Committee I
The Nuclear Option in the Past,
Present and in the Future

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NUCLEAR PROLIFERATION: PAST, PRESENT AND FUTURE
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by

Marcelo Alonso
Principal Research Scientist
Florida Institute of Technology
Melbourne, Florida, USA

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Marcelo Alonso
Florida Institute of Technology

Since the end of WW II one of the more, if not the most, serious concerns of all people in the world has been to preserve this planet and avoid a nuclear war. On the positive side, in spite of the huge arsenal of strategic and tactical nuclear weapons (NW) accumulated over the years by the US and the former SU and the innumerable military conflicts we have witnessed since WW II, no NW have been used again. But this should not be a great consolation: the fact that countries have refrained from using NW does not necessarily mean that it will always be that way. As long as countries try to solve their differences by the use of force the danger of a nuclear confrontation remains, and should continue to be a serious concern.

This concern has profound political, social and ethical components that have been analyzed extensively and profusely. The purpose of this paper is more limited: to provide an overview of the national and international efforts to minimize the risk of a nuclear war by regulating, restricting and containing the development and possession of NW. This is what has become known as the nuclear non-proliferation regime. Any nuclear non-proliferation regime must have two essential goals: achieving nuclear disarmament by the NWS (and thereby eliminating vertical proliferation), and renunciation by the NNWS of efforts to build or to acquire NW (containing horizontal proliferation). To make a regime effective it must rely on international agreements, a system of safeguards coupled with inspection and verification procedures, and above all on the good faith of all nations involved.

It should be stated from the very beginning that nuclear non-proliferation efforts, like all disarmament efforts, are essentially of political nature, albeit having an important scientific and technological component. They are effective only to the extent that countries really renounce NW and are prepared to severely sanction those who do not.

1. THE PAST

It is well known that shortly after the discovery by O. Hahn and F. Strassman in 1938 of the fission of uranium (U) nuclei by neutron capture, it became evident that nuclear energy could be released in large amounts by a chain raction process (Weinberg, 1958). A controlled chain reaction allows the gradual release of nuclear energy in U-235 and as a by-product inevitably produces a new fissionable element, plutonium (Pu), out of U-238. The chain reaction, given the proper arrangement, can also occur very fast, releasing a large amount of energy in a very short time in what can be called an atomic explosion. The first controlled nuclear chain reaction occurred on December 2, 1942, in a covered stadium converted into a laboratory at the University of Chicago.

The first three nuclear bombs were exploded in 1945, less than three years later (July 16, "Trinity", at Alamogordo Test Site, New Mexico; August 6, "Little Boy", at Hiroshima; August 9, "Fat Man", at Nagasaki); the first and third were Pu bombs and the second was a U bomb. The story of how the first nuclear bombs were developed has been well documented and does not need to be repeated here (Smyth 1946: Glasstone 1950; Hawkins 1983; Rhodes 1987; Anderson 1991; Serber 1992).

Soon after the first nuclear explosions President Truman sought methods to control, both nationally and internationally, the power of the atom, as stated in his message to the US Congress of October 3, 1945. The US policy for controlling the atom was formulated in the Atomic Energy Act of 1946, which placed nuclear energy under civilian control (Mazuzan 1984) and restricted access to nuclear information. At the international level it was agreed jointly by the US, Canada and Great Britain (November 15, 1945) that to avoid the spread of nuclear weapons it was necessary to maintain a policy of secrecy, denying access of other nations to nuclear technical information and materials. The three governments realistically recognized that no secrecy policy could be fully effective against any nation bent on acquiring NW.

It is interesting to note that at this early stage the governments of the three countries recognized that there could be applications of nuclear energy other than to NW, and that these potential applications should be shared with other members of the UN. The dilemma between the "military" and the "peaceful" atom has not been resolved and remains the central issue of non-proliferation policies. It was put very clearly by Alvin Weinberg in his December 1945 statement to the US Senate's Special Committee on Atomic Energy: "Atomic power can cure as well as kill. It can fertilize and enrich a region as well as devastate it. It can widen man's horizons as well as force him back into the cave".

While pursuing a policy of secrecy and denial, the US sought to internationalize the atom, placing it under the umbrella of the UN (Acheson-Lilienthal report, March 1946). A proposal, later called the Baruch plan, was submitted to the UN on June 14, 1946. After two years of negotiations it ended in a deadlock due to irreconcilable differences between the US and the SU. This was the end of the first efforts to adopt an international nuclear non-proliferation regime.

History has shown that scientific and technological developments can not be kept secret indefinitely. As recognized by the Pentagon's Task Force on Secrecy (1969), what a group of qualified scientists has achieved, can also be achieved by any other equally qualified group given the proper conditions. That is why the policy of secrecy and denial was doomed to fail. In fact it was shattered dramatically by the explosions of nuclear bombs by the SU (August 9, 1949) and GB (October 3, 1952). Eventually France (February 16, 1960) and PRC (October 15, 1964) also exploded nuclear bombs. In addition the US developed an H-bomb (November 1952), quickly followed by the SU (August 1953), GB (1957) and PRC (1967).

This rapid proliferation of NW capability prompted President Eisenhower to reconsider methods for international control of the atom without unduly restricting genuine peaceful applications. Eisenhower's ideas were put forward in a UN address on December 8, 1953, in which he proposed an Atoms for Peace (AP) program (Pilat 1985). In the AP Eisenhower recognized the "double use" of nuclear energy and set guidelines for international cooperation in its peaceful use, without enhancing the risks of proliferation. In a sense the AP replaced the previous policy of secrecy and denial without totally eliminating it. The major points of the AP program were: a) governments would contribute fissionable materials to an IAEA, to be established under the aegis of the UN; b) the IAEA would be responsible for impounding, storing and protecting the contributed materials; c) the IAEA would allocate the contributed fissionable material to serve the peaceful pursuits of mankind, particularly to the production of nuclear energy.

