steps. The first stage is the collection and evaluation of information about a state. The second step is the development of a monitoring methodology specific to that state. The third step is the planning of safeguards to be carried out in both the field and the Agency's headquarters. The final step is the establishment of a safeguards conclusion for each state [AIE 16a].

A safeguards inspector must perform three types of verification at each nuclear facility. These are to verify the integrity of the reactor seals, to control the correct storage of new and spent fuel and the correct operation of surveillance cameras [HEN 16].

Technicians mainly have five handheld instruments at their disposal to carry out their inspection. An HM-5 (detector of multiple alpha, beta, gamma and neutron radiation) can detect the presence of radioactive materials and the enrichment of uranium. The second is a force sensor that operates in two ranges (up to 5,000 kg and up to 20,000 kg). The third instrument is an electrically cooled germanium gamma radiation detection system; the fourth is an ultrasonic thickness gauge. Finally, there is an attribute tester (gamma ray detector) of irradiated elements for underwater fuel, or a digital device for the observation of the Chernenkov effect, which remains dry and protected from water, associated with a camera that detects ultraviolet radiation emitted by spent fuel assemblies.

In the case of additional protocols, inspections require a special toolkit. The toolkit contains all kinds of instruments to collect information and verify reports: a camera, laser meter, GPS, voice recorder, flashlight, universal radiation meter, such as the HM-5 and an environmental sampling kit [FOU 16a].

The IAEA monitors more than one million sets of encrypted data that are collected by more than 1,400 surveillance cameras and 400 radiation sensors around the world. The containment of materials and equipment is ensured by more than 23,000 seals installed at nuclear facilities.

The IAEA's Next-Generation Surveillance System (NGSS) uses cameras that are protected by casings designed to reveal any attempt at tampering, and are equipped with long-life batteries that ensure their autonomy in the event of an absence of an external power supply for extended periods of time. Approximately 160 systems, with a total of 700 detectors and sensors, are installed in more than 40 countries.

Different types of automatic systems are used, depending on whether it is an enrichment facility, a reactor, a spent fuel storage site or a reprocessing plant.

The IAEA seals are the best known and most widely used safeguarding equipment. Despite their simplicity, these anti-fraud devices are highly effective in preventing unauthorized access to IAEA safeguarding materials and equipment. The IAEA uses several types of seals depending on the case. Some are designed to be installed underwater, others can withstand extreme conditions. The most common seals are metal seals, as well as Cobra seals, which incorporate a multi-core fiber optic cable whose ends are protected by the seal. There are also electro-optical seal systems and laser systems for containment verification [FOU 16b].

The IAEA's scientific safeguards depend on the laboratories located in Seibersdorf, Austria. These laboratories include two modern facilities. The Nuclear Materials Laboratory (NML) handles the sampling of nuclear materials and the Environmental Samples Laboratory receives and analyzes all environmental smear samples for traces of nuclear materials [JAW 16].

The analysis of environmental samples taken by smear tests allows the determination of all elements present in a facility, which have been used in the past or recently. This technique was first used in Iraq in 1990 in a nuclear facility, the Osirak or Tammouz reactor, which had been bombed on June 7, 1981.

Once collected, the samples are anonymously labeled and analyzed at the IAEA laboratories near Vienna, as well as in the IAEA's network of 19 accredited laboratories in many IAEA Member States (Australia, Brazil, France, Germany, Japan, Republic of Korea, Russia, the United Kingdom and the United States). The shipment of samples is also accompanied by "blind samples" for quality control purposes [DIX 16].

Satellite images are used to establish site maps. These provide valuable and accurate information about buildings and structures. For example, satellite imagery helps the IAEA monitor developments in the nuclear program of the Democratic People's Republic of Korea (DPRK), since the IAEA is not in a position to conduct physical verification activities in that country. In particular, the IAEA is monitoring activities at the Yongbyon site [QUE 16].

1.5.2.4. *Minor concealments under the NPT*

Some states voluntarily conceal a number of activities in the nuclear field that could lead to military applications. This was first observed in Iraq in 1981. This NPT signatory country was developing a nuclear program with a military vocation. It was demonstrated that a country bound to the IAEA by a comprehensive safeguard agreement could carry out activities contrary to the treaty without the IAEA's knowledge.

