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DIIS Brief

Upping the Ante – The North Korean Nuclear Deterrent

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Abstract
A party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) since 1985, North Korea in 2003 admitted that the country had nuclear weapons[1]; a message that stunned the world. The announcement was made following a long conflict with the International Community (IC) where first the North Korean regime had limited International Atomic Energy Agency (IAEA) inspections in 1992 and since had been playing a dangerous tit-for-tat game with the IC over its nuclear program.

Finally in late 2002, the remaining IAEA-inspectors were expelled from North Korea and the country announced in early 2003 that it would withdraw from the NPT, the central international agreement to limit nuclear weapons proliferation and ultimately get the nuclear genie back into the bottle.[2]

The crucial question is the extent to which the North Korean claim to possess nuclear weapons is correct. Much uncertainty exists over this issue, particularly as the very organisation tasked with – among other things – controlling nuclear proliferation, the IAEA, was not and still is not empowered sufficiently to carry out the task. This is not and has not been the case when it comes to North Korea and is not the case presently when it comes to Iran. Basically a discussion of intent versus capacity, this uncertainty has worked in North Korea's favour as the increasing likelihood of a North Korean nuclear deterrent has made North Korean nuclear disarmament an entirely different ballgame.

This DIIS-brief will first describe the international effort to limit the proliferation of nuclear weapons, including IAEA measures to control nuclear proliferation, which were not and can not be brought sufficiently to bear on the North Korean nuclear issue. Secondly, based on North Korea's nuclear capabilities, the brief discusses the country's claim that it actually does have a nuclear deterrent by attempting to outline the North Korean capability to produce sufficient amounts of fissile material.

[1] The statement was made to American officials engaged in negotiations with the North Korean regime over its nuclear program in April 2003. See among others CNN, "*North Korea admits having nukes*", 25th April 2003. Later, in February 2005, the country publicly declared that it had a nuclear weapons capability.
[2] NPT article VI calls for nuclear disarmament and eventual abolishment of nuclear weapons.

"This is a country in defiance of its international obligations. It sets a dangerous precedent for the integrity of the non-proliferation regime."

IAEA Director General, Dr. ElBaradei, December 2002 on the expelling of the last IAEA-inspectors from North Korea

Introduction

Some political science theorists advocate the general spread of nuclear weapons as a means of establishing equilibrium between rivalling powers and, as an example, point to the recent thaw in relations between young nuclear powers India and Pakistan. Both countries now boasting a nuclear deterrent, the argument runs that as rational state actors both now have an interest in avoiding confrontation.

In the real world, however, one example rarely constitutes a rule, and 45 years of both politically untenable and hugely expensive nuclear arms race during the cold war should more than adequately emphasise the common sense behind nuclear disarmament. Furthermore, some state actors already having nuclear weapons or others hoping to obtain them, are less than stable regimes. This triggers concern as to the future control over the “nuclear button”.

The general proliferation of dual-use products and nuclear weapons related technology and know-how readily for sale in a shadowy nuclear black market, may contribute to a future scenario where crude nuclear devices may end up with non-state actors. Rather than acting “rationally” to preserve a national homeland, presumably such groups would detonate their device sooner rather than later. There are thus multiple reasons for establishing and upholding a “nuclear order”.

In order to obtain a feasible “nuclear order”, it is ever more important that the IC agrees on the way ahead. An important step was the adoption of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in 1970 and the indefinite extension of the same treaty in 1995. But, perhaps even more crucially, firstly the IC must sufficiently empower the international institutions chosen to verify that nations comply with the NPT and secondly act swiftly and with resolve, when nations disregard their international commitments under the NPT.

Most recently the lack of coherent support for the IAEA has enabled two states, North Korea and Iran, to disregard their international obligations under the NPT. Both claming to pursue nuclear technology for purely peaceful means, as is their right under the NPT, the two countries have prevented the international community from gaining the necessary insight needed to take action to uphold the nuclear non-proliferation regime.

Discussing the North Korean nuclear program, this DIIS-brief will illustrate the limited means at hand for the IAEA to uphold the NPT, attempt to outline the nuclear capacity of North Korea and – as a consequence of inconsistent action from the IC – finally discuss the likelihood that the North Korean endeavour has indeed made the country a nuclear weapons power.

The Nuclear Non-Proliferation Regime and the Nuclear Fuel Cycle

Some have seen the emergence of nuclear weapons-states such as India and Pakistan and most likely also Israel outside the framework of the NPT as a clear indication that treaty-based nuclear non-proliferation spells disaster.

Others believe that the emergence of “only” three nuclear-weapons newcomers outside the

NPT over a period of some thirty years is a remarkable success.[3] The South African decision to abandon its nuclear weapons program comprising six operational gun-type devices is probably the most famous.

Nevertheless, the current regime is under pressure, as globalisation with its easier cross-border movement of products, services and knowledge has made an impact on the availability of components, materials and know-how central to a nuclear program and thus potentially a nuclear weapons program. Adding to the pressure, transnational actors such as illegal procurement networks[4] have been able to move swiftly across and around national and international barriers to illegal trade such as customs authorities and export control regimes.