This new US policy was legislated by the US Congress in the Atomic Energy Act (AEA) of 1954, which emphasized peaceful nuclear cooperation and the sharing of some nuclear technologies with cooperating "friendly" nations under mutually agreed verification and safeguards procedures. Specifically the AEA-1954 allowed for bilateral agreements between the US and cooperating partners, which required that the partners agreed not to use US assistance in nuclear materials and technology for any military purposes, and accept US inspections to verify compliance with the terms of the agreements. For all practical purposes the AEA-1954 established a US controlled non-proliferation regime.

Although the international "bank" of fissionable material never came into existence, the AP program had many immediate positive effects in relation to its two main objectives. 1) Two international conferences on the peaceful applications of nuclear energy were held in Geneva in 1955 and 1958 (a third was held in 1964) at which non-sensitive nuclear information and technology were made available to a large number of scientists from all over the world. 2) Nuclear scientists and engineers were trained in several "peaceful" nuclear technologies at centers in the US. 3) It became possible for any "reliable" country to acquire nuclear reactors for research and power (in fact the US contributed $ 350.000 toward the cost of a reactor). The first sale of a power reactor, to Italy, occurred in 1958. The nuclear reactors were supplied as turnkey projects and the recipient countries were not supposed to have direct access to the nuclear fuel in the reactors. 4) The IANEC was established in 1959 within the OAS, to promote nuclear cooperation between the US and Latin America. 5) The IAEA was established by the UN in 1957.

The IAEA main objectives were "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure..that assistance provided by it... is not used in such a way as to further military use" (Art. II of IAEA Statute). In more practical terms the IAEA was supposed to keep separate peaceful nuclear development to prevent possible proliferation, thus becoming the key element in a new international non-proliferation regime. To this end the IAEA was instructed to establish appropriate safeguards as well as inspection and verification procedures. In due time this task became the most important activity of the IAEA, monitoring over 900 nuclear facilities in more than 50 countries. All safeguards provisions contained in bilateral agreements between US and other countries were eventually transferred to the IAEA.

The IAEA safeguards and inspection procedures entered into effect in 1963. By agreement with each country the safeguards can be "full-scope", applying to all nuclear activities in the country (INFCIRC-153), or "partial" safeguards, applying only to certain facilities (INFICRC-66, Rev.2). The safeguards system relies on the following methods of verification: 1) materials accountancy, tracking in- and out-flow as well as inventory of declared fissile materials, 2) containment of declared fissile materials by physical barriers at a plant, 3) surveillance, using appropriate instruments to detect unreported movement of and/or tampering with safeguarded items.

However safeguards and the associated inspection procedures have some serious limitations from the non-proliferation point of view. In the first place safeguards are not intended nor designed to prevent proliferatios. They are intended only to verify non-proliferation undertakings using declared nuclear materials and to deter proliferation attempts by the risk of early detection. For safeguards to be fully effective the complete support of the goverments of the countries to which they are applied is required. And the IAEA Board of Governors must be prepared to condemn violations and so report to the UN Security Council, that can recommend or apply proper sanctions to violators, something that multinational political bodies may be hesitant to do. In any case the international acceptance of the IAEA safeguards system is a remarkable political development, which can only be explained by the seriousness of the consequences of nuclear proliferation. Most countries that have no intentions to make NW have placed their nuclear facilities under the IAEA safeguards, while countries wishing to preserve a NW option have refused to do so and at most have accepted only partial safeguards.

A second phase in reinforcing the international non-proliferation regime came about with the nuclear Non-Proliferation Treaty (NPT), negotiated during the 1960's, open for signatures in 1968, and that entered into force in 1970. The main objective of the NPT is to provide an international legal instrument for preventing the spread of NW to NNWS and to reduce the nuclear arsenal of the NWS. The NPT currently has over 140 signatories, although not all of them have ratified it, with some conspicuous absentees. The NPT also freezes the current division into NWS and NNWS, a situation considered unfair by many. But the NPT, while legally reinforcing the non-proliferation regime. does not basically change the prior situation: its effectiveness depends on the good faith of the adherents and says nothing about those who do not adhere to or violate it. Also the NPT does not provide a mechanism for detecting if a party to the treaty has begun advancing toward NW production if no specific treaty violations have yet occurred. Another weak point of the arrangements under the NPT is that although information about a proposed nuclear facility must be supplied as early as possible to the IAEA before nuclear material is placed into it, NPT safeguards apply only after the nuclear material is introduced in the facility. On the other hand the main political advantage of NPT is that it constitutes a formal international consensus or "nuclear bargain", that was only implicit in the AP and in the IAEA statutes.

Article I of the NPT stipulates that each NWS agrees not to transfer, directly or indirectly, NW or other nuclear explosive devices, and not to assist, encourage or induce any NNWS to manufacture or acquire NW or related devices. According to Art. II NNWS agree not to receive, acquire or manufacture NW or related devices, and not to receive or seek assistance in their manufacture. Art. III provides for each NNWS to accept IAEA safeguards to all sources or special fissionable materials in all peaceful nuclear activities within the country for the purpose of verifying treaty obligations and preventing diversion of nuclear materials for use in NW. Art. IV states that the NWS should facilitate to the fullest possible extent exchange for peaceful purposes of equipment. materials and technical information with the NNWS and to cooperate in the further development of the applications of nuclear energy for peaceful purposes. with due consideration to the needs of the developing areas of the world. Art. V affirms that the potential benefits from peaceful nuclear explosions should be made available to NNWS on a non discriminatory basis. Art VI establishes that each of the parties agrees to pursue negotiations on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament under strict and effective international control. Art VII states that any group of parties can conclude regional treaties to ensure the total absence of NW from their territories.