By declaring its renunciation of weapons of mass destruction in December 2003, Libya revealed the existence of a nuclear program for military purposes, unsuspected by the IAEA. While taking advantage, officially, of its adherence to the NPT and of a safeguards agreement with the IAEA, Libya had been able to import certain nuclear materials, carry out conversion activities, set up a centrifuge park intended to enrich uranium and obtain documentation relating to the design and manufacture of nuclear weapons [CHE 10]. This action was the work of A.Q. Khan, who sold the plans for a bomb and first-generation centrifuges to the Libyan President Gaddafi.

Finally, very serious doubts were expressed about Syria's nuclear activities. The American intelligence services transmitted information to the IAEA, that the installation destroyed by the Israeli air force in September 2007 at the Dair Alzour site, was a North Korean-designed nuclear reactor in the process of being completed. Similar to the one at Yongbyon, it was intended for the manufacture of weapon-grade plutonium that could be used to make a nuclear weapon. In 2009, two years later, the IAEA had still not obtained elements that would allow the Syrian authorities to deny the military vocation of this site [CHE 10].

1.5.2.5. *The case of North Korea*

Similarly, North Korea, which joined the NPT in 1985, has delayed concluding a comprehensive safeguards agreement with the IAEA for several years. This agreement was concluded a few days after the January 20, 1992 declaration on the denuclearization of the Korean Peninsula, in which both Koreas "*agree not to test, manufacture, produce, receive, possess, stockpile, deploy or use nuclear weapons*". At that time, suspicions about the conduct of military nuclear activities were already widely shared in the international community. In fact, the North Korean authorities immediately obstructed the verifications that the IAEA intended to carry out as part of the implementation of the safeguards agreement, going so far as to announce, in March 1993, their withdrawal from the NPT, a decision they would go back on three months later.

In early 1994, the Americans discovered that the North Koreans had begun to produce plutonium. President Bill Clinton wanted to make a pre-emptive strike on the reactor, but President Jimmy Carter went to Pyongyang and negotiated with Kim Il Sung, and then, following the latter's death in July 1994, with his son Kim Jong-il. At the end of the agreement, concluded in October 1994 with the United States, North Korea froze its military-scale activities, notably the Yongbyon reactor and reprocessing facilities intended to produce plutonium, in exchange for the construction of two light-water reactors by an international consortium (KEDO) and the delivery, until their entry into service, of 500,000 tons of oil per year. The United States did not respect this agreement. Oil deliveries carried on despite North Korean complaints in 1997, which explained the North Korean position [MOR 18]. Moreover, this agreement did not improve the IAEA's ability to control the non-diversion of nuclear materials. Also, no guarantee could be obtained on the existence of plutonium coming from the Yongbyon reactor, and whether there was a sufficient quantity to build one or more nuclear devices, before the suspension of its operation. On the contrary, from 1994 to 2002, North Korea pursued, without the knowledge of the international community, a program of uranium enrichment. It recognized this fact in 2002, which led to its withdrawal from the NPT in 2003 [CHE 10].

1.5.2.6. *The case of Iran*

In Iran, it was opposition movements that revealed, in the summer of 2002, the existence of the uranium conversion facility in Isfahan, the uranium enrichment facility in Natanz, the heavy water plant and the reactor under construction in Arak. The IAEA was not informed of their existence and could therefore exercise no control over them. As the IAEA later stressed:

> […] many aspects of Iran's nuclear fuel cycle activities and experiments, particularly in the fields of uranium enrichment and conversion, as well as research concerning plutonium, have not been declared to the Agency, contrary to Iran's obligations under its Safeguards Agreement, since 'Iran's policy of concealment' has led to numerous breaches of its obligation to comply with this agreement.

The exclusively civilian purpose of these activities has still not been attested [CHE 10].

Yet, Iran signed the General Guarantee Agreement (GGA) in 1974 and the Additional Protocol (AP) in 2003. Following these revelations, negotiations began in 2003 and 12 years later, led to the signing of a milestone agreement at the beginning of April 2015 between Iran and the "5+1" (Germany, China, United States, France, United Kingdom, Russia) [CON 15]. This did not prevent Iran negotiations from reducing its cooperation with the IAEA and resuming its activities related to uranium enrichment in February 2006 during these negotiations.