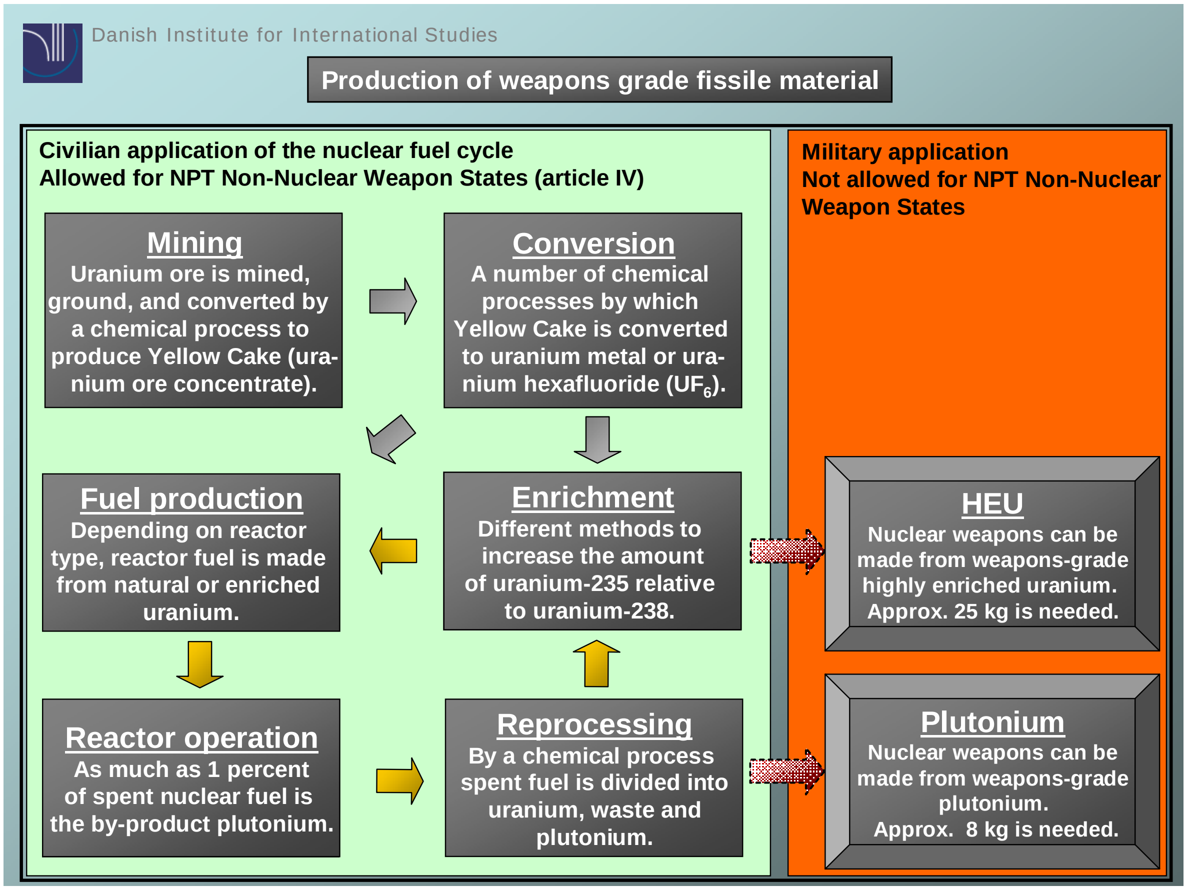

Figure 1. Mastery of the full nuclear fuel cycle holds challenging perspectives both for the non-nuclear weapons states under the NPT, which master that fuel cycle, and – particularly – the control regime which tries to uphold the NPT. As will follow below, North Korea has both a suitable reactor and the necessary reprocessing capability and has positively manufactured small amounts of weapons-grade plutonium.[5]

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[3] See among others William Walker, "Weapons of Mass Destruction and International Order", Adelphi Paper 370, The International Institute of Strategic Studies, 2004.
[4] The A.Q. Khan-network represented a particularly sophisticated procurement network, as it offered technical advice, components and equipment, as well as customer support. IAEA Director General ElBaradei has characterised the network as the "Wal-Mart of private-sector proliferation." Se among others The New York Times, 23rd January 2004, "*U.N. Official Sees a 'Wal-Mart' in Nuclear Trafficking*".
[5] The amounts of fissile material needed for a nuclear device depend on a variety of issues. Generally speaking the more advanced technology employed (primarily speed, precision and timeliness with which the fissile material is assembled to form a supercritical mass), the less than stipulated in figure 1 is needed. The Trinity shot on 16th July 1945 and the Fat Man bomb dropped on Nagasaki – both implosion devices – each used 6.1 kg

Set up by national bureaucracies, these barriers to illegal trade are disadvantaged by both a need to minimise the disturbance of the legal free movement of goods and services, which is a cornerstone of the international economy, as well as cumbersome international co-operation. Furthermore, illegal procurement networks probably don't have the weekend off or respect national holidays.

Central to the discussion is the right of non-nuclear weapons-states under NPT article IV to master the nuclear fuel cycle for purely peaceful purposes[6]. As illustrated above in Figure 1, it is the right of NPT non-nuclear weapons states to obtain control of all civilian application aspects of the nuclear fuel cycle; a right often invoked by both North Korea and Iran.

However, control of central processes such as enrichment of uranium and reprocessing of spent fuel to extract plutonium provides capacity not only to run civilian nuclear power plants but also capacity to produce weapons-grade fissile material. It is likely that at the time of the negotiation of the NPT in the late 1960s, it seemed inconceivable that many more countries than the nuclear weapon-states at the time would be able to build up the huge nuclear infrastructure that is required to control the nuclear fuel cycle.

Today, however, the IAEA estimates that some 35 to 40 states can produce fissile material in the necessary quantity and quality and – if intent exists – can manufacture a nuclear device.[7] Thus, as sensitive technology is becoming more readily available and proliferation is originating not only in the developed world but also in the developing world[8], the task of the IAEA as the global nuclear inspectorate is becoming more delicate.

The role of the IAEA

Under the NPT, all non-nuclear weapons states must accept and submit to the IAEA safeguard system in order for the IC to be able to verify that no nuclear material or technology is diverted from peaceful uses to nuclear weapons.[9] IAEA has changed this system, as the Iraqi nuclear weapons development program under Saddam Hussein and other clandestine nuclear programs demonstrated that a more intrusive system was needed.

Originally, a non-nuclear weapons state would declare nuclear facilities along with nuclear materials, and IAEA inspections were carried out facility-by-facility in accordance with that declaration. Thus, inspections under the then most intrusive regime – the Comprehensive Safeguards Agreement – were mostly an audit to make sure that no declared nuclear material

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of weapons-grade plutonium producing yields of approximately 21 kt. Modern nuclear devices use still less fissile material. See among others Robert S. Norris et al, "*North Korea's Nuclear Program, 2003*", Bulletin of Atomic Scientists, March/April 2003.

[6] The NPT article IV, section one reads: "*1. Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty."*

[7] See among others Mohamed ElBaradei, *"Towards a Safer World"*, The Economist, vol. 369, 16th October 2003.

[8] This phenomonen is also referred to as secondary proliferation. See among others Rødbro, *"Det Internationale Atomenergiagentur og den sekundære nukleare proliferation"*, DIIS-brief (only in Danish), March 2004.

[9] The NPT article III, section one reads: *"Each non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfilment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices."*

was diverted for non-peaceful purposes.

In the early 1990s the discovery of the clandestine Iraqi nuclear weapons development program along with both the South African nuclear weapons program and verification problems encountered in North Korea indicated a less than efficient approach. That led the IAEA to conclude that authority was needed to enable the Agency to verify that declarations submitted by member-states were not only *correct* but also *complete*.

This called for a more analytical approach to a given state's nuclear program: Rather than performing mere audits of state declarations, the IAEA in 1998 adopted the production and periodic update of State Evaluation Reports (SER) and of a corresponding action plan.[10] A SER will compare a state's declaration with all the information available to the IAEA, which could comprise inspection results, open source information and intelligence from third parties. This approach enables the Agency to pinpoint with higher accuracy any discrepancy between what a given state has declared and what is *really* going on in that state's nuclear program.