The NPT is reviewed every five years. The last review took place in 1990 and on that occasion there was the general consensus that, in spite of some flaws, it is basically a good instrument. The next review will take place in 1995. at which time the extension of the treaty will be considered. One complaint of the NNWS, repeatedly expressed in previous reviews. has been the failue of the NWS to fully comply with Art.VI. cease all testing. and stop the nuclear arms race, although several partial steps in that direction have been taken. However the situation has changed radically with the collapse of communism and the dissolution of the SU.

To reinforce the NPT the US Congress adopted the Nuclear Non-Proliferation Act of 1978 (NNPA-78) which regulates US exports of nuclear facilities and materials, requiring full-scope safeguards and restricting the fate of the spent fuel retrieved from such facilities. One consequence of the NNPA-78 has been that many previous bilateral agreements had to be renegotiated, to the discomfort of the second parties. The NNPA-78, although well intentioned was not realistic since it ignored that the US is not the only supplier of nuclear materials and facilities. Other countries (Canada. Australia, etc.) have also established restrictions and controls on their nuclear exports which supplement the NPT.

Several regional intergovernmental agreements have been established to strengthen the non-proliferation regime. 1) The Treaty for the Proscription of Nuclear Weapons in Latin America (Tlatelolco Treaty). open for signature since 1967. forbids the signatories to acquire NW and declares LA a NW-free zone. 2) The Convention on the Physical Protection of Nuclear Materials, adopted in 1979, is concerned with the protection against theft and sabotage and establishes the principle of "no sanctuary" for criminal offenders. 3) The Treaty of Rarotonga, signed in 1985 by 9 South Pacific states, declares the Pacific south of the Equator a NW-free zone. EURATOM (1957) and its technical counterpart, ENEA, promote cooperation among its member states.

Since nuclear materials and facilities are the subject of international trade, other less formal but nevertheless important instruments exist that contribute to minimize the risk of proliferation via nuclear trade. 1) The Exporters Committee (Zangger Com.) considers procedures for nuclear related exports in the light of the NPT: in 1974 it produced a "trigger list" of items whose export should be made contingent on application of IAEA safeguards to those items in the recipient country. 2) The Nuclear Suppliers Group (London Group) set in 1976 export rules that go beyond the Zangger Com. trigger list. and that restrict transfer of nuclear technologies. impose strict safeguards requirements on the equipment and materials traded. and forbid technical assistance to NNWS not members of the NPT. 3) The Coordinating Committee Consulative Group (COCOM) is concerned with the supply of materials and technology of potential military use to the former SU. to the PRC. and their allies. Another organization concerned with non-proliferation is The Uranium Institute. which is an international association of industrial enterprises in the nuclear sector with the purpose of fostering research into and information exchange about the use of U for peaceful purposes.

The preceding analysis shows that there is a large number of international. regional, national and specialized instruments and institutions for promoting the peaceful use of nuclear energy and deterring nuclear proliferation. Has this network or regime been effective? Before giving an answer we should first review briefly what it takes to make a NW, without going into too many details.

2. THE PATH TO NUCLEAR PROLIFERATION

In order to understand what must be safeguarded to prevent nuclear proliferation and the challenges posed, it is important to review the pre-requisites leading a country to acquire a NW capability, which basically are not different from the requirements for acquiring any other technological capability. The first requirement is to have a competent group of scientists, engineers and technicians; any country determined to proliferate can assemble such a group, probably without arousing any major suspicions. The second reqirement is to acquire the relevant information, a good deal of which. but not all. is classified or secret; with some efforts and persistence this is also possible. The third requirement is to have the proper industrial and manufacturing facilities (mainly chemical. metallurgical, mechanical and electronic): this is a much more difficult task. specially if the country does not possess a strong industrial infrastructure and the facilities have to be acquired clandestinely. And the fourth and most dificult. as well as essential, requirement is to possess suitable fissionable material for making a NW. that is HEU and/or Pu.

Of course it is possible that a country or a terrorist group could seize an existing NW, but this event is highly improbable and has not yet occurred. Recent reports suggest that Iran may have obtained surreptiously from Kazakhstan two or three soviet NW, but they have not been confirmed. Accordingly this possibility will not be discussed here (Wilrich 1974; Keeny 1977).

A U-bomb requires U that has been enriched well above the natural content of U-235 (0.711 %). While NPR operate with NU or LEU (less than 5 %), a NW requires HEU well above 20 %. The amount of HEU required depends on the bomb design and the enrichment level as follows:

Enrichment (U-235 %)	60	70	80	90	100
Critical mass (kg of HEU)	37	28	21	18	15

Weapons grade U (WGU) should have at least an enrichment of 90%.

Enrichment technologies are straightforward but sophisticated (gaseous diffusion. ultracentrifugation. electromagnetic separation, laser separation. aerodynamic separation. chemical enrichment) and require large elaborate dedicated installations. difficult to build and to conceal (Cohen. in Weinberg 1985). For a small enrichment program centrifugation and electromagnetic separation offer the best alternatives. even if the components are not easy to obtain in the open market. On the other hand LEU for NPR is available from many different suppliers (US. CIS. Eurodif, Urenco, etc.). Therefore any country having a reasonably small NP program has no real need for building enrichment facilities. Nevertheless, if a country decides to build a safeguarded LEU facility for its NP program, that by itself does not constitute a potential proliferation since LEU is not suitable for NW unless the LEU is fed into an unsafeguarded and most probably undeclared HEU facility (INFCE. WG III).

The other material suitable for NW is Pu, which is an unavoidable by-product of any nuclear reactor. It was used in the bomb exploded over Nagasaki. As U-fuel sits in a reactor, Pu-239 is produced as a result of reactions following the capture of neutrons by U-238. As time goes on, other Pu isotopes are produced: Pu-240, Pu-241, Pu-242, the relative proportion depending on the initial enrichment and the burnup, measured in MWd/TU (Fig. 1). When U-fuel is discharged from a nuclear reactor it contains a certain isotope mix of Pu, highly radioactive fission products and an appreciable amount of unburnt U. To extract the Pu in the spent fuel it is necessary to subject the fuel to a delicate, remote control. chemical operation called "reprocessing" (Chayes, 1977), which is well known but requires a highly specialized facility difficult, although not impossible. to conceal.

