Martin B. Kalinowski

New developments in the verification of nuclear arms control

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Herausgegeben von Martin B. Kalinowski und Hartwig Spitzer

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INHALT

Martin B. Kalinowski

NEW DEVELOPMENTS IN THE VERIFICATION OF NUCLEAR ARMS CONTROL

The nuclear arms control agenda is facing a deadlock. There are still 20,000 to 30,000 nuclear weapons world-wide and most of them are not yet covered by any arms control treaty. Both Russia and the USA have each at least 2,000 nuclear weapons still on high alert. This is enough for a nuclear exchange scenario that could cause a nuclear winter effect which would be lethal for many humans, animals and plants at least on the northern hemisphere. Though the Moscow Treaty (SORT) was signed in May 2002, it falls behind the substance of the START (Strategic Arms Reduction Treaty) process which it replaces since it does not include any means of verification. The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is not in force yet, negotiations for the Fissile Materials Cutoff Treaty (FMCT) have not even started. A further setback was the declaration of the USA in 2005 that the FMCT should have no verification system.

At the same time, verification related to horizontal nonproliferation has made significant progress. During the intrusive inspections in Iraq, new methods have been applied. The International Atomic Energy Agency (IAEA) has gained a legal foundation for enhanced inspections by the member states agreeing on the Additional Protocol in 1997. This has opened the doors for the nuclear inspections capabilities to become more effective and powerful. Unfortunately, reliance on nuclear safeguards is not considered sufficient any more by several states. Horizontal non-proliferation politics has turned to a more aggressive approach of counter-proliferation. These countries, in particular the United States, are following a path of exerting more international pressure as well as threat and the use of military power in order to enforce international nuclear norms.

This tendency was enhanced by the exposure of the most significant gap and biggest challenge for verification of nuclear non-proliferation, namely the detection of clandestine weapons-usable materials production. It became obvious for the first time with the shock caused by revealing the clandestine nuclear weapons program in Iraq in 1990. The next blow was the expellation of the IAEA inspectors by North Korea leaving the IAEA with no means to verify whether this country is separating plutonium. In 2002 Iran's uranium enrichment facilities have become known and were then put under on-site inspections and while Iran promised not to build again any unreported facility, there are no verification means in place to detect remotely any highly enriched uranium (HEU) or plutonium production that an NPT member state might operate somewhere clandestinely.

This verification gap is causing distrust in the IAEA nuclear safeguards system and increases the escalation dynamics related to Iran's nuclear program. I will therefore focus the remainder of this talk on the question how scientific research could contribute to closing the verification gap. The goal is to provide the IAEA inspectors with tools for remote detection of clandestine nuclear-weapons-materials production.

Ever since Iraq's clandestine nuclear program shocked the non-proliferation community in 1990, the IAEA tried to improve its nuclear safeguards system. First, the major 93+2 program was set up. It resulted in the 1997 Additional Protocol. Although it expanded the legal basis for more comprehensive safeguards activities, hardly anything has so far been achieved in providing the IAEA with technical means to detect clandestine activities from a distance. Environmental sampling is restricted to the locations that are routinely visited by inspectors anyway. Satellite imagery has been demonstrated as a powerful tool to detect clandestine facilities. Consequently, the IAEA established an analysis unit for satellite imagery. However, this tool is used mainly for investigation of known facilities, in particular for preparing inspections and for verifying building outlines as compared to those stated in facility declarations. Though uranium enrichment facilities have a few features that can be observed in satellite imagery (size of buildings, heat generation), this technology is not at all capable of providing an indication of clandestine plutonium separation.

In 1997 and 1998, a technical committee was brought together by the IAEA in order to study the technical possibilities of Wide Area Environmental Sampling (WAES) under the NPT Additional Protocol. The committee concluded that WAES was not feasible due to the enormous costs. According to this study, a network of monitoring stations with 25 km grid size, operating continuously, would be needed to cover relevant parts of the globe. Even if regions which lack the required infrastructure for clandestine reprocessing facilities were omitted, the whole system would require thousands of expensive detectors. The report of the technical committee was printed by the IAEA but has never been released to the public, although it is often referred to and even quoted in publications by experts who had served as committee members.

In spite of the lack of transparency, the following became known about the study: The simulation methods applied were outdated and the study was clearly biased against WAES; accordingly, the conclusion was that WAES is infeasible. The requirements on WAES defined by the study were far too demanding. New sensor technologies were not taken into account. In particular the ultra-sensitive trace analysis of krypton-85 allows for a radical cost reduction.

Progress in safeguards methodologies based on environmental sampling is not only urgently needed with regard to the Model Additional Safeguards Protocol related to the NPT. It would at the same time address verification issues for a Fissile Materials Cutoff Treaty (FMCT). For both treaties, further scientific-technical work is required and would support political progress in non-proliferation and disarmament of nuclear weapons. Even without a formal agreement, it would be highly beneficial to develop and demonstrate verification means that could be used as national technical means or by NGOs and independent citizens to detect clandestine nuclear activities, especially those related to fissile material production.

