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Topical Day

On Safeguards or the Non Proliferation of Nuclear weapons

Mol, 17th April 2007

SCK•CEN
Boeretang 200
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INTRODUCTION

Among the risks of nuclear energy as perceived by the public is the proliferation of nuclear weapons. Several international treaties aim at reducing the threat of nuclear arms proliferation, among which the Non Proliferation Treaty is the most well-known. The Non Proliferation Treaty foresees inspections in the countries that signed the treaty to verify that no diversion of nuclear material takes place for the manufacture of a nuclear weapon. These so-called safeguards inspections make use of the latest scientific developments in the measurement of nuclear material. To support the development of these inspection methods several Member States of the IAEA provide the Agency with a Support Programme. Belgium offers the IAEA a Support Programme since 1982. SCK•CEN has coordinated this programme from the start and therefore wants to celebrate its 25th anniversary with this Topical Day.

This Topical Day intends to give during the morning session an overview of the present developments in safeguards policy. In the afternoon the techniques will be discussed that the safeguards Inspectorates use at present to verify that no nuclear material is diverted from the civil nuclear fuel cycle.

PROGRAMME

08.30	Coffee and Registration
09.30	**Eric van Walle** - SCK•CEN, Belgium Welcome
09.35	**Olli Heinonen**– IAEA, Austria Welcome address IAEA
09.45	**Olli Heinonen** – IAEA, Austria Past and future trends for safeguards
10.30	**Tom Sauer** - University of Antwerp, Belgium What's the endgame: Virtual nuclear deterrence or proliferation?
11.00	Coffee break
11.30	**Maurizio Boella**, DG TREN Luxembourg The Evolution of the implementation of Euratom Treaty Safeguards
12.00	**Theo Van Rentergem** – Ministry of Economic Affairs, Belgium Export control of dual use items
12.30	Sandwich Lunch
14.00	**Klaas van der Meer** – SCK•CEN, Belgium Introduction to safeguards inspections
14.30	**Bernd Richter** – FZ Jülich, Germany C/S methods for safeguards
15.00	**Ane Håkansson** - Uppsala University, Sweden Nuclear safeguards measurements, non-destructive assay and stuff...
15.30	Coffee break
16.00	**Klaus Mayer** – TUI, Karlsruhe, Germany Illicit trafficking of nuclear material
16.30	**Arlette Etienne** – FANC, Belgium The implementation of the Additional Protocol
17.00	Reception – offered by SCK•CEN to celebrate the 25th anniversary of the Belgian Support Programme to the IAEA

PAST AND FUTURE TRENDS FOR SAFEGUARDS

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If we think back to the world of safeguards in the 1980s and the early 1990s, we surely could not have predicted the world we are in today. As we have moved towards strengthened safeguards, nuclear material accountancy, for example, is no longer the sole centre-piece. Safeguards has evolved to now encompass, in parallel to nuclear material accountancy, a comprehensive system of information collection and State level analysis, drawing upon expanded legal authority, and making full use of advances in technology for nuclear verification. As we look towards the future, what does our current vision hold for the future trends of safeguards? How much can we anticipate and begin to prepare for? One thing is certain: if we do not maintain the flexibility to continue to evolve and be ready to respond to changing future needs of the nuclear non-proliferation regime, the safeguards system may become vulnerable. One essential factor in maintaining this flexibility is intensified cooperation between the Agency and Members States.

Looking ahead of us today, we can see a two-layered vision of the future. We are able to identify with a fairly high level of confidence where we will be in the next 5 years, but we can also see a less focused and evolving landscape of what the world of safeguards might be beyond that. This paper outlines some specific objectives aimed at addressing the needs as we see them for the early years of the next decade, as well as recognising indicators of potential new dimenions in safeguards beyond that time frame.

WHAT IS THE ENDGOAL: VIRTUAL NUCLEAR DETERRENCE OR PROLIFERATION ?

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Proliferation is regarded as one of the major threats to international peace and security. States that are eager to acquire nuclear weapons will – in the end - succeed. It is idealistic to believe that proliferation can be halted as long as there are states that claim that nuclear weapons are "vital" for their national security.

There is a need for fresh thinking. The only realistic endgame is a world without nuclear weapons. Although the knowledge to build nuclear weapons will always exist, the weapons can be dismantled. Universality is a precondition: all states have to participate. The creation of a far-reaching verification regime is another condition. Cheating in a nuclear weapons free world is both unlikely (due to the verification regime and the non-nuclear norm) and ineffective, and therefore not attractive. If really needed, the rest of the world can build up nuclear weapons again as well.

To eliminate nuclear weapons is also an obligation under the Nuclear Non-Proliferation Treaty. How to convince states like Iran to fulfill their obligations (not to produce nuclear weapons) if we ourselves do not fulfill our obligations (to get rid of them) ? Such an approach is not tenable in term. Proliferation management has no endgoal. Learning to live without nuclear weapons will be one of the main challenges for the international community in the coming decades.

THE EVOLUTION OF THE IMPLEMENTATION OF EURATOM TREATY SAFEGUARDS

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The presentation will introduce the essential contents of the Commission staff working document "IETS" that has been recently taken note of by the Member States' Permanent Representatives at the European Council.

EXPORT CONTROL OF DUAL USE ITEMS

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Export control is one of the important pillars of the fight against the proliferation of nuclear weapons.

At the international level several instruments have been created in order to control the export of nuclear items. These instruments are the following:

- The article III, 2 of the Non-Proliferation Treaty and the accompanying Zangger Committee, to make this article applicable;

- The Guidelines of the Nuclear Suppliers' Group.

The objectives of both instruments are to transfer to non-nuclear weapon states nuclear items and nuclear duals use items only when these are exclusively used for peaceful purposes, e.g. not used for the fabrication of nuclear weapons or other nuclear explosive devices.

In order to allow exports of nuclear items and nuclear dual use items, apart from the peaceful purpose, a number of supplementary conditions have to be fulfilled, such as:

- For nuclear items: full scope safeguards, physical protection, commitment of the importing country to respect the conditions and only to re-export under the same conditions and after approval by the exporting country;

- For nuclear dual use items: fundamental principle of no export to a nuclear fuel cycle activity not submitted to safeguards; commitment of the importing state to respect the same conditions and to ask for prior consent from the exporting state before re-export.

Apart from the European regulation on the export control of dual use items (global regulation covering all items for civil as well as military applications, including the nuclear and nuclear dual use items), Belgium, as a member of the NPT and the NSG, has created its own specific legislation for the export control of nuclear items and nuclear dual use items. According to this legislation, these items can only be exported under the above-mentioned conditions and after granting a general licence and a nuclear authorisation. The licence can only be given after the granting of the authorisation. This last one can only be delivered by the Ministers of Economy and Foreign Affairs, after advice of a Commission called "Commission of Advice for the Non-Proliferation of Nuclear Weapons" (CANPAN/CANVEK). This Commission is composed of representatives of different ministers who have competence in the nuclear field and who have specific knowledge in some particular areas.