The Vienna Agreement on the establishment of control over Iran's nuclear program in return for the lifting of economic sanctions was signed on July 14, 2015. This agreement presupposed transparency and verifications because "An agreement that cannot be verified is an agreement that is not applied" (Laurent Fabius, July 14, 2015). On January 16, 2016, the IAEA Director General, Yukiya Amano, announced that Iran had completed the preparatory measures for the implementation of the Joint Comprehensive Plan of Action (JCPoA). The JCPoA was concluded in July 2015 between Iran and China, France, Germany, Russia, the United Kingdom, the United States and the European Union, a group known as the "E3/EU+3".

Iran's main commitments under the JCPoA are to refrain from using advanced centrifuges for 8–10 years, to conduct limited centrifuge research and to comply with a limited number of centrifuges at the Natanz Fuel Enrichment Facility. For a period of 15 years, Iran has agreed not to enrich uranium to more than 3.67%, to have its stock of this low-enriched uranium limited to 300 kg, not to practice uranium enrichment in the fuel enrichment facility in Fordou, not to build new enrichment facilities or new heavy water reactors and to export heavy water in excess [AIE 16b].

In addition, Iran has also agreed to provisionally apply the Additional Protocol, a legal agreement giving the IAEA broader access to information and locations, not limited to declared nuclear facilities and materials only. Under the JCPoA, Iran is required to implement voluntary nuclear-related commitments, known as "transparency measures", which include facilitating access by IAEA inspectors to uranium mines and processing facilities, and allowing the ongoing monitoring of centrifuge manufacturing and storage facilities. The number of IAEA staff working on verification and control in Iran doubled in 2016 from what it was before 2014. This leads to a significant increase in additional expenditure (9.2 million euros).

The JCPoA has significantly reduced the proliferation risks associated with Iran. For example, Iran now only has one enrichment site instead of two, and the number of centrifuges available to Iran has been reduced from 21,000 to 5,060. The stock of uranium available to Iran is now limited, and the time needed for Iran to acquire the fissile material necessary for a weapon has been considerably increased. With the restrictions imposed by the Vienna Agreement, it would take Iran at least a year, if it decided to embark on the arms race, to accumulate the material necessary for a bomb by the uranium route. Obtaining plutonium is made even more difficult with the absence of a means of conversion in Arak and of a reprocessing plant.

The US withdrawal from the Iranian nuclear deal on May 8, 2018, led to the reinstatement of US sanctions against Iran, which the US subsequently decided to strengthen. Despite this American withdrawal from the agreement, which France

expressed its deep regret about, the agreement remains in place. It involves Iran and the so-called E3/EU+2 states, i.e. France, the United Kingdom, Germany, Russia and China [FRA 19c]. The potential remains for the US to re-enter the agreement with its change of President in January 2021.

As of July 1, 2019, the quantity of uranium enriched to 3.67% ^{235}U in Iran was 205.0 kg. Taking into account the JCPoA and the decisions of the Joint Commission, Iran's total stock of enriched uranium thus exceeded 300 kg of UF_6 enriched to 3.67% ^{235}U (or the equivalent in other chemical forms), since the quantity of 300 kg of UF_6 corresponds to 202.8 kg of uranium [CEA 18; IEA 19a; IEA 19b].

On July 7, 2019, Iran announced that it would resume the enrichment of its uranium at the rate of 4.5% (prohibited by the 2015 agreement), but which remained lower than the necessary rate for the manufacture of a bomb. This quickly became a reality. Every day the stock of low-enriched uranium increases by 5 kg and would have been about 551 kg in November 2019, according to the IAEA. Iran resumed enrichment at Fordo and restarted 1,000 centrifuges in addition to the 5,044 authorized, which represents a qualitative leap. Iran assures that it will not be released from its obligations, in 60-day phases, only to induce the other signatories of the July 2015 agreement to take steps to circumvent US sanctions. The measures announced by Tehran were reversible, but they have become irreversible, and in two months, Iran could decide to move to an enrichment rate of 20%. Beyond that, it is very easy to reach an enrichment rate of more than 90%. In this case, the July 2015 agreement would be broken, with an automatic return of UN Security Council sanctions (snap-back) and European economic sanctions would be added to those of the United States.