Visionary thinking combined with cutting edge science and technology is required to identify practical procedures for Wide-Area Environmental Sampling. This can only be achieved by a group that is not bound by diplomatic constraints and short-term approaches.

To address this need and to support the IAEA in developing new verification methodologies, the International Network of Engineers and Scientists Against Proliferation (INESAP) organized the establishment of an independent Group of Scientific Experts (iGSE). This network of excellence is attempting to follow the precedence set by the highly influential work of independent expert groups who supported progress towards a nuclear test ban treaty in the past.

The goal for the iGSE will be to develop and demonstrate technologies and procedures for remote sensing and other novel methodologies that allow detection of clandestine nuclear-weapons-usable materials production. The expected outcome will be technical progress in related verification methodologies, their demonstration in field exercises, and the public availability of new measurement results as well as of conclusions that can be drawn with respect to production of plutonium and highly enriched uranium (HEU) production. The unique features of this project are the combination of the required expertise; the independence of scientists from governmental, diplomatic and organizational interests; and ensured unrestricted publication of the results.

The technical areas to be considered by the iGSE should focus on the issues with the greatest urgency and the best prospects for significant progress. Therefore, environmental sampling is selected as the first topical focus.

The most promising new sensor technology is the ultra-sensitive trace analysis of krypton-85. This radioactive isotope is a by-product of plutonium breeding and released into the atmosphere during chemical separation of nuclear fuel. Therefore, it is a good indicator for plutonium separation. It will allow for radical cost reductions in any concepts of sampling and analyzing air for nuclear safeguards. The technology is now being developed at the Carl Friedrich von Weizsäcker Center for Science and Peace Research here at the University of Hamburg. It is based on an atom trap and, therefore, called atom trap trace analysis (ATTA). This method is highly selective and sensitive because only krypton-85 atoms are guided by finely tuned laser beams into a trap where they are identified by their fluorescence quanta. One by one they are counted. The first such device has been built at the Argonne National Laboratory and went operational in 1999. It is used for ground water and ice core dating studies and had not been previously considered for safeguards applications.

The research project at the University of Hamburg has two goals. The efficiency of counting krypton-85 atoms will be increased and the instrument will be optimized for applications in the field. The main advantage of ATTA in comparison to the traditional beta counting method is the required sample size. In order to reach the required minimum detectable concentration with one-hour beta counting a sample volume of 100 liter air has to be taken. This needs to be pre-processed in the field in order to reduce the volume of the shipping container. The pre-processing removes the noble gas fraction from the air by cryo-adsorption. Since this requires liquid nitrogen and electric power in the field, sample taking is too expensive for large-scale routine applications. In contrast, ATTA could be successfully applied to samples of 1 liter. This would be very cost-efficient. If applied as random sampling during routine inspections, the air sampling would cause almost no additional costs.

Regarding Wide Area Environmental Sampling, the future improvements in implementing a sampling scheme based on ATTA could raise the usefulness and quality of krypton-85 sampling in comparison to the monitoring scheme that was previously studied and discarded due to its high costs.

Shorter sampling periods could reduce the detection thresholds by one order of magnitude. Mobile air samplers could be used instead of having stationary monitoring sites. The mobility would allow the inspection agency to undertake surprise measurements on very short notice.

However, it still remains unclear to what extent and under what conditions remote sampling in combination with transport modeling can detect clandestine plutonium separation of significant quantities with sufficiently high detection and low false alarm probability. In order to evaluate this, simulation studies are under way at the University of Hamburg in cooperation with the Max Planck Institute for Meteorology in Hamburg.

Atmospheric transport simulations will be used to determine optimum procedures for location-specific and wide area environmental air sampling to detect clandestine reprocessing activities. Based on the results on sensitivity and source attribution, the inspection procedures will be optimized in order to achieve maximum detection probability with optimum source location.

It is our goal to provide the IAEA with all information and technology required to implement this krypton-85 tracer approach and to close the safeguards gap regarding the detectability of clandestine plutonium production.

For detecting unreported production of highly enriched uranium, the task is even more challenging, because the signatures are weaker. This problem will be tackled by the Carl Friedrich von Weizsäcker Center as well.

I hope with this example I have convinced you how scientific contributions could help to solve a problem that could otherwise lead to the escalation of a conflict. The Carl Friedrich von Weizsäcker Center intends to help closing the verification gap related to clandestine nuclear-weapons-materials production. Together with other new technologies and inspection procedures this will hopefully provide the IAEA with capabilities to detect any possible clandestine activities in countries like Iran. As a result, trust in verification could be gained and that country could be permitted to use enrichment facilities for low enriched uranium (reactor fuel) and thus a further escalation of the current nuclear conflict could be prevented and the danger of preemptive measures could be minimized.

These new technologies will have to be put in perspective to the long-term goal of a nuclear weapons free world and environmental monitoring activities will play an important role in facilitating future treaties like the proposed Nuclear Weapons Convention.