INTRODUCTION TO SAFEGUARDS INSPECTIONS

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Introduction

In this chapter the historical development of safeguards approaches will be discussed. The first systems verified only parts of the nuclear fuel cycle. Often this was a bilateral agreement with the supplier of the nuclear technology (at that time most of the times the US). The *Non-Proliferation Treaty* changed this situation by demanding verification of the complete nuclear fuel cycle in Non-Nuclear Weapon States. The *Additional Protocol* extends the verification to non-declared nuclear activities.

Development of safeguards systems

In 1957 the IAEA was founded with a twofold purpose:

- to stimulate the peaceful use of nuclear energy
- to verify that nuclear energy is used in a peaceful way

Here we will deal with the verification of the peaceful use of nuclear energy.

INFCIRC/26

The first system for *safeguards* is described in the document INFCIRC/26 [1]. It was founded in 1961 with the explicit notion that it was a test and would be evaluated after two years in order to eliminate its shortcomings. It was limited to two types of facilities: reactors with a power less than 100 MW_{th} and research institutes. In 1964 it was extended to larger reactors and fissionable material produced in a reactor.

For a good understanding of this first system it should be noted that the purpose of the system was not to provide the world with a comprehensive safeguards system but merely that it provided the exporting country with a guarantee that the delivered installation, equipment, nuclear or other sensitive material, services and knowledge would not be misused for military purposes. Although the purpose of INFCIRC/26 was rather limited, more activities like equipment and services fell under safeguards due to its limited purpose. As said, installations, equipment, nuclear and other sensitive material, services and knowledge could be verified by the IAEA.

The system focussed on the verification of the presence of nuclear material under safeguards and that safeguarded installations did not process nuclear material that was not under safeguards. Both nuclear and certain non-nuclear material were accounted for during inspections. Furthermore it was verified, among others, that there were no undeclared technical adaptations to the installations. This is called Design Information Verification (DIV). In 1964 the system was extended to reactors with higher power and to nuclear material that was produced in inspected installations and nuclear material.

A particular feature was that safeguards on certain material could be suspended by performing a swap. This shows clearly that the system was not designed as a comprehensive safeguards system for a completely peaceful nuclear fuel cycle.

Safeguards could be applied based on a bilateral agreement (e.g. if an exporting country demanded safeguards), on a multilateral agreement (e.g. in the framework of EURATOM) and unilaterally (when a State wanted to show the international community that it had no nuclear weapon ambitions). The system only used routine inspections of nuclear material and installations. No follow-up measures were foreseen in case an inspection showed misuse of nuclear material or an installation.

INFCIRC/66

In 1965 INFCIRC/26 was adapted to a greater extent and became INFCIRC/66 [2]. The basic philosophy did not differ a lot from that of INFCIRC/26; during inspections it was verified that nuclear material or installations were not misused for military purposes. In 1966 and 1968 there were important revisions of INFCIRC/66, in which reprocessing plants on one hand and conversion and fuel fabrication plants on the other hand were included in the safeguards system.

In INFCIRC/66, the inspection competences of the IAEA and the administrative obligations of the inspected installations were extended. Apart from the above-mentioned routine inspections, the IAEA started with the execution of initial inspections to verify that new installations were built and operated according to the declared initial design. In addition, the IAEA had now the possibility to perform special inspections in order to clarify certain information. In this way the exporting country had a better guarantee that exported material could not be misused for military purposes. However, under INFCIRC/66 it is still perfectly possible that, apart from the installations and material inspected by the IAEA, a State has one or several nuclear installations where nuclear material is produced or processed for military purposes.

It is not a coincidence that the only three States that still have installations inspected under INFCIRC/66 are India, Israel and Pakistan. All these three countries have built a nuclear weapon arsenal.

General principles are that the inspections are facility-oriented, that inspections should not hamper economic activities and that the information obtained by the IAEA remain confidential.
Under INFCIRC/66 not only routine inspections can be performed, but also initial and special inspections are foreseen when necessary. Initial inspections aim to verify the initial design of a facility, while special inspections aim to clarify situations that could otherwise lead to inconclusiveness of inspections. Special procedures are foreseen for different types of facilities.

INFCIRC/153(NPT safeguards)

In the mean time the international community became ready to accept a more comprehensive, full-scope inspection regime. This was partly due to the quality of the IAEA safeguards inspections. In 1968 the Non Proliferation Treaty (NPT) was signed and entered into force in 1970. The Non-Nuclear Weapon States (NNWS) declared not to have the intention to develop nuclear weapons, while the Nuclear Weapon States (NWS), i.e. those States that exploded a nuclear weapon before January 1st, 1967, promised not to give support to NNWS to develop a nuclear weapon and to reduce their nuclear weapon arsenals. However, there has not been put a time limit on the latter and therefore during a long time no progress was made in the reduction of the nuclear arsenals, on the contrary.

The five NWS according to the definition of the NPT are China, France, Russia, United Kingdom and the United States. Their nuclear installations are excluded from safeguards inspections, although all NWS have made voluntary offers that certain peaceful nuclear installations are subject to safeguards. All civil nuclear installations in France and the UK are subject to the EURATOM safeguards inspections in the framework of the Euratom Treaty. The NPT has been signed by almost 190 parties.
With the end of the Cold War and the economic costs of maintaining a vast arsenal of nuclear weapons the two superpowers have started to reduce the amount of nuclear weapons (see figure 1). While in the period 1987-1988 the total number of nuclear warheads had a peak of more than 65.000, at present the number is reduced to about 20.000. The Moscow Treaty foresees a further reduction to about 5.000.

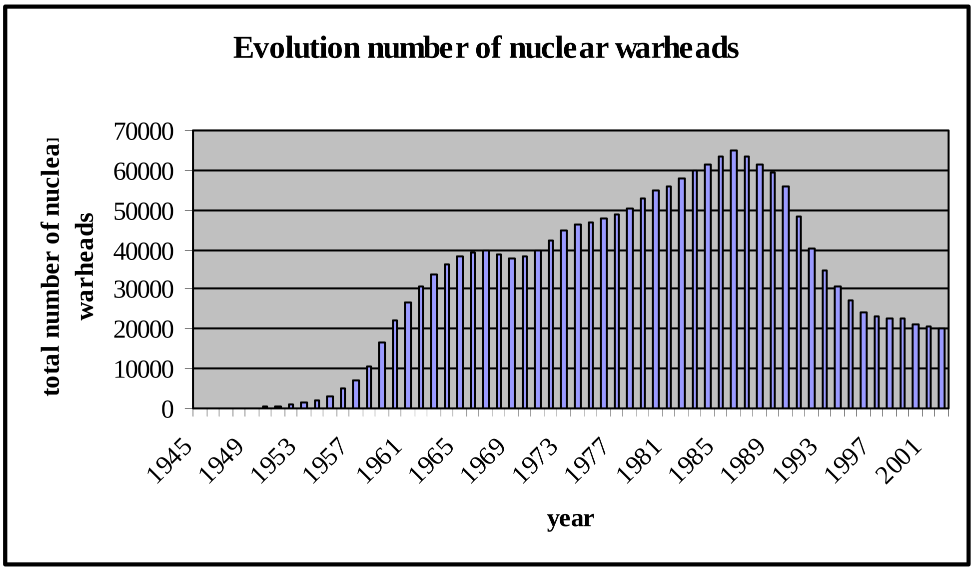

Figure 1 Evolution of the total number of warheads [3]