Without going into technical details. the best isotope for making a NW is Pu-239. A weapons grade Pu (WGPu) is one that contains very little of the heavier isotopes. particularly Pu-240. Therefore, according to Fig. 1. for producing WGPu the nuclear fuel should be subject to a low burnup (less than 3000 MWd/TU). But this is a very inefficient way of using nuclear fuel for power generation. For economic reasons irradiation levels in NPR should be as high as possible. between 10 000 MWd/TU and 40 000 MWd/TU, depending on the design, and therefore the spent fuel from NPR contains a relatively large proportion of the heavier Pu isotopes. (This is particularly true of LWR, that must be stopped for refueling; the Canadian CANDU and the Russian RBMK reactors can produce better quality Pu because they can be refueled while in operation). However that does not mean that the Pu produced in NPRs is unsuitable for NW; it only means that a nuclear device with such Pu is less reliable and has a lower explosive yield than with WGPu. The critical mass of an optimally designed Pu bomb depends on the isotope mix:

Isotope mix (% Pu-239/Pu-241)	60	70	80	90	100
Critical mass (kg of Pu)	7.8	6.7	5.6	5.0	4.4

Each ton of spent fuel from a LWR irradiated for 20 000 MWd/TU contains about 9 kg of Pu. A 1000 MWe LWR discharges about 25 to 30 tons per year of spent fuel containing more than 200 kg of reactor grade Pu. sufficient for several NW. That means that a reprocessing facility. even if it is associated with a NP program and the Pu separated is not of the optimum quality for NW. is considered a potential proliferation risk. even more if it is unsafeguarded (INFCE. WG 5). To support this point. it appears that the US carried out in 1977 an explosive test with reactor grade Pu from a power reactor, although the details and results are still secret.

Therefore the best way of avoiding Pu-proliferation might be not reprocessing the spent fuel from any reactor and instead store it indefinetely (R. Lester in Weinberg 1985; Cohen 1977), preferably in an isolated safeguarded international facility (PRC unofficially offered such a facility in the Gobi desert). Another alternative is to return the spent fuel to the original supplier, which usually is a NWS (as the former SU always required). In the 1960's it was assumed that reprocessing was essential for the long term economics of NP. This does not seem to be the case at present, but in the opinion of many reprocessing spent fuel in an international facility or by a NWS may be a better alternative than indefinite storage.

The concern about nuclear proliferation was so profound in the US during the Carter administration that non-reprocessing of civilian nuclear fuel was made the centerpiece of Carter's nuclear policy. As a consequence the Barnwell, S.C., reprocessing plant was left unfinished at a considerable cost to taxpayers. An International Nuclear Fuel Cycle Evaluation (INFCE) was convened in 1977 with participation of over 500 experts from 66 countries, to determine ways of minimizing the danger of nuclear proliferation via civilian NP programs. No matter how useful it might have been from the technical stand point, INFCE was an exercise in futility and did not reveal anything that was not already known. A safeguarded civilian nuclear power program is "not" the route to proliferation. If the front and back ends of the fuel cycle are left open in a country the danger of proliferation is practically zero. Closing the front end of the fuel cycle does not imply a proliferation risk as long as it is done in a safeguarded facility in which only LEU can be produced. Closing the back end, i.e. reprocessing, brings the country closer to NW capability, but this can be minimized by proper application of safeguards and inspections. Still, the best is not reprocess. From the proliferation point of view the IAEA considers a "significant" quantity the possession or the diversion of 25 kg of HEU or 8 kg of Pu, in accordance with the critical masses quoted above.

Besides the 5 NWS (US, UK, CIS, France and PRC), with about 260 NPR, there are about 170 NPR in 20 NNWS. Only few of the NNWS have acquired sensitive facilities for their civilian NPR that could lead to proliferation. Therefore the "linkage" of civilian NP programs with nuclear proliferation is a largely unfounded myth, fueled by antinuclear activists and negated by experience. The much more likely conclusion is that any country that decides to acquire a NW capability can and will do so in a covert fashion, using unsafeguarded facilities, following the most feasible path for the country regardless of economic considerations, as experience has shown.

3. THE PROLIFERATION EXPERIENCE

We shall now review briefly the known and suspected attempts at proliferation (Spector, 1988). The first break of the non-proliferation regime so carefully built during the 1960s was the explosion, in May 1974, in the Rajahstan desert, of an Indian nuclear device containing about 15 kg of Pu. The irony was that the Pu had been produced in a 40 MW NU/HW research reactor (CIRUS) supplied in 1963 by Canada, with HW provided by the US (and later on by Norway) supplemented by a HW plant built in 1962 by the FRG near Nangal. The Pu had been separated at the Trombay Nuclear Research Center. None of the facilities used had been under IAEA safeguards. Although India called it a "peaceful" nuclear explosion, the international reaction was so severe that India has not tested any more nuclear devices, although India has continued developing a "peaceful" nuclear program and many Indian installations still remain unsafeguarded.

Presently India has 8 HW plants producing about 60 T/yr, one LEU centrifugation plant (Trombay), 6 research reactors, two are NU/HW (CIRUS and Dhruva) and one is a fast breeder (FBTR), 7 NU/HW power reactors and 3 more under construction, and 3 reprocessing plants (Trombay, Tarapur, Kalpakham), none of which is safeguarded (only Tarapur is partially safeguarded), with a total reprocessing capacity of about 250 T/yr of spent fuel. It has been estimated that India's capacity for separating Pu is about 150 kg/yr, enough for 30 NW, and that the total amount of Pu produced up to 1992 is well in excess of 500 kg of Pu, enough for about 70 NW. Only the Pu extracted from Rajahstan I and II NPR (about 70 kg/yr) is safeguarded. India also has the capacity to deliver a nuclear device using the short range (160 km) missile "Prithwi". It is interesting to note that in 1988 India leased from the SU a nuclear power submarine, "Chakra" (Charlie I class) for traing and plans to lease two more; these submarines are not a violation of the NPT as long as they are not armed with NW. Therefore, for all practical purposes India is an undeclared NWS.