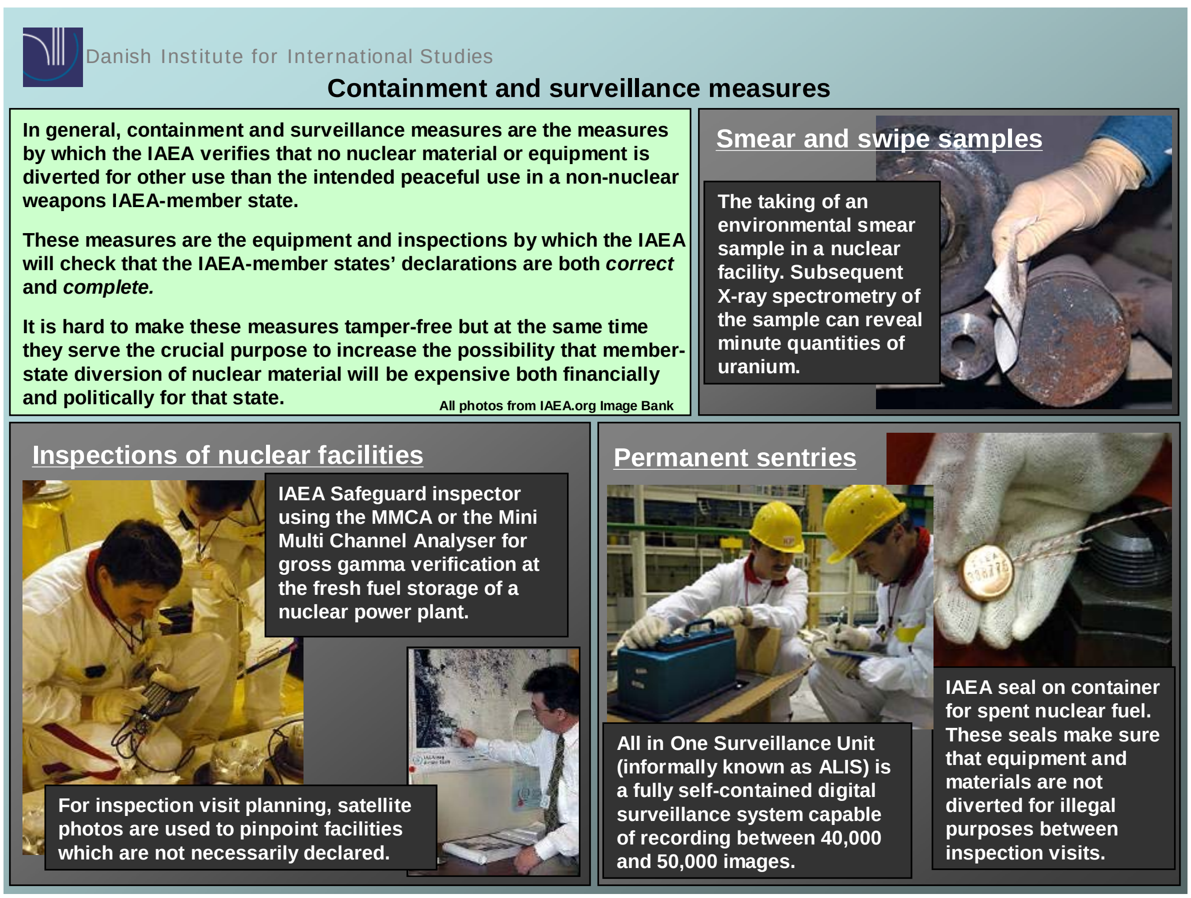

Figure 2. If allowed by IAEA-Member State, a host of measures can be used to ensure that declarations on nuclear materials and activities submitted by that state are both complete and correct.

In tune with the above, the Additional Protocol to the Comprehensive Safeguards Agreement had been introduced by the IAEA in 1997. The chief novelty of the Additional Protocol was a right for the Agency to conduct inspections to establish that are no *undeclared* activities or

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[10] See among others Pierre Goldschmidt, *"The Urgent Need to Strengthen the Nuclear Non-Proliferation Regime"*, Carnegie Endowment Policy Outlook, January 2006.

facilities in a given non-nuclear weapons state that has concluded an Additional Protocol with the Agency.[11] In other words: to move inspections out beyond declared facilities.

With the Additional Protocol, the safeguards system has been strengthened both in terms of effectiveness and efficiency. The safeguards system still comprises a number of measures – some of which are illustrated in Figure 2 above – by which the IAEA independently can verify the declarations made by member-states concerning their nuclear material and activities.

But the degree of intrusiveness has been elevated with the Additional Protocol, thus giving the IAEA authority to conduct inspections and perform swipe sampling at places of its choosing rather than just installations declared by the member-state. In that way the Agency is better suited at identifying early indications of *incomplete* declarations and thereby indications of nuclear material and/or activities diverted for purposes other than peaceful.

However, as has been clearly demonstrated by North Korea since 1992 – and for that matter by Iran since 2003 – the IAEA's efficiency is no better than the state under scrutiny – but sadly also some IAEA-member states as well as the IC in general – allows it to be.

The International Negotiations about the North Korean Nuclear Program

The international negotiations about the North Korean nuclear program have developed into a protracted tit-for-tat game between primarily North Korea on one side and the USA on the other. Basically, North Korea insisted that its nuclear program was peaceful and aimed at power generation; but the country demanded US security guarantees before it gives up its nuclear program. On the other hand, the US demanded and demands North Korean denuclearisation before security guarantees can be discussed.

At the very core of the issue is the question of just how advanced the North Korean nuclear program is. The level of the country's technological proficiency can be translated into nuclear weapons capability, and the uncertainty on North Korea's nuclear capability remains the primary lever for the North Korean regime to extract concessions from the IC in return for a pledge to close down the country's nuclear program.

An NPT-member since 1985, North Korea submitted its first declaration on all nuclear material subjected to safeguards on 4th May 1992. Among other things, North Korea stated that around 100 grams of plutonium had been separated from damaged fuel rods from the country's 5 MW(e)-reactor[12] at North Korea's primary nuclear facility at Yongbyon. Allegedly, the separation had taken place during one single campaign in the spring of 1990.[13] Subsequently, also in 1992 North Korea presented plutonium oxide containing approx. 62 grams of plutonium to IAEA inspectors.[14] This demonstrated ability to separate plutonium.

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[11] In principle there are three types of safeguards agreements: The Comprehensive Safeguards Agreements; INFCIRC/66-type Safeguards Agreements, which are not comprehensive but rather item specific; and the Additional Protocols. Furthermore, the five NPT nuclear-weapons states have offered some or all civilian nuclear materials and/or facilities for the application of safeguards. See www.iaea.org/publications/factsheets

[12] The size of a nuclear reactor is measured in thermal power (t) or popularly put "heat". A power reactor output is also indicated in electric power (megawatt electric (MW(e))), which is normally 25-35% of the thermal power. North Korea insists that the 5 MW(e)-reactor at Yongbyon is a power reactor.

[13] See David Albright, *"North Korean Plutonium Production*", Science and Global Security, Volume 5, 1994.

[14] See Dr. Siegfried S. Hecker, *"Visit to the Yongbyon Nuclear Scientific Research Center in North Korea"*, statement given before the US Senate Committee on Foreign Relations on 21st January 2004.

Analysis of IAEA-swipe sampling taken at Yongbyon revealed with a high degree of probability that plutonium with a very high proportion of the isotope plutonium-239 – even if only on a laboratory scale – had been extracted. This demonstrated ability to produce weapons-grade plutonium in reactor fuel and subsequently extract it in a reprocessing plant.[15]

Carried out later in May 1992, the first IAEA-inspection had the task to verify North Korean information and assess the completeness of the declaration. However, after analysis during the summer of 1992, IAEA pointed to inconsistencies between North Korean declarations and inspection results based on among others swipe samples taken at Yongbyon. This lead North Korea to suspend IAEA-inspections in 1993. Subsequently, following North Korean threats to withdraw from the NPT[16], the IAEA brought North Korea before the UN Security Council (UNSC) in April 1993.