Recently, France, the United Kingdom and Germany criticized Iran in a letter addressed to UN Secretary General Antonio Guterres for developing "*nuclear-capable ballistic missiles*". Indeed, an Iranian long-range Shahab-3 missile was tested in April 2019 [MAL 19].

1.6. Actions of NGOs

The group of NGOs working on disarmament is difficult to quantify. Initiatives abound, statutes, funding and doctrinal orientation vary. They are mostly American and European, among democratic states, and on the contrary, there are very few in countries with authoritarian regimes. The size of NGOs varies greatly, from two-member NGOs to coalition NGOs, such as Abolition 2000, which brings together 2030 organizations from 93 countries. Some have an impressive number of activists, such as the International Physicians for the Prevention of Nuclear War

(IPPNW). Organizations can be very hierarchical, like Greenpeace, or very loose, like the Parliamentarians for Global Action [MAR 02b].

The British example for NGOs is significant. 173 British disarmament NGOs are grouped together in the Abolition 2000 network. Many have a local or regional dimension, some with a religious or professional notation, and many use the words "nuclear" and "peace" in their titles. The most active British NGOs in the field of disarmament are the Acronym Institute, created in 1995, BASIC (British American Security Information Council), ISIS (International Security Information Service), VERTIC, PPNN (Programme for Promoting Nuclear Non-proliferation), Pugwash, born of the Cold War and awarded the Nobel Peace Prize in 1995, CND (Campaign for Nuclear Disarmament) and Labour Action for Peace [MAR 02b].

1.6.1. *The main actions of NGOs for disarmament*

Historically, after the 1948 People's Congress for Peace in Wroclaw, the World Movement of Peace Supporters was formed and encouraged the creation of national committees. In France, the "*Combattants de la Liberté*", created by Charles Tillon at the end of 1947, became the "*Conseil national français du movement de la paix*" in 1951, commonly called the "*Mouvement de la paix*".

The *Mouvement de la paix* became the first NGO concerned with disarmament. Its first major action was when the World Peace Council, meeting in Stockholm, issued the Stockholm Appeal [AMI 19a] on March 19, 1950.

Thereafter, a multitude of NGOs was created and had common and coordinated actions on a cyclical basis. The first UN Special Session on Disarmament (SSD1) in 1978 was an opportunity for NGOs to organize their relations and cooperation. For example, with the creation of the International Mobilization for Survivals (ImfS) in October 1977, a coalition of national and international peace and disarmament NGOs. This coalition sent messages to the UN and above all organized an International NGO Conference on Disarmament in the spring of 1978 in Geneva, before the SSD1. This Conference brought together 500 representatives of 85 transnational NGOs and 200 national NGOs from 46 countries. At the SSD1, about 800 people from 236 NGOs were present, plus 500 Japanese delegates from 200 Japanese NGOs. However, this initiative was a failure because the positions of the states did not change at all. The roles of NGOs were therefore limited to raising awareness and educating the public.

The second UN session on disarmament in 1982 (SSD2) was the occasion for an anti-nuclear campaign, attracting one million people to Central Park, New York. The American NWFC (Nuclear Weapons Freeze Campaign) mainly mobilized on

US-Soviet nuclear weapons negotiations and testing, while European organizations (the British Campaign for Nuclear Disarmament, the Dutch Interchurch Peace Council and the German Greens) were interested in intermediate-range nuclear forces (Pershing 2 and SS-20).

The next action opposed the National Missile Defense (NMD) and mobilized several hundred NGOs. NMD had two drawbacks in the eyes of NGOs: it promoted nuclear proliferation and it was very expensive. However, anti-NMD NGOs were confronted by pro-NMD NGOs, such as High Frontier, or the Centre for Policy Studies [MAR 02b].

While non-governmental organizations have become, in recent years, the driving force behind disarmament processes, it is largely as a result of the paralysis that has hit the United Nations, particularly the Geneva-based Conference on Disarmament, which "constitutes the single multilateral disarmament negotiating forum" [BOU 14].

The Luxembourg International Forum on Nuclear Disaster Reduction, held in early June 2019 in Rome, brought together experts from around the world to consolidate efforts in nuclear safety. The leaders of five major international organizations committed to the control of nuclear weapons took part in the discussions: the Nuclear Threat Initiative, the Pugwash Movement, the Global Zero Movement, the Russian Council on International Affairs and the James Martin Center for Nonproliferation Studies (United States) [SKO 19].