In the same way that India's NW effort can be attributed to the threat posed by PROC, Pakistan has been trying since 1972 to develop an "Islamic" bomb, in response to the "Hindu" threat (Weissman 1981). Pakistan possess only one small NPR (NU/HW, 125 MWe), built in 1972 near Karachi and supplied by Canada, and a 5 MW HEU/HW (PARR) research reactor, near Rawalpindi, supplied in 1965 by the US through the IAEA; both reactors are under IAEA safeguards. In addition Pakistan has ostensibly developed a comprehensive program for producing HEU (90 %) and the eventual fabrication of a NW. The centerpiece of the program is the Kahuta enrichment plant using several thousand ultracentrifuges, that started operation in 1984. This effort was possible thanks to Dr. A. Q. Khan, who had been working at Urenco, in the Netherlands, until 1974. Although the Kahuta plant was designed for LEU (<5%) it was upgraded by 1988 to produce HEU.

Pakistan has also built two HW plants (Multan and Karachi) for support of the reactors, a UF6 production plant (Dera Ghagi Khan) smuggled from the FRG, a fuel fabrication plant (Chashma /Kundian), a reprocessing plant (Chashma) initially supplied by France and technically under IAEA safeguards, and other suplementary facilities. For carrying out the program Pakistan organized an extensive procurement network, obtaining from several Western countries equipment and know how (special steels, electronic switches or krytrons, etc.) using dummy corporations and trans-shipments through third countries. It also appears that PRC has provided Pakistan with the design of a U bomb. The estimate is that by 1988 Pakistan had produced about 100 kg of HEU, sufficient for 3 or 4 NW, and that presently it may have twice as much this quantity. Pakistan has not exploded a nuclear device but has tested all non-nuclear components of a bomb. Therefore it is reasonable to conclude that Pakistan possesses a de facto NW capability, although strictly speaking it is not yet a NWS.

Next to Pakistan, the country about which there is almost the certainty that has a NW capability is Israel, most probably since 1968, although the Israeli program has been kept under great secrecy. It started in 1956 with an agreement with France to acquire an EL-3 type, 24 MW, NU/HW research reactor, built at Dimona, in the Negev desert, and that entered into operation in 1963. The reactor was designed with a larger cooling capacity and there is the suspicion that it has been upgraded up to at least 40 MW, may be as high as 70 MW. It is suspected that the Pu produced in the reactor is separated into WGPu at an underground reprocessing plant, also at Dimona. That means that Israel can produce at least 10 kg/yr of WGPu, and that more than 100 kg of WGPu have been produced so far, sufficient for 50 to 60 NW. Israel has a HW production plant at Rehovoth to supplement the 20 tons of HW obtained in 1959 from Norway and a smaller amount from France. Other nuclear facilities include a 5 MW, HEU/LW research reactor, supplied by the US, a fuel fabrication plant at Dimona, and a small enrichment plant (2-3 kg/yr), possibly using laser separation. Besides its own domestic supply of U, Israel has obtained NU from several sources (Argentina, South Africa, Central African Republic, etc.). Israel has obtained several special components of the program by surreptitious methods (800 krytrons from US during 1980-83, 100 kg of HEU from FRG during 1962-65, etc.). Although it is believed that Israel has all the necessary elements to manufacture NW, it has exploded none. It has also two ballistic missiles (Jericho II, 650 km; Jericho IIB, 1500 km) capable of delivering NW. Therefore for all practical purposes Israel, that is not a party to the NPT, can be considered a NWS.

South Africa is another country with potential NW capability. It has ample U and Th ores. It is suspected that since the enrichment plant at Valindaba entered into operation in 1975 (subsequently upgraded in 1981) S.A. has produced about 500 kg of low and high enriched uranium. A larger enrichment plant, also at

Valindaba, started operation in 1988 so that the total current amount of HEU is much larger. A small reprocessing plant at Pelindaba started operation in 1987. It is safeguarded only when safeguarded spent fuel is reprocessed. S.A. has all the required facilities for fabrication of the fuel for its LEU/LW power reactors (Koeberg I, 1984, and II, 1985, each 922 MWe) and its 20 MWt HEU/LW research reactor (SAFARI I) at Pelindaba, supplied in 1965 by the US. The enrichment capacity of S.A. is insufficient for the domestic needs and SA has imported LEU from Belgium, Switzerland and presumably from PRC.

In 1991 S.A. signed the NPT and a safeguards agreement with the IAEA. It has declared it has no intentions of manufacturing NW. There is no proof that SA has built a nuclear device, although in 1977 US and SU satellites detected preparations for a test at the Kalahari desert, and in 1979 a suspicious flash was observed by a satellite.