The safeguards system that should verify the agreement made in the NPT is described in the document INFCIRC/153 [4]. Contrary to the earlier systems, it implies a comprehensive verification of all nuclear material and all nuclear installations in a State. This is worded in INFCIRC/153 as *"...on all source or special fissionable material in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control ...."* The phrase *"...in all peaceful nuclear activities ..."* seems to open a door for separate military nuclear activities, but since a State by signing the NPT commits itself not to develop, acquire or possess nuclear weapons, any nuclear activity in the State is (or should be) automatically peaceful.
As noted, INFCIRC/153 focuses on the verification of nuclear material. Nuclear installations will be inspected, too, since most of the nuclear material is present there. Services, equipment and non-nuclear material like heavy water or zircaloy tubes are not inspected anymore, since one assumes that a comprehensive inspection of all nuclear material covers all possible misuses.
The material balance of all nuclear material in a State is taken together to verify whether no nuclear material is diverted from the peaceful nuclear fuel cycle. During inspections special attention is paid to proliferation-sensitive installations, in casu enrichment and reprocessing plants.
In the course of time the nature of the inspections has changed somewhat. In the beginning one relied completely on routine inspections, but later on in some special situations unannounced and random inspections were applied. In some large-scale

installations that process a lot of so-called direct-use material, i.e. nuclear material that can be used virtually directly in a nuclear weapon without a complicated chemical or physical process, IAEA inspectors are present continuously. This situation is however rather exceptional.

The NPT remains partly a matter of confidence. At the start of the inspections, States shall give a full declaration of all nuclear material under their authority. The signature of the NPT obliges a State to give a full declaration of nuclear material within 180 days after signature. In case they don't do this or they acquire clandestine material there is a possibility to cheat. Certain cases have been discovered by the IAEA in the course of time. Often these cases were rectified after diplomatic pressure.

INFCIRC/540 (Additional Protocol)

The limitations of INFCIRC/153 became clear in the aftermath of the First Gulf War and the discovery of a clandestine nuclear weapon programme of Iraq. Although Iraq had signed the NPT and its declared nuclear installations were subject to regular inspections, the IAEA had not been able to reveal this programme. By the way, the IAEA should not be reproached for this, since the IAEA had no mandate to look for a clandestine programme outside declared nuclear installations.

After the First Gulf War the IAEA has started a research programme to design inspection methods and systems that would be able to detect similar clandestine programmes. This so-called 93+2 programme started in 1993 and aimed to produce a proposal after 2 years. This was not entirely a coincidence, since in 1995 the NPT Review Conference was held, during which the future of the NPT had to be defined, whether one should continue indefinitely, for a limited period or eventually even abandon it. Although in 1995 the 93+2 programme head no final results yet, the NPT Review Conference decided to prolong the NPT indefinitely.

The research programme resulted in 1997 in the publication of INFCIRC/540 [5], also called the Additional Protocol (AP). From 1998 on States can add this AP to an existing safeguards agreement that is based on INFCIRC/153. The aim of the AP is that, apart from the classical safeguards inspections on declared nuclear material and installations, the IAEA is also authorised to verify for non-declared activities in a State. These non-declared activities are defined in a general way, but with a special attention to enrichment and reprocessing activities with a purpose to produce direct-use material for a nuclear weapon.

Dating February 2006 there are three safeguards systems in force/ INFCIRC/66(Rev. 2) for India, Israel and Pakistan, INFCIRC/153 with or without INFCIRC/540 for the 188 States that have signed the NPT. More and more States access the AP. This is partly due to the fact that the Nuclear Suppliers' Group (NSG), a group incorporating most countries exporting nuclear technology and material, demands from importing States that they have signed the AP.

Present inspection regimes

The political aim of safeguards inspections in the framework of the NPT is to assure that a NNWS will not acquire nuclear weapons and to deter these States to do this be performing effective inspections. The technical aim, based on this, is formulated in INFCIRC/153 as:

> *"[…] the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other*

nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection."

'Timely detection', *'significant quantity'* and *'risk of early detection'* are defined quantitatively below[1].
The IAEA does not need to have a proof based on facts regarding to the manufacture of a nuclear weapon. It is sufficient to conclude that there has been no diversion of nuclear material from the civil fuel cycle or, as formulated in INFCIRC/153, that "*[...] the Agency is not able to verify that there has been no diversion of nuclear material required to be safeguarded under the Agreement to nuclear weapons or other nuclear explosive devices [...]*"

The above-mentioned aim is the basis of the inspection methods described hereafter. The core of the IAEA inspections is nuclear material accountancy. The operator of an installation is obliged to maintain accountancy of all nuclear materials present in his installation. Plutonium, high and low enriched uranium are accounted in grams, thorium and natural and depleted uranium are accounted in kilograms. The accountancy is based on a beginning inventory and inventory changes due to receipts, shipments, production, consumption, losses or other causes. The inventory changes have to be reported to the IAEA by means of Inventory Change Reports (ICR) and together with the beginning inventory they result in an ending inventory.