Unlike biological and chemical weapons, the atomic bomb is not yet the subject of a treaty prohibiting its development, production, acquisition, financing, stockpiling and transfer. On March 27, 2017, and again on June 15 of the same year, United Nations conferences were held "for the purpose of negotiating a legally binding instrument to prohibit nuclear weapons with a view to their complete elimination". However, the chairs of the five nuclear powers, the United States, Russia, the United Kingdom, France and China, remained empty. This is the reason for the international campaign for the abolition of nuclear weapons that ICAN has begun. The Arms Observatory, the International Network of Parliamentarians for Nuclear Non-Proliferation and Disarmament and Greenpeace France are members of the International Campaign to Abolish Nuclear Weapons (ICAN) [BOU 17]. In 2019, the ICAN campaign, launched in 2007, brought together more than 540 non-governmental organization partners, including about 50 in France, in 103 countries. The ICAN-France collective was created in the spring of 2009, taking over from the French campaign for nuclear disarmament, which already included many associations (see http://icanfrance.org/).

1.6.2. *NGOs and the Nobel Peace Prize*

The Nobel Prize in Physics has been awarded to more than 30 nuclear physicists and the Nobel Prize in Chemistry has been awarded to about nine nuclear chemists, as well as a Nobel Prize in Physiology, for their scientific work in the nuclear field [AMI 13].

The idea that the use of nuclear weapons could lead to catastrophic consequences remains a basis for their deterrent effect. The horror experienced by the victims of the Hiroshima and Nagasaki bombings was tangible proof of this. The Norwegian jury for the Nobel Peace Prize has also honored many personalities and organizations.

The first laureates to be rewarded were American chemist and physicist Linus Carl Pauling (in 1962), for his commitment against nuclear weapons testing; the Japanese Prime Minister Eisaku Sato (in 1974), for his renunciation of the nuclear option for Japan; the physicist Andrei Sakharov (in 1975), notably for his commitment to disarmament; the diplomats Alva Myrdal and Alfonso Garcia Robles (in 1982), for their "central role" in disarmament negotiations at the UN.

In 1985, the International Physicians for the Prevention of Nuclear War (IPPNW) was recognized for "services to humanity" in disseminating information about the catastrophic consequences of nuclear war, and in 1995, the NGO Pugwash and Jozef Rotblat were recognized for "their efforts in reducing the role of nuclear weapons in international politics and, in the long term, to eliminate them". Still on the theme of abolition, the Nobel Committee provided a powerful sounding board for President Obama's Prague speech in 2009, in which he shared his vision of a "world without nuclear weapons" [DEC 17].

In 2005, the Nobel Peace Prize was awarded to the International Atomic Energy Agency (IAEA) and to Mr. El Baradei, its director at the time, "for their efforts in preventing the use of nuclear energy for military purposes".

Finally, in 2017, the anti-nuclear NGO ICAN, which used the theme of the consequences of a nuclear war, saw its action rewarded with the Nobel Peace Prize, a few months after the adoption of the Treaty on the Prohibition of Nuclear Weapons (NPT). However, the concrete benefits of this treaty for international peace and security are much less obvious than the risks it presents of blocking any progress in nuclear disarmament [DEC 17].

In addition, the "Don't bank on the bomb" project reflects the NGOs' search for other ways to delegitimize nuclear weapons. This initiative, implemented by the Netherlands-based NGO PAX, establishes a ranking of companies and investments

in the field of nuclear weapons in an annual report, denouncing the financial institutions ("Hall of shame") investing in the 27 companies identified as being involved in the production and maintenance of nuclear weapons [DEC 17].

1.7. The military denuclearization of a state

Several countries have voluntarily stopped their military nuclear programs. Of these, South Africa was the most advanced state in its program as tests had been conducted. However, its nuclear weapons were never really operational because they were too large to be delivered. However, the first bombs, including those from Hiroshima and Nagasaki, were designed for air delivery. They were not vectorizable, but they became so.

1.7.1. *South Africa: the example of the complete denuclearization of a country*

The denuclearization of South Africa is a unique case, since it is the only state that possesses atomic weapons that voluntarily renounces them. Moreover, during this denuclearization, South Africa split into two new states: South Africa and Namibia.