A few countries are marginally potential proliferators. Libya and Iran can not produce a NW but would love to get one by whatever means they can. Until the dismantling of the nuclear arsenal of the SU this was a remote possibility. Germany and Japan possess sufficient nuclear facilities to make NW but have renounced to do so and are not considered proliferation risks. Argentina and Brazil are two countries with some nuclear capability, having all the facilities for closing the nuclear fuel cycle. Argentina has a fuel fabrication plant, a low enrichment plant (Pilcaniyeu, 1983) and a reprocessing plant (Ezeiza, 15 kg Pu/yr, 1990). It also has three NU/HW power reactors (Atucha I, 320 MWe, 1974; Embalse, 600 MWe, 1983; Atucha II, 745 MWe, 1993?) and 6 research reactors. Brazil has facilities for fuel fabrication, low enrichment (Resende, jet nozzle, 1968; Ipero, 1980, and S. Paulo, 1987, both ultracentrifuge), and reprocessing pilot plan, (S. Paulo). Brazil also has one power reactor in operation (Angra, LEU, 626 MWe) and two under construction, as well as three small research reactors. Brazil and Argentina have declined to join the NPT and the Tlatelolco Treaty, but they have signed safeguards agreements with the IAEA (December 1991). Also in 1991 both countries agreed to ban explosive nuclear devices from their territories and agreed on a mutual, bilateral inspection regime. Therefore neither of the two countries are perceived at present as posing a proliferation risk.

Another country suspected of proliferation intentions is North Korea, that signed the NPT in 1985 but only in April 1992 agreed on an inspection procedure with the IAEA. In May 1992 NK submitted to the IAEA a list of nuclear-related sites ready for inspection, but the list has been considered by some intelligence analysis as incomplete. The first team of IAEA inspectors visited North Korea May 26-June 5, 1992. NK operates at its nuclear site, Yongbyon, about 120 km north of Pyongyang, a 30 MWt NU/graphite reactor provided by PRC, which is adequate for the production of WGPu. It is also suspected, supported by reconnaissance photos, that NK operates a reprocessing plant. However NK denies that such a plant exists and only recently, May 1992, declared that it has produced a small amount of Pu in an unfinished experimental facility. This was confirmed by the IAEA DG, H. Blix, during his visit to NK in May. Thus it may be assumed that NK has not yet reached a NW capability and does not pose an immediate proliferation risk. However NK is a country to which the UN must apply some pressure in order to fully clarify the situation. Hopefully the PRC will also apply some pressure to prevent NK from reaching a NW capability.

The most notorious and well substantiated proliferation effort has been that of Iraq. In September 1975 Sadam Hussein announced his intention of developing a nuclear program and entered into an agreement with France for an Osiris-type 70 MWt HEU research reactor, later on called called Osiraq or Tammuz I, and for an 800 kWt Isis-type critical assembly, designated Tammuz II. The Osiraq could have been used to produce WGPu by surrounding the core with a blanket of U fuel rods. However the agreement with France was not clear about safeguarding Osiraq against possible proliferation. Iraq also acquired from Italy the necessary facilities for fuel fabrication and a hot cell for reprocessing. Israel considered Iraq's program a security threat and complained, to no avail, to the French government. Eventually, in a daring air attack, Israeli warplanes destroyed Osiraq on June 7, 1981 (a prior attempt by Iran, on September 30, 1980, failed to destroy the reactor). On September 25, 1981, the IAEA condemned the Israeli attack and cut off aid to Israel. The destruction of Osiraq was the first time that force was used unilaterally in the name nuclear non-proliferation.

The Israeli attack did not deter Sadam from pursuing his nuclear arming, which was an important political weapon for attaining his ambition to become the superpower of the arab world. Eventually Iraq secretly developed, at an enormous cost, an extensive network of nuclear facilities, code named Petrochemical Three (PC-3), to produce HEU and perhaps WGPu and related technologies for NW manufacturing (nuclear initiators, reflectors, electronic firing systems, etc.). The extent of the program was not fully discovered until Iraq's defeat in the 1991 Gulf War (Fig. 2). According to IAEA reports Iraq was developing an implosion type NW and a delivery missile system. The IAEA inspection teams verified that the al-Atheer plant, that had survived the Gulf War and that they destroyed in April/May 1992, was ready to work on production of NW as soon as HEU produced in the enrichment plants was delivered to it. It should be noted that while Iraq, a party to the NPT, was developing its secret nuclear program the IAEA was allowed to send technical cooperation experts and conducted regular safeguards inspections at the Tuwaitha Nuclear Research Center.

The primary enrichment technologies chosen by Iraq were ultra centrifugation (the plan was to manufacture several thousands) and electromanetic separation using old devices called "calutrons", later nicknamed "baghdatrons" (13 calutrons were in operation at the time of the war, 17 were being installed and up to 90 were planned, capable of producing up to 15 kg/yr of HEU). Gaseous diffusion was also considered, although this is a much more difficult technology and Iraq did not progress very much in this direction. Iraq mined 119 tons of NU and acquired 422 tons from Brazil, Portugal, Nigeria, Germany and Italy. Iraq also bought about 50 kg of HEU from France and the SU and enriched some of its own NU. Iraq had planned to make Pu by irradiating NU in a reactor, and was able to obtain about 3 g at the time of the Gulf War.

The irony of the Iraq episode is that most of the components were obtained in a disguised way from companies in, for instance, the US, Germany, Francee, Great Britain, the Soviet Union and Yugoslavia, through an elaborate procurement network, showing that any country willing to pay the price and take the risk can acquire a NW capability using regular trade channels. This has highlighted one of the loopholes in the non-proliferation regime: the trade of equipment and materials that have other uses besides in the manufacturing of NW and that therefore are not in a trigger list. It also has shown that a country wishing to proliferate at any cost is a formidable challenge to the non-proliferation regime. It required the approval by the UN Security Council of three resolutions (687, 707, 715) in 1991 and a lot of pressure, to force Iraq to reveal the extent of the nuclear program, allow on-site inspections by a team of UN inspectors, and eventually destroy most of the facilities (IAEA 1991). Had Iraq delayed the Kuwait invasion for at least a year it might have been able to manufacture a primitive nuclear device that would have given Sadam tremendous bargaining power. And without the Gulf War the UN Security Council and the IAEA BG most probably would have done nothing in spite of the evidence about Sadam's nuclear program accumulated prior to the Kuwait invasion.