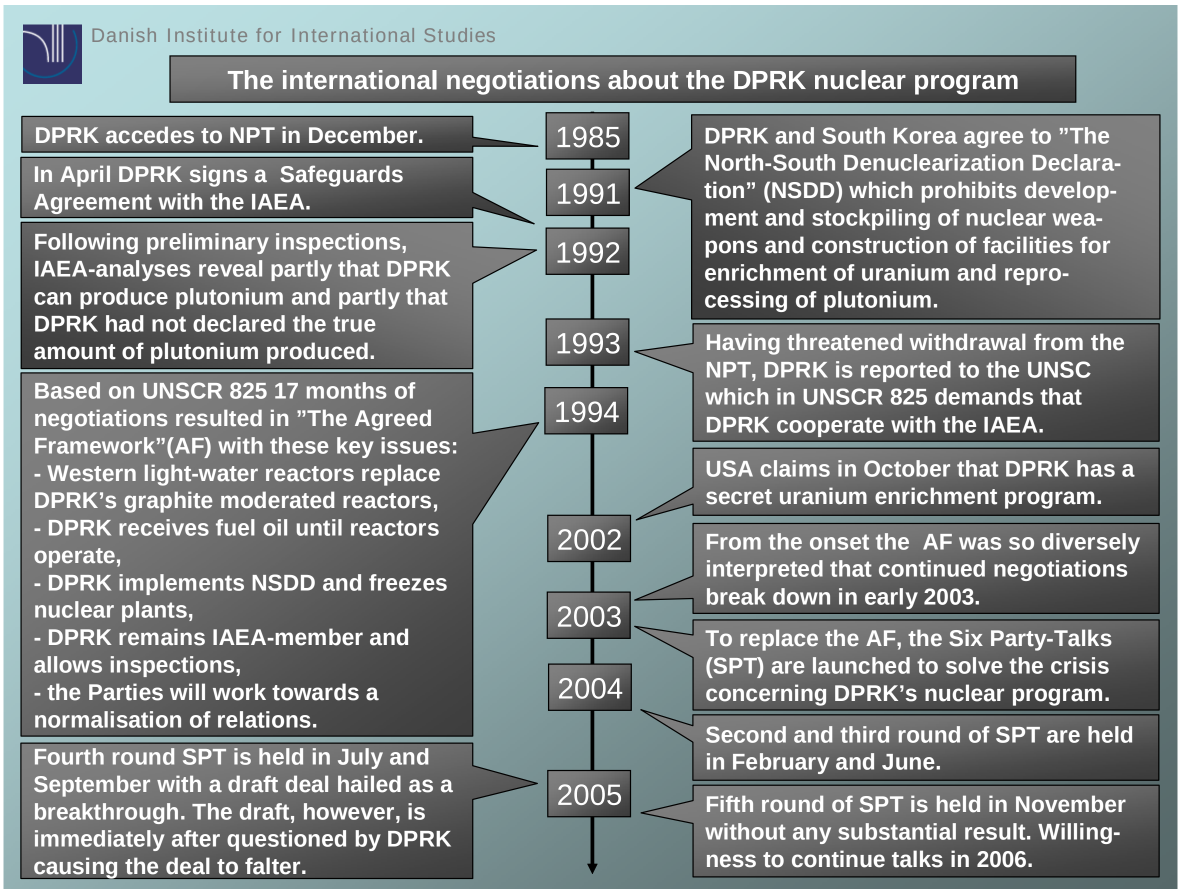

Figure 3. The international negotiations over the North Korean nuclear program.

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[15] See David Albright, *"North Korean Plutonium Production*", Science and Global Security, Volume 5, 1994. Albright quotes IAEA reporting according to which approx. 97.5% of the plutonium in the initial IAEA samples taken at the Radiochemical Laboratory was plutonium-239 and about 2.25-2.5% was plutonium-240. It was thus high quality weapons-grade plutonium.

[16] Under the NPT article X, a member state is authorised to withdraw from the treaty. *"Each Party shall in exercising its national sovereignty have the right to withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country. It shall give notice of such withdrawal to all other Parties to the Treaty and to the United Nations Security Council three months in advance. Such notice shall include a statement of the extraordinary events it regards as having jeopardized its supreme interests."* Strangely, under the treaty no direct sanctions follow from a withdrawal, but as also pointed out by Pierre Goldschmidt, in *"The Urgent Need to Strengthen the Nuclear Non-Proliferation Regime"*, Carnegie Endowment Policy Outlook, January 2006, a revision of article X is unlikely.

Thereby, the dispute over the North Korean nuclear program kick-started international negotiations over the program. At the same time, because of North Korean obstruction to inspections, the program was sent down a path, which has been characterised by less and less international supervision and surveillance of that same program. Thus, apart from an ability to produce weapons-grade plutonium in very small quantities, the scope and nature of the North Korean nuclear program have become increasingly shrouded in uncertainty.

The negotiations have now carried on for more than twelve years. The dispute was initially an issue between North Korea and the IAEA over declared amounts of nuclear material. With the first referral to the UNSC and the resulting UNSC Resolution 825, subsequent negotiations were lifted onto a different level. Rather than being a dispute between the IAEA and a member state, the issue called for the first of two international attempts to solve the crisis.

In 1994 17-months of negotiations between North and South Korea and the USA led to the Agreed Framework under which North Korea in return for a moratorium on plutonium production and an eventual dismantling of its nuclear program would receive international help as well as nuclear power reactors. However, the negotiations faltered because of differing perceptions of the detailed terms of the agreement, and finally after a row over a possible North Korean uranium enrichment program in early 2003, the collapse of the talks was a fact.

Chinese attempts at restarting talks initially failed, but in July 2003 a new framework was established, as the two Koreas, Japan, Russia, China and the USA agreed to find a solution to the North Korean nuclear program. This also suited North Korea well as the introduction of more parties to the negotiations firstly meant more national agendas – and thereby more room for manoeuvre for North Korea – and secondly the addition of Japan as another affluent potential donor besides the USA.

These negotiations have become known as the Six Party-Talks. At the heart of the issue was – again – the going price for conducting a complete, irreversible and verifiable North Korean nuclear disarmament. New North Korean demands made in the fall of 2005, however, complicated the interpretation of a potential September 2005 breakthrough in the talks, which ground to a halt in early 2006.

During the entire course of the international negotiations, North Korea has maintained the pressure on the IC by continuously sparking anxiety about the state of its nuclear program and related means of delivery systems.

Thus, in 1993 and 1998 North Korea launched missiles across Japan. Claiming to attempt to bring a satellite into orbit, North Korea vehemently denied Japanese and American accusations that in the last of these launches, it had in fact test fired a nuclear capable medium range ballistic missile.[17]

In 2002, following a dispute about a possible – and if existing illegal, as no such program had

[17] In June 1993 North Korea launched a Nodong-1 missile across Japan. Based on obsolete Soviet technology from the Scud missile, the Nodong-1 is a liquid fuelled, single stage missile with a calculated range of 1,000 km. In August 1998 a Taepodong-1, claimed to be a space launch vehicle, was fired across Japan but the third stage malfunctioned and failed to bring its payload into orbit. The Taepodong-1, however, is believed to be a liquid fuelled, two-stage missile with a calculated range of 2,200 km but is still not believed to be operational.

been declared, as it should under the NPT – North Korean uranium enrichment program, the country expelled the remaining IAEA-inspectors and in early 2003 withdrew from the NPT.[18] Later in 2003 North Korea fired two missiles into the sea between South Korea and Japan.[19] Also in 2003, North Korea announced that it had reactivated its nuclear program and had begun reprocessing spent nuclear fuel to extract weapons-grade plutonium.