An IAEA inspection should be preceded by a so-called Physical Inventory Taking (PIT) by the operator of the inspected installation, during which the operator verifies internally whether the present nuclear material is confirmed in the accountancy books. The IAEA performs an annual inspection during which the nuclear material accountancy is first verified on paper. Subsequently the inspectors verify physically (parts of) the book inventory to see whether it agrees with the real inventory. This is called Physical Inventory Verification or PIV. For the timely detection of a diversion there are interim inspections for direct-use material; for irradiated material the interim inspection takes place every three months, for unirradiated material the interim inspection is every month. Differences between the inventories are called Material Unaccounted For (MUF). The MUF is

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[1] timely detection

Nuclear material is defined in three categories. Unirradiated plutonium, the isotope ^{233}U and High Enriched Uranium (HEU) is called direct-use material. This material requires none or little processing before it can be used in a nuclear weapon. The process time is estimated in terms of a few days to a week. Irradiated fuel containing plutonium, ^{233}U or HEU is defined as irradiated direct-use material. This material requires reprocessing before usable in a nuclear weapon. The process time is estimated to be a few months. Low enriched uranium (LEU), natural or depleted uranium and thorium are defined as indirect-use material. This material has to be chemically converted and enriched or irradiated and subsequently reprocessed before being usable in a nuclear weapon. The required process time is estimated to be one year.

significant quantity

The amount of nuclear material necessary for making a nuclear weapon is military secret, but estimates have been made. For plutonium and ^{233}U it is 8 kg, for high enriched uranium it is 25 kg of ^{235}U. For low enriched uranium it is 75 kg ^{235}U. The latter is due to the losses that occur during the enrichment and conversion process in order to obtain high enriched uranium usable in a nuclear weapon. For natural uranium the estimate is 10 tonnes, for depleted uranium and thorium it is 20 tonnes.

risk of early detection

During an inspection the IAEA inspectors make a sampling plan for the timely detection of a diversion of a significant quantity of nuclear material. The detection probability of such a diversion is a function of many parameters, but in general the detection probability for a diversion of direct-use material is 90% and for irradiated direct-use and indirect-use material 50%. Note that these numbers are valid for one single inspection, so for subsequent inspections the detection probability increases.

evaluated to see whether it is acceptable or not in function of e.g. the measurement uncertainties of the used verification methods. The physical verification of the inventory is executed with the help of several techniques described below.

Containment and Surveillance

Nuclear material that is declared not to be used in the near future can be made inaccessible by means of a seal. In case the material is needed, the Agency has to be informed beforehand. The technological advancement of the used seals ranges from simple (lead seals) to very sophisticated (ultrasonic seals). Also camera surveillance is often applied, where photos are taken at regular intervals to verify whether no abnormal changes have occurred.
When measures of containment and surveillance have been applied successfully, there is less need for a very thorough verification of the inventory of the guarded nuclear material, since one assumes there has been no change of the physical state of the nuclear material. In safeguards this is called "Continuity of Knowledge" (CoK).

Item counting

The first step to make a physical inventory of the nuclear material is counting the number of fuel elements, fuel rods, plutonium cans, etc. These numbers are the basis for making a sampling plan, where the inspector decides how many items he will measure with a certain predetermined accuracy.

Weighing, volume determination

Simple but effective methods are the determination of the mass and volume of samples. Often these methods do not stand alone, since a malevolent operator could replace nuclear material by dummy material with the same mass and/or volume.

Non-destructive measurement methods

In general these are nuclear measurement methods like gamma-spectrometry or neutron counting, but also calorimetry is used for the measurement of plutonium. These techniques are relatively easy to perform and give an accurate estimate of the quantity and nature of the investigated nuclear material. However, sometimes the nature of the material or the way it is used or stored complicates interpretation of the measurement and will influence the accuracy of the measurement. This is especially the case with irradiated fuel.

Destructive measurement methods

Here we can think of mass spectrometry and chemical concentration determination. These techniques often give a very accurate result, but are relatively expensive and time-consuming.

No safeguards is applied to uranium mines or ore processing. Safeguards is started on any nuclear material of a composition or purity that is suitable for fuel fabrication or for enrichment. However, States are obliged to inform the IAEA about import and export of uranium and thorium. Safeguards is terminated when nuclear material is consumed or diluted in a way that it is not relevant anymore from safeguards point of view. Nuclear material that is used in non-nuclear activities is exempted from safeguards, as is nuclear material in very small quantities (e.g. sensing equipment) or plutonium containing more than 80% of ^{238}Pu.

The above-mentioned methods are used in the classical safeguards inspections in the framework of INFCIRC/153 and aim an as accurate as possible verification of the physical inventory of the nuclear material as declared by the operator.
In the framework of the Additional Protocol additional inspections are to be carried out to verify the absence of undeclared activities in a State. The AP has an extensive obligation for a State to declare nuclear activities and research, with the aim for the IAEA to obtain a global and comprehensive picture of the fuel cycle in a particular State. Since the nuclear industry is pre-eminently operating on an international level, the IAEA can look for (in)consistencies by comparing import and export data. Furthermore the AP gives the IAEA inspectors more extensive inspection and access possibilities. In this way installations can be visited almost without any announcement in case there are reasons to do so. The additional inspection techniques are the following:

Satellite monitoring

The IAEA has the possibility to acquire satellite photos and to analyse them. In case any suspicion arises an inspector can be sent to the installation to clarify the situation.

Environmental monitoring

By taking swipe samples or samples of ground, water or air from the neighbourhood of a nuclear installation and analysing them, traces of high enriched uranium or plutonium can be found. This can be an indication of non-declared enrichment or reprocessing activities. With help of this method the IAEA could show that the enrichment centrifuges in Iran had produced high enriched uranium, which had been denied by the Iranian authorities to conceal that the centrifuges originated from Pakistan.
A more global sampling is also possible, e.g. sampling of ^{85}Kr in the atmosphere to detect reprocessing activities. This technique is still subject to discussion and can only be used after an explicit approval of the IAEA Board of Governors.

Analysis of open source information

Analysing the information from annual reports of the nuclear industry or from articles in scientific magazines or papers may show (in)consistencies in declared activities.

The inspection techniques in the framework of the AP often have a soft, vague component. They will give indications that something suspicious may be going on in a State, but will not give a hard proof. An on-site inspection is often necessary to investigate the indications offered by these soft techniques. Therefore the AP includes extensive possibilities for the IAEA inspectors to access at nearly any moment nuclear facilities.

Conclusions

Safeguards approaches have developed in the course of time following the political will of States to show the international community their fulfilment of their obligations in the framework of the non-proliferation of nuclear weapons. States have gradually accepted a certain loss of sovereignty for the sake of openness.

References

[1] INFCIRC/26 “The Agency’s Safeguards” IAEA March 1961.
[2] INFCIRC/66/Rev.2 “The Agency’s Safeguards System” (1965, as Provisionally Extended in 1966 and 1968) IAEA September 1968.
[3] “Global nuclear stockpiles, 1945-2002” *Bulletin of Atomic Scientists* November/December 2002, p. 103
[4] INFCIRC/153 (Corrected) “The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons” IAEA June 1972.
[5] INFCIRC/540(Corrected): “Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards” IAEA September 1997.

General references

[6] IAEA *Safeguards Glossary 2001 Edition*, Vienna, IAEA, 2002.

[7] David Fisher “History of the International Atomic Energy Agency: The First Forty Years” *STI/PUB/1032* IAEA Vienna 30 September 1997.