In a different perspective, the transformation of the SU into a CIS has created what might be called "instant" proliferation, because the former Soviet installations are scattered over several of the new independent republics, mainly Russia, Belarus, Ukraine and Kazakhstan, which all suddenly possess NW and delivery systems in their territories. All the republics have expressed their intention to abide by the NPT and transfer to the Russian Federation the NW in their territories under the condition that they will be destroyed, a process that might take some time, even years. However special attention must be paid to the large inventory of fissile materials that have not yet been placed in warheads and can be easily diverted (Kay 1992). The former soviet ministry of Atomic Power, Engineering and Industry was transformed in January 1992 into the Russian Ministry of Atomic Energy, but its authority is restricted to the RF. The former soviet agency Technabexport will continue as a CIS agency in charge of trade in commercial nuclear fuel services provided by CIS members, with the assurance that the trade will be subject to international safeguards. In addition in March 1992 B. Yeltsin issued a decree by which all future exports of nuclear materials.

equipment and technology will require that the importing country places "all" of its facilities under IAEA safeguards, a condition required by all major exporters. The concern that nuclear scientists and engineers working in the former SU nuclear program might pose a proliferation risk by migrating or passing information to other countries is exaggerated and not justified, being based on the presumption of a lack of responsibility of this technical personnel while this sense of responsibility is granted by the West to those working in their nuclear programs (Kapitza 1992). Therefore CIS "instant" proliferation does not seem to pose at the moment a new risk.

A different matter is the disposal of american and soviet NW as a result of nuclear disarmament. In late 1991 President Bush announced the US will dismantle about 3000 tactical NW and place the rest in storage (nuclear artillery shells, warheads for short range missiles, anti-submarine nuclear bombs). Shortly after former President Gorbachev announced that the SU would adopt the same measures and dismantle more than 10 000 tactical NW, a process that is already under way. This process may take a few years to be completed and poses a proliferation challenge: to make sure that the main components and the fissile material (HEU and WGPu) are rendered useless for NW and that no diversion will take place during the process. Disposing over 500 tons of HEU is relatively simple: it is sufficient to dilute it with U-238 down to a low enrichment not usable for NW. This might even be a profitable operation by selling the LEU for use in civilian NPR.

Disposing of WGPu is a more serious task. It can not be rendered harmless by diluting it with other Pu isotopes for reasons given in Part 2; in addition these isotopes are not readily available. Mixing the Pu with U-238 or Th-232 and even spiking it with spent fuel still makes it possible to recover the Pu by standard chemical methods. The Pu could be destroyed by bombarding it with protons from an accelerator or it could be sent into space, but these are expensive measures. One possibility would be to use it in breeder reactors in NWS. Another possibility would be to use the Pu to fabricate MOX fuel elements for use in civilian reactors. Therefore, to make sure that the disposal of NW is not a proliferation risk the best is to conduct the operation under international safeguards and store the removed fissile materials in international facilities until they are disposed in one way or another (Hippel 1992).

4. THE FUTURE

The seriousnes of the Iraq experience has forced many people to reconsider the non-proliferation regime, the effectiveness of its instruments, and the role of the UN Security Council and of the IAEA. An extreme position, held by a few, would be to declare the present non-proliferation regime ineffective and look for alternatives that provide a more solid barrier against proliferation (Weiss 1991). This does not seem to be the best procedure and a more constructive option might be to look for means of reinforcing the current regime to assure that situations like that created by Iraq do not occur again (Pilat 1992; Kay 1992; Scheinman 1991). This boils down to strengthening the IAEA safeguards and inspections procedures, and for the UN Security Council to provide a clear and strong political support to the IAEA inspection procedures and reports (Blix 1991). In the case of Iraq it became clear that the fact that the UN Security Council stood behind IAEA inspections was a decisive factor in changing the opposition of the Iraqi government (Kay 1992).

Regarding the application of safeguards it is essential that the IAEA inspection rights be reinforced by (1) allowing access on short notice of IAEA inspectors to sites that might require inspection at the discretion of the IAEA based on information available to it; (2) expanding the monitoring capability of the IAEA, including sharing of aerial reconnaissance and other specialized techniques for detecting clandestine activities; (3) providing the IAEA with other intelligence related to efforts by suspected proliferators, gathered by concerned nations. Additional measures could include establishing an international registry of nuclear transactions; this might require expanding the trigger list, including items of possible double use, and full cooperation and monitoring by the suppliers.

Securing long term strong political support to the IAEA is more problematic because the UN Security Council is a highly politicized organ. For example the IAEA D.G. could be instructed to supply to the UN SC (via the IAEA BG if so required) information about any resistance by a member country to the inspection procedures outlined above, or any potentially proliferating activity detected by the IAEA or reported by a concerned country. But even if this measure is adopted, there is no guarantee that the UN SC will act promptly and effectively. One thing is to be able to invoke authority and another thing is to have the clout to exercise it.

Concerning the NPT, which is the most important legal instrument of the non-proliferation regime, it was initially agreed by the signatories that 25 years after the NPT entered into force, a conference was to be held to decide "whether the Treaty shall continue in force indefinetely or shall be extended for an additional period or periods" (NPT, Art. X.2). The extension conference will take place in 1995. It is very important to start as early as possible to build a consensus in support of an extension of the NPT without modifications (Fischer 1992). It is true that some important countries (e.g. India, Pakistan, Israel) are not parties to the Treaty and that among the more than 140 parties to the Treaty there may be different opinions about its effectiveness and fairness. Some NNWS feel that the NPT is discriminatory and has not succeeded in forcing the NWS to reverse the arms race and fulfill their obligations under Art. VI. Others feel that the regime should be reinforced by tightening the controls on nuclear trade. And other countries do not perceive themselves directly threatened by proliferation, although they prefer a de-nuclearized world; this is the case of most NNWS.