This anxiety has been all the more emphasised, as North Korea persistently hampered or denied IC-access to its nuclear and related programs. With IAEA-monitoring of the North Korean nuclear program limited since 1992 and since 2002 effectively removed, important indications of the aim and nature of this program essentially dried out. Add to that an extremely closed society, from which only little information escapes government control, and any attempt at metering out a realistic view of the nature of the North Korean nuclear program becomes very difficult.

Overall, it would thus appear that North Korea has an interest in maintaining negotiations as a viable option but at the same time wishes to keep these negotiations as complex as possible. In the North Korean view, complexity here spells firstly a possibility to raise the price for nuclear disarmament, and secondly a possibility to continue already existing efforts to produce plutonium and quite possibly to continue to develop a nuclear weapons capability.

The True Nature of the North Korean Nuclear Program

Little is known about the North Korean nuclear program and the country's claim to possess nuclear weapons. The primary prerequisite for a nuclear weapons capability – production of weapons-grade fissile material – is, however, a hurdle, which North Korea surmounted around 1990, as already described above. The key question remains how much weapons-grade fissile material North Korea has been capable of extracting from spent nuclear fuel over the past some 16 years.

North Korea has chosen the plutonium track for production of fissile material. Thus, its ability to acquire a sufficient amount of fissile material in the necessary quality hinges on three factors: 1) A suitable reactor[20] in which irradiation of nuclear fuel will generate plutonium in the fuel. 2) Sufficient amounts of nuclear fuel irradiated to generate the necessary quality of plutonium in the nuclear fuel. 3) A facility to reprocess the spent fuel to extract the plutonium.

In terms of the above requirements North Korea has two key facilities, as illustrated below in Figure 4. Firstly, the 5 MW(e) experimental reactor with a construction that favours generation of plutonium when reactor fuel is irradiated during reactor operation.

Secondly, a reprocessing plant – which is referred to by North Korea by the more peaceful term "Radiochemical Laboratory" – where irradiated fuel can be reprocessed and plutonium

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[18] When North Korea expelled the IAEA in December 2002, it prompted strong reactions from the IC and the IAEA: In the IAEA Board of Governors resolution GOV/2003/3, it among other things states that it *"Deplores in the strongest terms DPRK's unilateral acts to remove and impede the functioning of containment and surveillance equipment at its nuclear facilities and the nuclear material contained therein, including the expulsion of IAEA inspectors, which renders the Agency unable to verify, pursuant to its safeguards agreement with the DPRK, that there has been no diversion of nuclear material in the DPRK…"*

[19] The missiles are believed to have been short-range anti-ship missiles and thus not ballistic missiles capable of threatening for instance Japan. Still, as there – again – was no prior notification, the launches caused concern.

[20] The North Korean 5 MW(e)-reactor as described in more detail in figure 4 is well suited for production of plutonium.

generated in reactor fuel can be extracted, apparently on an industrial scale. [21]

However, even if the facilities needed to ensure capability to produce weapons-grade plutonium have been determined, the facilities have not been under constant IAEA surveillance and thus the amounts of plutonium produced and extracted remain shrouded in uncertainty.

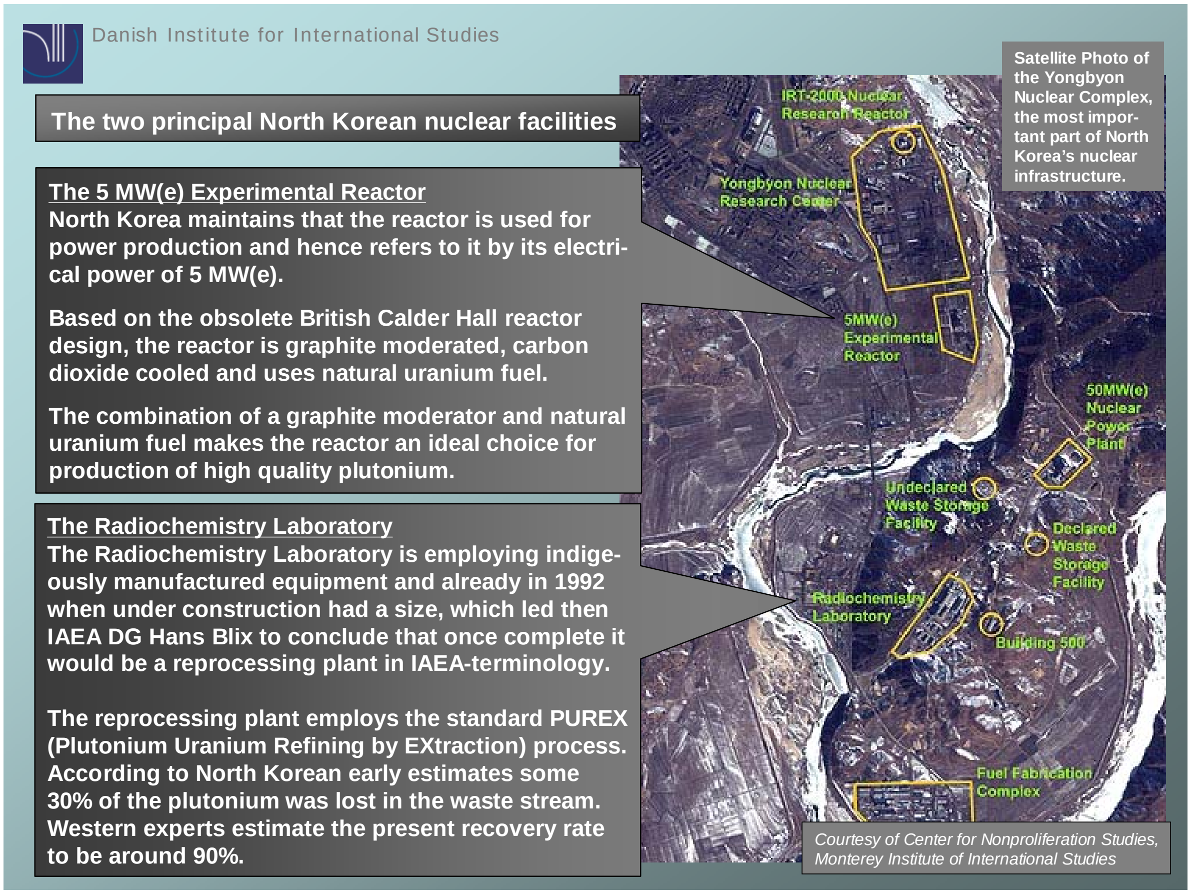

Figure 4. Satellite overview of the Yongbyon nuclear complex some 100 km north of the North Korean capital, Pyongyang.