C/S METHODS FOR SAFEGUARDS

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The model safeguards agreement between the International Atomic Energy Agency (IAEA) and states required in connection with the Treaty on the Non-proliferation of Nuclear Weapons (NPT) of 1968 is known as INFCIRC/153. For the purposes of the European Union it was modified to become INFCIRC/193, known as the Verification Agreement between the European Commission, IAEA, and non-nuclear weapons states. It attributes to containment and surveillance (C/S) the role of “important complementary measures”. The fundamental function of C/S is to enable detection of anomalies that could indicate diversion of nuclear material or undeclared use of a facility.

The C/S equipment categories are optical surveillance systems, sealing systems, and monitoring systems. C/S plays an increasing role in the back end of the nuclear fuel cycle, i.e., in reprocessing facilities, spent fuel storage facilities, spent fuel consolidation, and final repositories. It seems that, under the IAEA’s Integrated Safeguards, C/S will still play an important role in nuclear power reactors. The design and performance of C/S instrumentation is subject to safeguards specific requirements, the most important of which are reliability, tamper resistance, and data security.

In the 1990s, a transition took place from a variety of analogue video technologies to one single digital technology with the DCM14-based optical surveillance systems becoming the IAEA’s standard system technology. It gave rise to establishing guidelines for unattended remote monitoring and measurement systems which could also be applied to the design and operation of unattended radiation monitoring systems. The idea behind this is the integration of C/S, radiation monitoring, and electronic sealing systems in C/S systems providing a higher functionality but at the same time rendering safeguards at declared facilities more effective and efficient.

Optical surveillance plays a major role in IAEA safeguards. About 800 cameras connected to about 400 surveillance systems installed in about 170 facilities worldwide, part of them being operated in remote monitoring mode, are a great challenge. It is not expected that, under Integrated Safeguards, this situation will change drastically. Currently, the IAEA is also fielding about 30,000 passive seals, 2,000 active seals, and about 350 special application seals per year.

While the IAEA will be using the DCM14-based surveillance systems for a few more years, the development of a next generation surveillance systems (NGSS) technology is already under way. The plan is to start fielding of NGSS in 2009. Regarding electronic sealing, production of the new EOSS electronic seal has started in 2006, with the IAEA implementing a replacement programme for the hitherto used VACOSS sealing system.

A still existing gap in C/S is the lack of safeguards specific containment verification methods. Therefore, safeguards experts from Member States Support Programmes have identified possible techniques and recommended to concentrate efforts on developing appropriate approaches for containment verification that could be implemented within three years from now.

In conclusion, C/S has reached a high standard and provides for unattended and remote monitoring applications. C/S has a future also under Integrated Safeguards. The reason for applying unattended and remote monitoring systems will be to reduce inspection effort in declared facilities. It is even conceivable that, with appropriate C/S instrumentation, facility operators could perform safeguards activities in the absence of inspectors. The IAEA intends a transition from its DCM14-based surveillance technique to the Next Generation Surveillance Systems technology which is under development. In contrast to implementing only one type of surveillance technique, the IAEA needs and has available a variety of sealing systems for different applications. In the past, it has been neglected to define criteria for the IAEA how to determine when a new (e.g., electronic) sealing system needs to be developed. Another shortfall has been to identify and develop containment verification methods and techniques, where now Member States Support Programmes will spend a greater effort in cooperation with the IAEA.

NUCLEAR SAFEGUARDS -MEASUREMENTS, NON-DESTRUCTIVE ASSAY AND STUFF…

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–If you throw away a stone, will it drop to the ground after a while or not?
–What about the feeling one may experience on a vacation, wondering if one turned off the tub water before leaving home? One may be pretty sure that the water was turned off, but can one really *know* that?

These two examples represent two, highly unofficial, categories where two different strategies have to be employed in order to gain knowledge. In the first example it is sufficient to perform an experiment and most probably you will hear a "thud" after a few seconds when the stone hits the ground. However, in the second example this strategy is not possible. Here you have to turn back and check if your house is flooded or not. There is a word for such a check, namely *verification* and we will turn back to this issue later on.

What is knowledge? How can we gain knowledge? Is knowledge inherently connected to observation of reality? These are some questions that have occupied great minds for thousands of years. For sure, in modern times questions like these have relevance for virtually any human activity and their importance has, in fact, increased. Why so? Well, mankind measure things much more than previously simply because we have a numerous of measuring gadgets at hand today, but more importantly: we are completely dependent on that reliable and measurable information is supplied to, for example, the engineers that construct our cars to be safe and functional. Indeed, the function of modern cars are dependent on microprocessors that, in turn, are dependent on information supplied by various sensors in order to get the vehicle running. This is, by the way, something that everybody with a broken car knows today; it is completely beyond any normal person's ability to get the thing moving again.

The branch of philosophy that deals with knowledge is called epistemology. Its probably impossible (at least to this author) to pinpoint the very first step man took in order to grasp the notion of knowledge. An early account is, however, that of Plato (428-348 BC). Simple put, in his view, knowledge stems from the intersection between "Belief" and "Truth" as is schematically shown in fig 1.

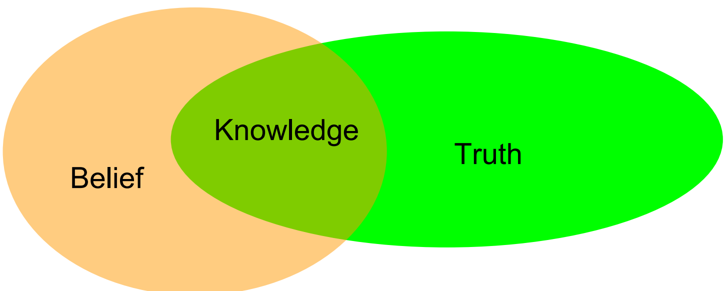

Figure 1. Knowledge according to Plato.

Needless to say, this picture gives rise to some serious concerns. First and foremost one needs some sort of definition of "Belief" and "Truth", otherwise "Knowledge" becomes meaningless.
To continue, the ancient people seem to have been somewhat divided when confronted with the issue whether measurements are important pathways to profound knowledge about nature or not. For example, one prominent thinker prior to Plato, Parmenides (515-450 BC), thought the only way of gaining true knowledge was to *think* about how nature is constructed (he was thus an extreme rationalist). For natural reasons he couldn't have heard of Plato but anyway, how Parmenides possible could make a distinction between "Truth" and "Belief" is not easy to realise. Even worse, in order to *think* about nature he needs to *know* at least something about it (e.g. his own existence, but this notion would lead us to the ideas of Descartes, a subject which is completely beyond the scope of this essay) and that needs some information through his senses, which basically form devices for *measurements*! On the other hand, the semantics around the phrase "true knowledge" may perhaps play a role here since the strategy of Parmenides must imply a subjective definition of specific knowledge as true or false, i.e. essentially worthless to other people, at least if you are an engineer.