In 1979, South Africa's nuclear weapons manufacturing facilities were transferred from the Pelindaba Nuclear Research Centre to the South African Weapons Corporation (Armscor), which developed the Kentron Circle facility. This facility was built in 1980 and is located 20 km west of Pretoria. It was later renamed Advena.

The organization of South Africa's militarized nuclear program is described in Figure 1.4.

At Pelindaba, pistol-type mini nuclear weapons have been developed. Armscor installed a production line there in 1981 and produces at least one nuclear device each year with an output of 10 to 18 kilotons.

Advena's central laboratories have built platforms for launching intercontinental ballistic missiles (ICBMs). Work to produce warheads with advanced designs has also been developed. On the same site, in collaboration with Israel, a missile with a range of 2,000 km was designed and tested. It was close to the ICBM Jericho II. The construction of Advena was completed at the same time as the end of South Africa's nuclear program, before the 1994 election of Nelson Mandela [GLO 11].

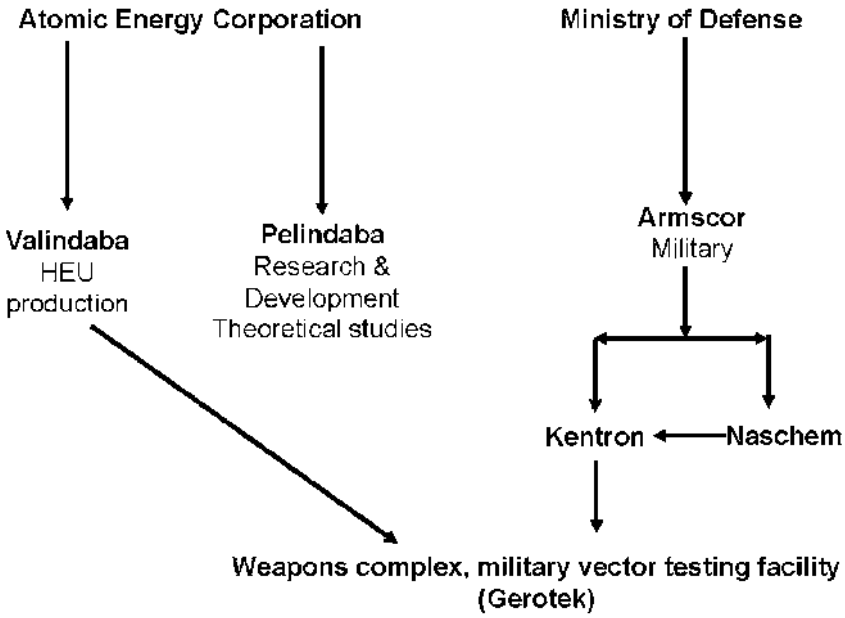

Figure 1.4. *Organizational structure of the South African nuclear program according to an IAEA member in August 1992 (source: [ALB 16])*

The end of South Africa's nuclear program should be seen in the context of major political developments in the region. First, in December 1988, South Africa, Angola and Cuba signed a tripartite agreement for the gradual withdrawal of Cuban troops from Angola. In April 1989, Namibia gained its independence. In September 1989, F. W. de Klerk was elected president. He immediately took steps to bring about fundamental political reforms aimed at ending apartheid and creating a democratic South Africa. Within a short time, the nuclear weapons program had become a liability. In November 1989, the government decided to stop the production of nuclear weapons. On February 26, 1990, de Klerk issued written instructions to end the nuclear weapons program and dismantle all existing weapons. The nuclear materials were to be melted down and returned to the Atomic Energy Corporation (AEC) in preparation for South Africa's accession to the NPT.

The government also decided to not admit the existence of the nuclear weapons program before joining the NPT. As a result, the decommissioning project, like the nuclear weapons project, was classified as top secret. Dismantling began in July 1990. On September 6, 1991, all of the highly enriched uranium (HEU) had been removed from the weapons, melted down, and returned to the AEC for storage. Shortly after the last of the material was sent to the AEC, the Circle building was

completely decontaminated, and the equipment that had been used to remelt and sink the HEU was sent to the AEC. The Advena/Circle facility was converted to a non-nuclear commercial operation. De Klerk's revelation that South Africa had developed a nuclear arsenal was finally made in 1993 [ALB 94].