North Korea did accept IAEA-safeguards in 1992, but limited the surveillance in 1993 following the crisis over North Korea's incorrect declaration of plutonium production. In 1994 North Korea continued its policy of impeding IAEA-inspections particularly of the reprocessing plant. Following from the 1994 Agreed Framework, the country did, however, accept a moratorium on its nuclear program under IAEA surveillance.[22] This moratorium lasted until late 2002.

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[21] Following an IAEA-inspection of the North Korean nuclear facilities, Dr. Hans Blix, then Director General of the IAEA, in a press briefing in Beijing, May 16, 1992, stated that the Radiochemical Laboratory was characterised by the IAEA as a reprocessing plant.

[22] See Global Security.org at http://www.globalsecurity.org/wmd/world/dprk/yongbyon.htm, *"Under the "Agreed Framework" the DPRK agreed that there would be no operations at the facilities covered by the freeze and no construction work of any kind, either at existing facilities or new, related facilities; that the spent fuel from the 5 MWe reactor will be stored and disposed of in a manner that does not involve reprocessing in the DPRK; and that any movements of nuclear material or equipment within those facilities, any necessary maintenance work by the operator and any transfers of nuclear material out of the facilities would have to be carried out under the observation of IAEA inspectors or under other IAEA arrangements…. IAEA uses all technical means available to monitor the freeze at these facilities, such as using seals that can indicate instances of tampering, using video cameras, and making short-notice inspections. The particular method(s) used depends on the circumstances at*

Thereafter the IC has had very little insight into what has been going on regarding the North Korean nuclear program.

Unexpectedly, however, in January 2004 an unofficial American delegation was allowed to visit Yongbyon, including the reprocessing plant. More importantly, a distinguished nuclear scientist on the delegation, Dr. Siegfried S. Hecker,[23] was given a (controlled) tour of the 5 MW(e)-reactor[24] and parts of the reprocessing plant and time to discuss technical questions with the staff.[25] Finally, as another surprise, while at the reprocessing plant he was shown the final product in the form of a small metal funnel claimed to be plutonium.

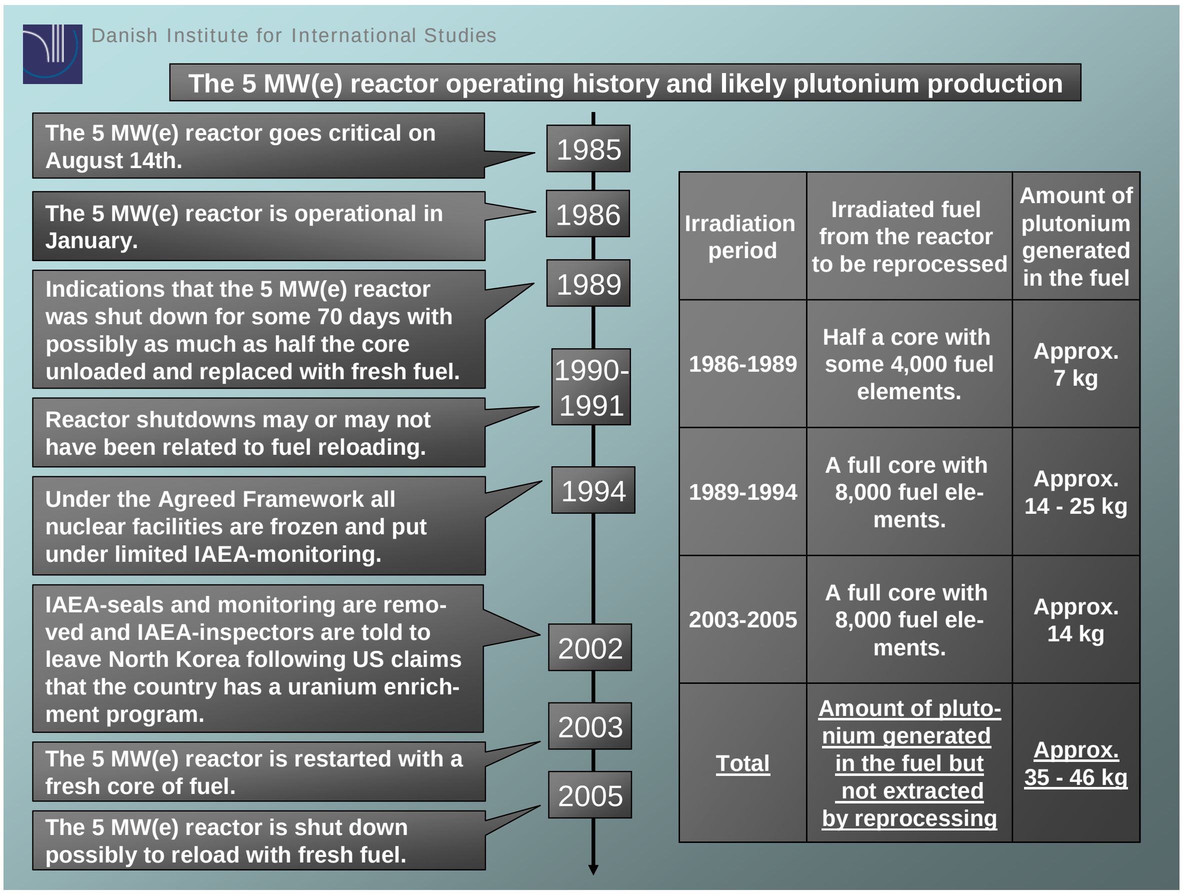

Figure 5. One of several estimates at North Korea's plutonium production[26]

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each of the three facilities. The primary monitoring method was the use and frequent verification of tamper-indicating seals on equipment and installations throughout the "frozen" nuclear facilities. Video cameras are also used for surveillance. Finally, short-notice inspections were used to monitor certain equipment and areas in the frozen facilities that have not been allowed to be sealed." (author's emphasis).

[23] See Dr. Siegfried S. Hecker, *"Visit to the Yongbyon Nuclear Scientific Research Center in North Korea"*, statement given before the US Senate Committee on Foreign Relations on 21st January 2004. A metallurgist, Dr. Hecker was director of Los Alamos National Laboratory from 1986 to 1997 and will thus have intimate knowledge of production and processing of fissile materials used for nuclear weapons.

[24] The American delegation was toured through the reactor control room and the observation area for the reactor hall. See Dr. Siegfried S. Hecker, *"Visit to the Yongbyon Nuclear Scientific Research Center in North Korea"*

[25] Specifically Dr. Hecker outlines the constraints imposed upon the visit to the reprocessing plant as such: *"Radiochemical Laboratory – 3rd floor corridor that allowed for viewing of the hot cell operations through shielded glass windows and a conference room. (This facility is also inside the second high-security area)."* In other words, the North Koreans ensured that Dr. Hecker only saw what they wanted him to see.

[26] See also David Albright, *"North Korean Plutonium Production"*, Science and Global Security, Volume 5, 1994.