On the other hand, in ancient times there where quite a few excellent experimentalists who tried to go beyond the normal application of measurements, such as building chicken houses and pyramids. Among these one may mention Eratosthenes (276-194 BC) who around 220 BC measured the circumference of the earth to be 40 000 km with an unbelievable small error. It turned out, however, that his measurements were affected by a number of profound errors that, astoundingly, cancelled each other out (this phenomenon is not uncommon even today and of course of serious concerns in all kind of measurements, and which always calls for a healthy suspiciousness to experimental data). In this context one should also be decent enough to remark that there were indeed other people and other ancient civilizations for that matter, although not European, that very much liked to measure things. For example the ancient Chinese were quite skilful to measure astronomical entities with great accuracy.

The simple picture of Plato is not irrelevant for the borne experimentalist of today. In fact, if we for a moment substitute "Truth" with "Measurement" and "Belief" with "Model", or perhaps "Theory", one ends up rather closely with a typical strategy of a modern measurement. This is illustrated schematically in fig. 2.

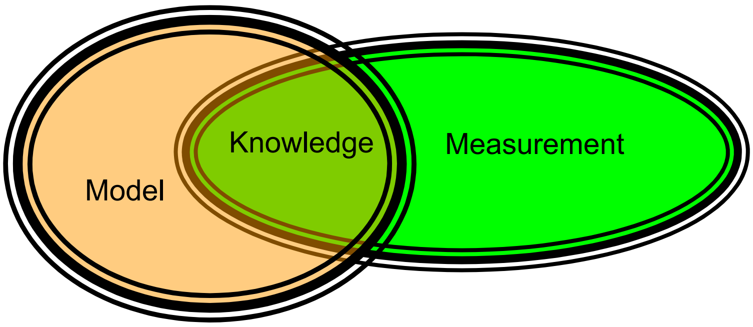

Figure 2. A philosophical basis of an experiment.

In simple terms, figure 2 says that if results of a measurement coincide with the relevant output of a model, we can be pretty sure that we have gained some knowledge of whatever we are measuring. Or can we? The rims of the two ellipses in figure 2 represent the inevitable uncertainty connected to all measurements and models and this fact causes epistemological problems. Let us illustrate this by taking a simple and, for that matter, a stupid example:

If you want to determine your weight you may first weigh a super tanker and perhaps you conclude it to possess a mass of 100 000 tonnes. Then you enter the boat and weigh it again. By calculating the difference between the results of these two measurements you will, in principle, obtain your weigh. What the measurement consists of in this example is quite obvious but what about the model? The simple model here is that the difference between the two measurements will give you a measure of your weight.
Referring to figure 2 again, will the model and measurement coincide? The scale with which you determine the weight of the super tanker will for sure not give you a reliable measure on your weight. Even if you utilise a super scale that weigh things in one part of a million, the result would only give you the information that you weigh 0, 100 or perhaps 200 kg. Not a very useful knowledge when your doctor urges you to give him your weigh within a half of a kilogramme.

In conclusion, the accuracy, or the "rim" in figure 2, of the measurement will be very thick and the accuracy of the model will be correspondingly bad. The latter since the whole idea of taking differences of such large numbers (the weigh of the super tanker + your weigh - the weigh of the super tanker) in order to obtain a small number is a really bad idea. However, although it is such a bad idea, similar measuring strategies are, in fact, suggested now and then, a subject that we do not want to dwell deeper into here.

Above was an example of a category of knowledge catching where the conceptual idea behind the measurement was to determine a specific quantity (your weight) even though both the measurement and the model were bad and, consequently, gave a bad result (no knowledge). There is another category where the measurements can be performed with high accuracy but the model may be bad or incomplete and, for that very reason gives new insights, i.e. knowledge that was not the primary target of the measurements. Here is an example of such a category where the measurements can be performed with a high accuracy but the model is, well, not entirely correct.

Assume that you want to decrease your total energy consumption in your well-insulated, electricity-heated villa high up in the northern Sweden, where winter temperatures often go down to 40 °C below zero. How do you achieve this? Well, nowadays the public debate often urge us to purchase "low-energy bulbs" because they are of an "environment friendly" construction, i.e. they give you more light for less amount of electricity (the fact that these bulbs contain Mercury, which is a dreadful chemical when released in nature, is for some reason seldom mentioned). So for a substantial amount of money you change all the old bulbs in your house and start to count kWh.
After a while you check (by measuring) your electricity consumption and conclude that the bill from your electricity supplier will certainly not become more attractive to you. Why? The new bulbs used perhaps 80 % of the energy to produce light and 20 % to produce heat while the contrary was true for the old bulbs that, in fact, contributed to the heating of your house.

Here the process of gaining knowledge gave not only information about the actual energy consumption but, more important, gave new knowledge. By just rationalising the findings of your measurement you came to the conclusion that the investment in new bulbs perhaps was somewhat rash.
Needless to say, this category is of utmost importance in science where the use of imperfect models is most common and, hence, can be used to create new insights into the mechanisms of nature.

To gain knowledge of an entity one thus need to construct a model that interconnects the various measured parameters in a way that is rational and built on previous knowledge and/or axioms. Such a model may be simple, e.g. gaining knowledge of the volume of a

box requires measurements of the three sides of the box and, through the operation of multiplying these three dimensions (the model), the volume pops out.
A model can also be overwhelmingly complicated. We shall not go into the ins and outs of the Standard Model in high-energy physics where quarks, Higgs bosons and other strange things are common knowledge to at least some people today. It may, however, be appropriate to mention the part of the Standard Model that is called quantum electrodynamics (QED) a model that has been experimentally confirmed to be exact in one part of 10^{12} or so.

In spite of the extraordinary precision of the extremely complex theory of QED, it seems reasonable to argue that a complicated model possesses a higher probability to be wrong. Therefore it can be a good idea to formulate as simple models as possible.
William of Occham (1285-1349), a Franciscan monk and nominalist with obviously a lot of time to think about tricky questions, formulated a principle that later on became known as Occham's razor. Here is one interpretation of this principle: *do not increase the number of entities required to explain a phenomenon beyond what is really necessary*. In practice, Occham's razor tells us that whenever we have to choose between different models, we should go for the simplest one. In this context we can think of Occham's razor as a tool to make the rim of the "Model" in figure 2 as small as it can be and that by using rational means.

In conclusion:

- Measurements can be considered as standalone entities but their relevance is strongly linked to models, theories or purposes.
- All models and measurements are afflicted with uncertainties.
- Models should be kept as simple as possible.

Now, let us turn our attention to safeguards and apply these ideas.