It is too premature to forecast what will be the most probable outcome of the 1995 NPT Extension Conference. The two crucial aspects will be reinforcing the IAEA safeguards and verification procedures, and exploring how to achieve global nuclear disarmament and stop nuclear testing. Perhaps the most reasonable thing to do would be to extend the NPT for another 25 years, and in a supplementary document or declaration give IAEA stronger political support and urge the NWS to fulfill their obligations. A positive step in this direction has been the agreement in May 1992, between the US and the four CIS nuclear republics to sign START. Shortly after G. Bush declared the US intention to reduce underground testing of NW. A critical issue (David A. Kay, personal communication) for the success of the 1995 conference and the future of non-proliferation might be how convincingly and effectively the IAEA deals with the countries posing more serious proliferation risks (Iraq, North Korea, etc.).

Assuming the use of NP continues to grow worldwide (Starr 1992), one way of minimizing the incentive of NNWS to acquire sensitive facilities to fully support their NP programs could be to agree on the construction of international facilities for handling all aspects of the nuclear fuel cycle (enrichment, fuel fabrication, reprocessing and storage), properly safeguarded by an international force (INFCE 1980; Chayes 1977; Weinberg 1985). As indicated earlier in this paper, this idea has been under consideration since the emergence of the nuclear era, but for many reasons it has never materialized, particularly because the political conflicts in the world have made the idea unattractive and the NNWS have either accepted to depend on bilateral agreements with suppliers, that are not always reliable, or have decided to build their own facilities.

Hopefully if a peaceful and democratic world, in which differences and conflicts among nations are solved without recourse to military force, is achieved, international agreements might become more reliable and acceptable and therefore international nuclear fuel facilities can provide a practical and stable arrangement for the safe use of NP. It is regrettable that partly because of the threats of wars and the fears of terrorism and repressive dictatorial governments, the world can not develop efficiently an excellent and clean energy source that is badly needed for satisfying the needs of all peoples in the world and for the preservation of the environment

In conclusion the fate and effectiveness of the nuclear non-proliferation regime depends basically on the termination of the nuclear arms race (which, as a result of the conclusion of the Cold War and the June 1992 agreements between Bush and Yeltsin, seems now closer), on the political will of all NPT signatories to fulfill their obligations to the Treaty, on the approval and enforcement of strong safeguards and verification procedures, and on the political will of the UN bodies to impose severe sanctions on violators, which experience has shown are not fully effective, and the use of a multinational force. But above all, a safe de-nuclearized world will be possible only when the people of all nations learn to live in peace among themselves and with the people of other nations, under democratic governments that are concerned with the welfare of their people and respect and protect their fundamental rights. That places the responsibility for the future of the world in the hands of a few leaders.

LIST OF ABBREVIATIONS

AEA: Atomic Energy Act, US Congress
AP: Atoms for Peace program
BG: Board of Governors
CIS: Commonwealth of Ind. States
ENEA: European Nuc. Energy Agency
FRG: Federal Rep. of Germany
GB: Great Britain
HB: hydrogen bomb
HEU: highly enriched U (>20%U-235).
HW: heavy water (D2 O)
IAEA: Int. Atomic Energy Agency
IANEC: Interame. Nucl. Energy Com.
LEU: low enriched U (<20%U235, <5% in NPR)
LW: light water (H2 O)
MWd/TU: megawatts-days per ton of U (a measure of energy extracted from U)
NNPA: Nuclear Non-prolif. Act, US Congress
NNWS: non-nuclear weapons states
NP: nuclear power
NU: natural U(0.711%U-235)
NPT: Non Prolif. Treaty
NTBT: Nuclear Test Ban Treaty
NPR: nuclear power reactor
NW: nuclear weapon
NWS: nuclear weapons states
PRC: Peolple's Rep. China
RF: Russian Federation
SALT: Strategic Arms Limit. Treaty
START: Strategic Arms Reduction Treaty
SU: Soviet Union
UN: United Nations Org.
SC: Security Council
WGU: weapons grade U (>90% U-235)
WGPu: weapons grade Pu (90% Pu-239)

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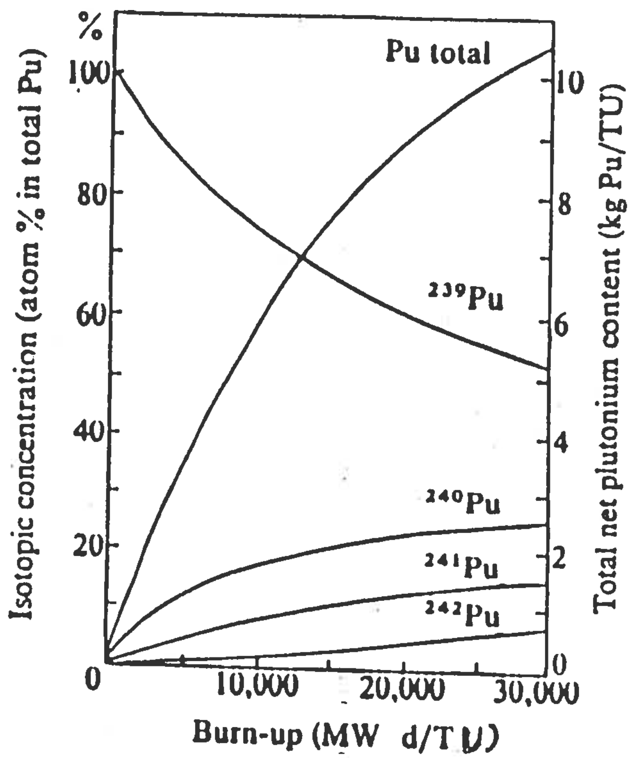

Fig.1. Isotopic Composition of Pu as a function of the burn-up in a LWR (Gylden, N, & Holm, L.W., , ERDA-tr-45, 1974)

Fig. 2. Iraq nuclear installations at the time of the Gulf Wa 1991.