When it comes to the plutonium production potential of the 5 MW(e)-reactor, a number of parameters are of importance. Primarily of interest are the questions at what power level the reactor is operating and how often the fuel is replaced, since fuel irradiated for too long will contain too large a quantity of undesirable plutonium isotopes.[27]

Dr. Hecker was able to confirm that the 5 MW(e)-reactor was operating and apparently also at the time running smoothly. However, this assessment is based on visual inspection of the control room gauges during the tour and does not indicate if the reactor had been operating smoothly in the previous year, as the North Korean officials claimed it was restarted in February 2003.

An educated guess at the above potential would amount to an annual production capacity of approx. 5,5 kg of weapons-grade plutonium at a reactor operational capacity of approx. 75%.[28] Figure 5 above is one estimate of the amount of plutonium produced in the reactor fuel. It must be emphasised, however, that the uncertainty is substantial.

The next crucial bottleneck is the capacity to reprocess the spent fuel and extract the plutonium. The existence of the reprocessing plant at Yongbyon is well documented but the capacity and efficiency of the plant is more uncertain. There is in other words a limit to the knowledge, which can be deduced from satellite imagery as opposed to actually having hands-on experience from the plant.

Specifically, how well does the industrial scale reprocessing of spent fuel and the extraction of plutonium work and how much plutonium is lost in the waste stream? An important parameter in this connection is the ability to have the reprocessing plant operating continuously, as frequent shutdowns can increase the quantity of plutonium lost in the waste stream.

During the visit the North Korean hosts informed their guests that the plant had a capacity to reprocess 110 tonnes of spent uranium fuel per year. Dr. Hecker noted that the industrial-scale reprocessing facility appeared in good repair[29] and more importantly, based on his visual impressions and conversations with plant staff, assessed that the necessary facilities, equipment, and technical expertise required for industrial-scale reprocessing of spent reactor fuel and extraction of plutonium were present. Particularly the ability very competently to enter

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[27] In its nuclear reactor, North Korea uses magnox fuel — natural uranium (>99% uranium-238) metal, wrapped in magnesium-alloy cladding. About 8,000 fuel rods each weighing some 6.2 kg constitute a fuel core for the reactor. In general, when irradiated in a reactor, U-235 in uranium fuel will fission and keep the chain reaction running, while U-238 in the same uranium fuel will absorb a neutron and then decay into plutonium (plutonium-239). Fuel that remains in the reactor for a long time begins to become contaminated by the isotope plutonium-240, which is less desirable in a nuclear weapon. Plutonium that stays in a reactor for a long time (reactor-grade, with high "burn-up") contains 20 - 30% Pu-240; weapons-grade plutonium contains less than 7% Pu-240. It is possible to make a nuclear weapon from reactor-grade plutonium, albeit with a relatively lower yield. See among others CRS Report for Congress, *"North Korea's Nuclear Weapons – How soon an Arsenal?"*, 1st August 2005.

[28] See among others Daniel A. Pinkston et al, "*Special Report on the Shutdown of North Korea's 5MW(e) Nuclear Reactor*", April 2005, Monterey Institute of International Studies, cns.miis.edu/pubs/week/pdf/050428.pdf

[29] The reprocessing plant had been frozen since 1994 in accordance with the 1994 Agreed Framework and presumably was not reactivated before early 2003. In his statement before the senate mentioned in footnote 22, Dr. Hecker describes what he encountered in terms of capacity and know-how: *"At the Radiochemical Laboratory we confirmed that they possessed an industrial-scale reprocessing facility. The facility appeared in good repair. They demonstrated the requisite facilities, equipment, and technical expertise required for reprocessing plutonium at the scale in question. They use the standard PUREX (plutonium uranium extraction) process for separating plutonium from the fission products and uranium fuel. They answered all our technical questions about the reprocessing chemistry very competently."*

into conversation about reprocessing chemistry, could indicate that the plant staff were not just reciting textbook knowledge but actually had hands-on experience.

One issue is the extraction of plutonium from spent reactor fuel – in itself a taxing process – but quite another issue is the production of plutonium metal and casting this metal into a weapons core. As plutonium is polymorphous[30], controlling the geometry and dimensions of a plutonium metal weapons core while casting it, is an extremely delicate procedure. For that reason the presentation of the alleged plutonium funnel as illustrated in Figure 6 below is very interesting, as the funnel – if indeed it was plutonium – is an indication of a good level of proficiency in controlling plutonium casting.

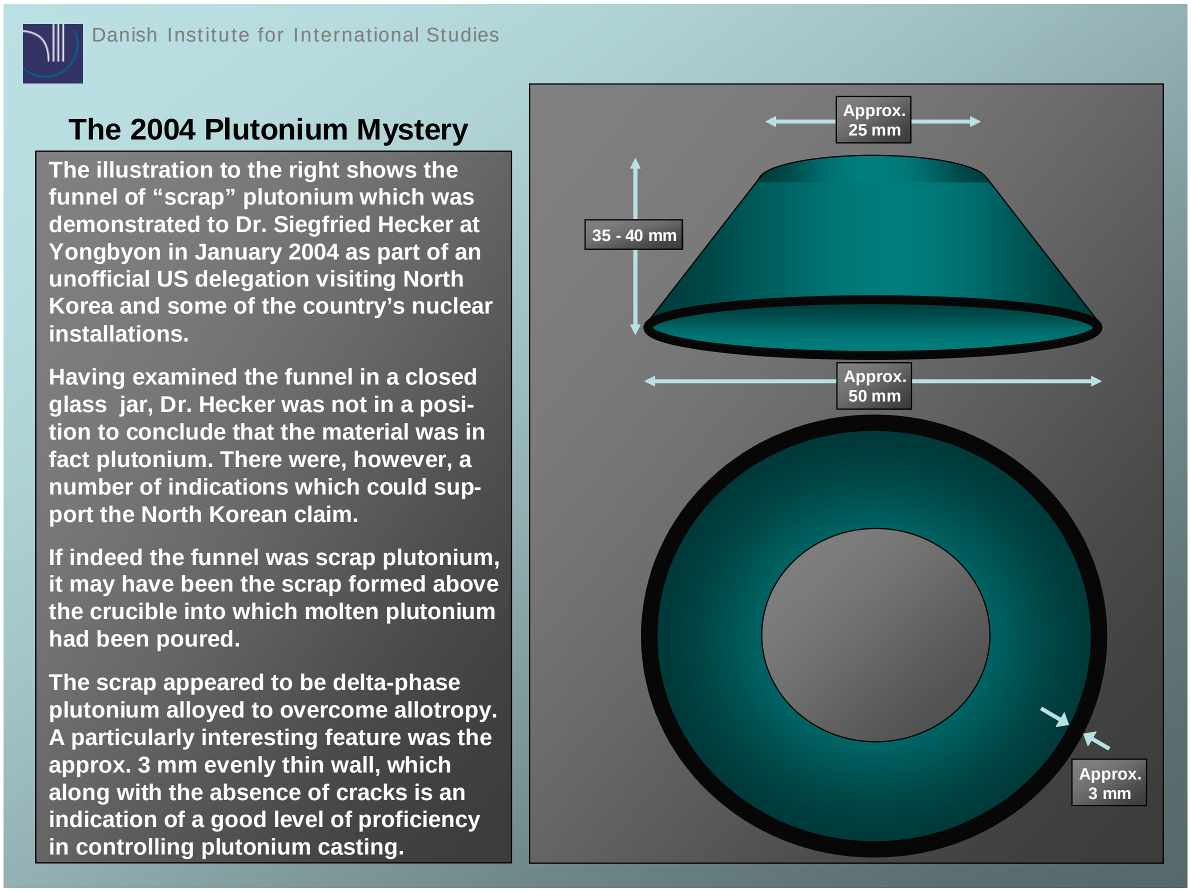

Figure 6. The funnel claimed by the North Koreans to be plutonium which Dr. Hecker was allowed to examine superficially at Yongbyon in January 2004.