One basic goal of safeguards is to achieve knowledge of the amount of fissile material in a specific location, e.g. a spent nuclear fuel assembly, at a specific occasion. An important source of such knowledge is the operator's accountancy, which basically is bookkeeping of all material of interest. However, it is required that the accountancy is controlled, or *verified*, regularly.
Here it may be appropriate to raise a word of caution. There is some confusion going on in the use of the concept of "verification". In nuclear safeguards verification could mean the *process* bringing about a certainty that parameters of a spent fuel assembly is in agreement with the declared data. Verification could also mean that a certainty *has been* achieved. This conceptual ambiguity may not seem too dramatic, but it has far-reaching negative consequences partly for the method development and partly for the formulation of what measurable quantities that are relevant for nuclear safeguards and with what precision these must be determined for "certainty" to be achieved. Thereby we also touch upon the process of *determination*, which is semantically connected with the concept of verification.
To illustrate the connection between these notions and also the problems safeguards faces if the concept definitions lack in unambiguousness, we choose as our example a spent nuclear fuel assembly being stored at an interim storage for spent nuclear fuel, which is to be verified by an inspector from the IAEA.

All fuel assemblies to be stored are accompanied by a declaration containing a large number of parameters. By a suitable measuring method we can check that the fuel parameters A, B, C, … are in agreement with the declared values. It should be noted that to make the comparison between the measured and declared values, A, B, C, … must be *determined.* If the inspector finds that the actual properties of a fuel assembly are in agreement with the declared ones, what has he accomplished? Perhaps the *process* leading to his knowledge that the fuel is in agreement with the declarations is the actual verification. It could also be so that the *knowledge* of the agreement of the fuel parameters is the essence of verification. However, in the latter case, what happens if the parameters of a fuel assembly do not agree with declared values? Can the assembly still be considered verified and, frankly, is it really the assembly that is verified or is it the fuel parameters? Another question: The measured values of A, B, C, … possess uncertainties, how small must these be in order to state that the properties of the fuel are in agreement with the declared ones?

In another case (perhaps unlikely, but still something that nuclear safeguards must be prepared for) the documentation of declared fuel parameters is missing. The inspector measures the fuel parameters. What has he accomplished? Verification? He has evidently determined the fuel parameters, but without connection to declared values (the model) the concept of *verification* lacks meaning.

The concept of verification is thus in its nature relative, while determination rather is an absolute concept because the measured values do not depend on additional information. As pointed out above, the *relevance* in the concept of determination has, in this context, only meaning in relation to additional information.

In this scenario we are forced to realize that nuclear safeguards can only conclude that the properties of the fuel assembly *seem* to correspond to the expected ones and articulate criticism and possibly approve of the fact that the fuel declaration is missing.

It is thus, most probably, a good idea to bear in mind that verification cannot be a general way of getting *knowledge* of an object itself. What it does, however, is to provide the means that leads to knowledge whether an operator keep his accountancy in good order or not.

What is the epistemological implication of this reasoning? Probably something like this: To gain that kind of knowledge of an object that eventually give us the possibility to draw conclusions about the actual fissile content, it seems reasonable not to perform safeguards measurements in order to verify declared data (this data could even be missing). Instead we should seek for methods that measure entities directly linked to the fissile content.

In figure 3, the implication of this scheme is sketched. Here measurements of “primary entities” lead, through the determination process, directly to knowledge of the fissile content while the “secondary entities”, although comparably easy to measure and therefore often chosen are not directly related to the fissile content.

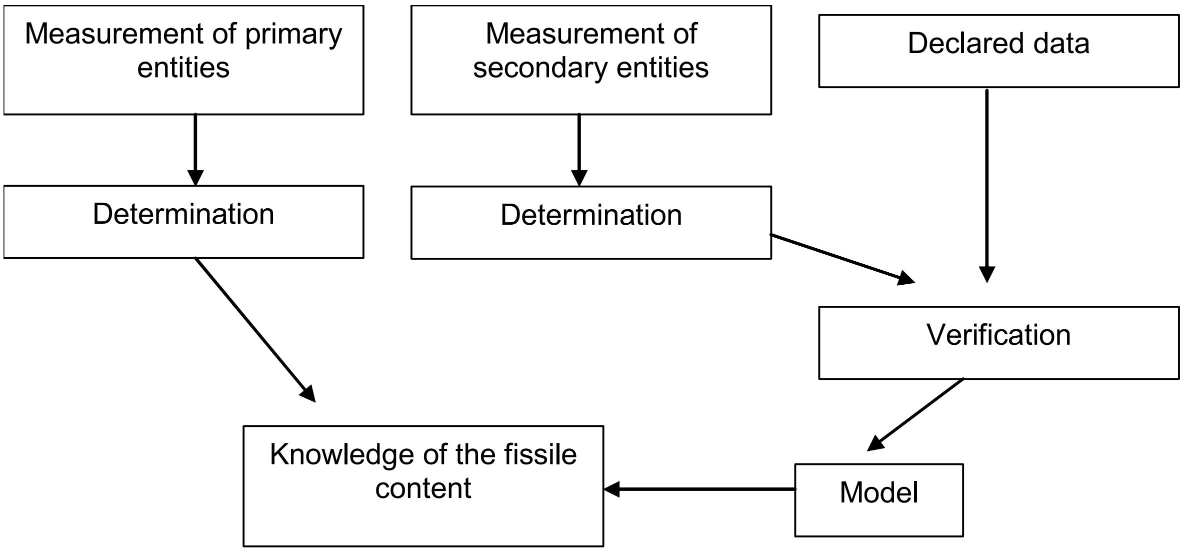

Figure 3. Illustration of the conceptual connection between determination and verification in safeguards. For being useful for gaining knowledge of the fissile content, verification needs the addition of a model, which can be rather complex, see text.

As discussed and indicated in figure 3, verification alone does not offer sufficient information in order to draw conclusion about the fissile content. To do so, a model that interconnects the properties of the spent fuel assembly with the fissile content must be applied. Such models do exist in the form of the various core simulators and depletion codes. However, these codes are rather complicated (a word of caution from Occham) and, in addition, several fuel parameters must be determined (each affected with uncertainties) in order to verify their correctness against declared data as the latter form input to the computer codes that calculate the fissile content. Thus, if the general strategy is to rely on calculations, verification of the input parameters is a necessity, otherwise the old truth, “trash in-trash out” applies quite nicely.
As a consequence, we should refer to our dear monk, Occham, and choose, as our strategy for developing measuring techniques, the *conceptual* simpler scheme that enables us to gain knowledge of the fissile content directly from measurements and the determination process, i.e. methods based on measurements of “primary” entities.

The tricky question is now if it is possible to perform measurements that directly leads to knowledge about the fissile content? The answer becomes a simple “yes” if we want to destroy e.g. a fuel assembly by using the methodology of Destructive Assay or DA. Unfortunately, DA can only be utilised in very special cases and is not suitable for routine inspections since it requires advanced laboratory resources. In addition, the methodology is, obviously, quite intrusive. Non-Destructive Assay (NDA), on the other hand, offers potentially the means for much simpler measuring strategies, but can it solve the specific problem? Let us take a look on this issue.