At the time of the dismantling of its military nuclear program, South Africa possessed six atomic weapons, with a seventh in the process of assembly. In 1991, South Africa's enrichment plant Y had produced 993 kg of highly enriched uranium, including 677 kg of the isotope 235 [ALB 16]. The conversion rate of 68.2% was close to the threshold of 90% necessary to make a weapon. The South Africans were thus close to the goal.

The split of South Africa had various consequences on the demobilization of troops and their disarmament [DZI 17].

Namibia is a successful model of an international approach to disarmament and demobilization (DD). Namibia has been assisted by two UN structures, the United Nations Transitional Assistance Group (UNTAG) and the United Nations High Commissioner for Refugees (UNHCR), which have effectively carried out their military and repatriation tasks in Namibia's successful transition to independence. This was facilitated by the fact that Namibia's liberation movement comprised a single armed formation, the People's Liberation Army of Namibia (PLAN). The official law enforcement force, SWATF (South West Africa Territorial Force) and the unofficial Koevoet (the counter-insurgency arm of the South West African Police Force) were eventually disarmed. The government decided to implement the aptly named Peace Project. This plan focused on the placement of ex-combatants in activities that were paid for, mainly in the civil service [DZI 17].

In South Africa, the unstable political and security contexts that followed the splitting of Namibia paralyzed disarmament efforts, contributing to the proliferation of illicit small arms and light weapons, some of which were subsequently used as instruments of armed crime [DZI 17].

1.7.2. Other states that have renounced nuclear weapons

Switzerland committed itself very early on, as early as 1945, to the acquisition of nuclear weapons. This process of nuclearization was halted in 1968, when it signed the NPT, and was then definitively abandoned in 1988.

Swedish research on nuclear weapons began in 1945, conducted by the Swedish National Defence Research Institute (FOA, *Forsvarets Forskningsanstalt*). In 1955,

Sweden was well advanced in its research on atomic weapons. In 1958, the Swedish Parliament had to choose between two programs, L (Loading Program) and S (Protection Program), depending on whether or not it was producing nuclear weapons. In 1968, Sweden was preparing to test an atomic bomb but, for various economic and diplomatic reasons, the government decided to dismantle its military nuclear program to join the negotiation process that would lead to the signing of the Non-Proliferation Treaty [JON 01, JON 10].

Two South American countries, Brazil and Argentina, had secretly developed military nuclear programs [GOL 06]. Changes in political regimes, with the fall of the military and the takeover by civilians in both countries, led to a renunciation of the bomb in the 1980s. This led to the creation of a regional bi-national safeguards agency in 1991, known as the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) [GOL 18].

In 1991, at the time of the dissolution of the USSR, Belarus, Kazakhstan and Ukraine possessed nuclear weapons on their territory. These three countries became independent and returned them to Russia. Thus, an agreement was signed in 1991 (Budapest Memorandum) between Russia and Ukraine. Under this agreement, Ukraine received sovereignty and territorial safeguards and, in return, it returned its nuclear arsenal to Russia. The annexation of Crimea and continued Russian aggression on Ukraine's eastern border directly defied this agreement [MEY 19].

1.8. Conclusions

The UN policy of non-proliferation has had mixed success as a number of countries (South Africa, Libya) have abandoned their military programs and signed the NPT. However, this policy has also suffered many setbacks since a number of states have acquired control of atomic bombs (India, Pakistan and North Korea), and this number is likely to increase in the short and medium term (Iran and Saudi Arabia).

International treaties are currently undergoing a serious crisis. For example, only one international treaty has been ratified (NPT), but it is on hold. In addition, nuclear deterrence is increasingly being challenged by some non-nuclear weapon states. This is the case, for example, for the Vatican, which no longer seems to accept the concept. In the face of this accumulation of negative facts, non-nuclear-weapon states have recently adopted the TIAN Treaty and 50 states ratified it on October 24, 2020 (mainly states from South America, the Caribbean, Oceania and Africa). It therefore entered into force on January 22, 2021.

The probability of an intentional or accidental explosion is increased today due to the considerable investment in nuclear weapons, their associated systems and their modernization. The increased reliance on automated false alarm detection systems also increases the risks. In addition, technological advances favor terrorists because their needs for specific expertise will be less. Therefore, to completely eliminate nuclear risk, the only solution is the total elimination of nuclear weapons [UNI 17].