By allowing Dr. Hecker a tour of sensitive installations at Yongbyon and letting him engage in conversation with staff there, the North Korean authorities took a calculated risk to show him sufficiently to convince the world that the regime has nuclear weapons. However, rather than direct access to the plutonium metal as described in Figure 6 above, Dr. Hecker was given a sealed glass jar containing the funnel. Also, he was not given access to or had been advised

[30] Plutonium undergoes more phase transitions at ordinary pressures than any other element. As plutonium is heated it transforms through six different crystal structures before melting. Physical properties like density and thermal expansion vary significantly from phase to phase making it one of the more difficult metals to machine and work.

to take with him the necessary equipment to positively identify the metal as plutonium.[31]

By far the most challenging aspect of nuclear weapons production is the acquisition of fissile material in the necessary quantity and quality. However, the processing of that fissile material into a weapons core and the designing of an efficient assembly mechanism to start a nuclear chain reaction is no small matter in itself. To that should be added that the North Korean choice of plutonium as fissile material limits the weapon design to an implosion device, which already is the more complicated design.[32]

Little is known about North Korea's ability to design and produce an efficient physics package, which will produce a nuclear chain reaction. In 2003 according to South Korean sources there were reports of up to 70 high explosive tests, which may – or may not – be related to testing of the shell of high explosive lenses needed to assemble the fissile material in an implosion device.[33]

Again, in terms of complexity, one issue is to design and build a nuclear *device*, which will yield a nuclear explosion. Such a device may have as its primary purpose to send a political message when detonated in e.g. a remote mountainous area. An altogether very different issue is to minimise the whole physics package while maintaining the nuclear yield and thus produce a nuclear *weapon,* which can be delivered by for instance a ballistic missile.[34]

Without these qualities, there is little deterrent value. But the true status of North Korea's nuclear program is unknown. It is known, though, that North Korea has capability to produce small amounts of weapons-grade plutonium – and that knowledge was established in 1992 or fourteen years ago. It is highly likely that North Korea has continued its research and development in the area since then.

Conclusion

Very few facts are known about the North Korean nuclear program: North Korea has produced weapons-grade plutonium, if even in minute quantities. Both a plutonium production capacity and a reprocessing capacity exist, but lack of international surveillance has made any guess about the quantity of extracted weapons-grade plutonium very difficult.

This follows from the fact that many parameters crucial to any assessment of weapons-grade plutonium production capacity in North Korea are at best uncertain if not just unknown. Furthermore, often one parameter must be based on other parameters equally uncertain and will thus amplify the weakness of the preceding argument.

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[31] See footnote 23. The North Koreans did, however, demonstrate with a Geiger counter that the metal in the glass jar was radioactive.

[32] In principle two nuclear weapon designs are used to assemble fissile material to form a supercritical mass; the gun-type design (as used in the Hiroshima bomb) and the implosion design. The implosion design employs a spherical shell of high-explosive lenses around the fissile material to compress – or assemble – this to form a supercritical mass, a process that requires extremely delicate and precise dimensioning and timing of the explosive lenses. Since plutonium-239 has a high spontaneous fission rate compared to uranium-235, a gun-type design is too slow an assembly form, for which reason plutonium requires an implosion design.

[33] See among others "Pre-nuclear blasts in North Korea", The Sydney Morning Herald, 10th July 2003.

[34] Ballistic missiles are the preferred means of delivery for nuclear weapons as a ballistic missile is very difficult to counter compared to airplanes or other means of delivery. However, a nuclear weapon delivered by a ballistic missile is subjected to both stringent limitations in terms of weight (typical ballistic missile payload is 1,000 kg) and dimensions, as well as severe dynamic stresses particularly during re-entry into the earth's atmosphere.

It is very likely that North Korea in the early 1990s extracted small amounts – measured in several tens of grams – of weapons-grade plutonium. Thus, taking into consideration the time span since then and the level of technological proficiency in plutonium generation and reprocessing capability, it is a reasonable assumption that North Korea has produced somewhere between 35 and 46 kg of weapons-grade plutonium.

The issue of a North Korean nuclear capability is therefore a discussion of intent versus capacity. The North Korean regime has very cleverly exploited the few facts available to the IC; its own status as an extremely secluded society; the ensuing speculation following from IC access to mainly only remote monitoring; and the effect of a series of the country's own antagonistic statements and actions. North Korea has thus successfully turned uncertainty and perceived threat into a powerful negotiation tool with which concession upon concession can be wrought from the IC.

Thus, one result of the North Korean nuclear brinkmanship is an IC taken hostage by its own inability to gain *complete* and *correct* knowledge of the North Korean nuclear program from the outset *and* act when the necessary access to establish that knowledge was denied.

One important lesson to be drawn from the North Korean nuclear issue is that while seemingly endless negotiations about the North Korean nuclear program continue, so very likely does determined work on the North Korean nuclear deterrent. It is highly likely that also other countries are looking to the seemingly never-ending crisis about the North Korean nuclear program and are learning! On the other hand, by now the IC should have learned from both the North Korean and the Iranian nuclear issues to sufficiently empower the relevant international agencies to avoid future nuclear issues, as this is certainly in the interest of international peace and stability, both regionally and globally.

It is likely that the nuclear struggles with North Korea and Iran have been lost, which is all the more unfortunate for the future integrity of the NPT. This should certainly galvanise international efforts to prevent more such cases. In the IAEA, the IC has at its disposal a competent and suitable tool to monitor nuclear programs and report on non-compliance so early that international action may nip illegal diversion of nuclear material and technology in the bud.

One important lesson from the North Korean nuclear issue is that it is imperative that the IAEA is empowered to deal effectively also with recalcitrant states AND that the states in question can see an advantage for them to co-operate with the IAEA. Sticks and carrots therefore need to be employed to ensure that development. More general UNSC backing to the IAEA in terms of swift and comprehensive action is needed when a diversion of nuclear material is identified or better still, even suspected. The carrots could comprise economic incentives such as access to organs of for instance international trade and commerce provided prior full acceptance of the Additional Protocol to the Comprehensive Safeguards Agreement.

The crucial issue is to ensure full participation from a given non-nuclear weapon state from the very outset. As long as the burden of proof to identify diversion of nuclear material or activities for illegal purposes rests with the IAEA, the agency will always be one step behind. With more states accumulating the needed capacity to develop nuclear weapons programs, time is of the essence if the International Community is to preserve the NPT and the frail promises of that treaty.

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