How can we draw conclusion about the content of a fuel assembly? For illustration, one may recall when children get their Christmas gifts they usually shake the packages in order to use the sound coming out to draw conclusions whether the content is “hard” or “soft”, the latter indicating grandma’s knitted socks and, consequently, a disappointing Christmas. On the other hand, it may turns out that the “soft sound” emanated from the longed-for teddy bear. This example, by the way, illustrates the interesting problem of misinterpretation of experimental data.

In a similar way we can draw conclusion about the interior of a spent fuel assembly by using some kind of signals emanating from the assembly. In fact, a spent nuclear fuel is tremendously radioactive. It emits gamma and particle radiation at a very high pace, which is, in principle, easy to measure and this radiation gives us the opportunity to learn more about the fuel.

Basically, NDA may be divided into two groups of technologies: qualitative and quantitative. Qualitative techniques are foremost used for verifying that radioactive objects are located on the right spot and at a time when they should be there. According to the previous discussion, such techniques cannot form a basis to obtain knowledge about the specific object. They do, however, give an indication that the operator fulfils the requirements put on his activities. Examples of qualitative techniques are the Spent Fuel Attribute Tester (SFAT) and the Cerenkov Viewing Device (the ICVD and the proposed digital version, DCVD).

To get *quantitative* data and, hence, potentially knowledge about an object, one is confined to use various spectroscopic techniques. By using such techniques it is possible to identify the elements that are responsible for the radiation and the amount of these elements that reside within the fuel assembly. The amount of the radioactive elements depends in various ways on different fuel (and reactor) parameters and this fact enables determination of these parameters.
A prominent technology found in this group is High-Resolution Gamma-Ray Spectroscopy (HRGS). This technique offers data with excellent properties but suffers from the fact that the detectors used must be cooled to temperatures corresponding to that of liquid nitrogen, i.e. 77 K or –196 °C. Presently this means bulky and fragile equipment, not fully suitable for inspection use. Also, the penetrability of gamma radiation through the heavy material of a fuel assembly is not large, implying that the data obtained represents only a part of the total volume of the fuel assembly. Hitherto there is no method, based on gamma-ray spectroscopy, available that can be used for direct determination of the fissile content of a spent nuclear fuel. Instead, the methods are based according to a verifying scheme with the addition of a model as shown in figure 3.

A third, and in certain aspects intermediate group, may be defined by the various techniques based on neutron measurements. In principle one may perform spectroscopic measurements by using adequate neutron detectors but their spectroscopic performance is not comparable with gamma spectroscopy. On the other hand, in safeguards one normally encounters more or less mono-energetic neutron radiation, implying that the use of refined and, therefore, expensive equipment is not necessary. The neutron radiation indicates that fission reactions occur in the spent fuel and it makes sense to argue that the intensity of the radiation is proportional to the number of fission reactions per unit of time. Consequently, the results from such measurements, in principle, form a measure of the amount of fissile material within the fuel assembly. This sounds simple enough, but in practice difficulties arise regarding the interpretation of the measurements. Therefore, as in the case of HRGS, knowledge about the fissile content is normally obtained by verifying the fuel parameters and using an adequate model.

Conclusions

Measurements performed in Non-Destructive Assay form integral and important parts of today's safeguards. However, to put it a little bit blunt, the basic task to conclude how much fissile material there is within a spent nuclear fuel, cannot be solved by present techniques, at least when it comes to the epistemological aspect of the problem. On the other hand, from the state-of-the-art measurements together with suitable computer codes we can draw conclusions regarding the fissile content but the question is how sure we can be that the conclusions are correct? Even the well-known methods for analysing and calculating measuring accuracies will not provide an answer here. With such methods we can only conclude that we are 90 % or perhaps 99 % sure that the conclusions were right. From an epistemological point of view, such statements are obviously not very attractive.

To illustrate: If we determine fuel parameters such as cooling time and burnup (we leave the definitions of these parameters since they are of no importance in this context) and conclude that they agree with the declared values within ± 2 %, say and with a confidence of 90 %. Can we then state that everything is ok? Furthermore, if we use these values in a suitable computer code, calculate the fissile content and find it to be (6.7 ± 0.05) kg with a 90 % confidence, is that accuracy sufficient for safeguards purposes? The definite question is of course if it is possible to define a "sufficient" accuracy anyway.

These were some examples of questions that, from a theoretical point of view, should be addressed and analysed carefully. Obviously, from a practical or experimental point of view, such an undertaking would be more or less impossible. But the results of such an analysis could still serve as a means to formulate performance goals for the development of new safeguards technologies.

Of course one should always aim at developing methods that are as accurate as possible (taking into account practical considerations such as simplicity, cost, little intrusiveness etc) but without a firm epistemological platform, the development process will probably not become as efficient as it could be.

To measure is to know (unknown engineer)

NUCLEAR FORENSICS AND THE FIGHT AGAINST ILLICIT TRAFFICKING OF NUCLEAR MATERIAL

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Reports on seizures of nuclear material (i.e. uranium or plutonium) and of radioactive sources continue to attract the attention of the public and are reason of concern, due to the proliferation risk associated with it and due to the hazard associated with such material. The three main steps related to combating illicit trafficking are: prevention, detection and response. An essential element of the response process is to provide clues on the origin and intended use of the material. This aims at improving the control of nuclear material (e.g. physical protection and safeguards) at the source in order to prevent future thefts or diversions.

The phenomenon of nuclear smuggling and illicit trafficking of nuclear material has led to the development of a new branch in science: nuclear forensics. Classical forensic techniques address the criminalistic part of the case, i.e. the identification of the suspect criminal. In contrast to that nuclear forensics focuses on the nuclear material. The key challenge is the specificity and complexity of the nuclear area and the particular requirements for handling such material. Nuclear forensic science makes use of analytical techniques that were actually developed for applications related to the nuclear fuel cycle, hence also the appropriate and safe handling of the samples during the investigations is assured. For interpretation of the results, nuclear forensic science relies to a large extend on the expertise and experience of the investigating scientists. Knowledge in areas such as radiochemistry, nuclear physics, reactor physics, material science and in the nuclear fuel cycle are required. The conclusions, however, need to be supported by reference data wherever possible.

The border-crossing phenomenon of illicit trafficking of nuclear materials calls for a co-ordinated international response. A number of international initiatives are addressing this area, e.g. the IAEA, the nuclear smuggling international technical working group (ITWG) and the US DoE Second Line of Defence Programme.

The presentation will provide an overview on the mechanisms of response to illicit trafficking and an insight in nuclear forensic investigations.

THE IMPLEMENTATION OF THE ADDITIONAL PROTOCOL

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The Non-Proliferation Treaty imposes on non-nuclear weapon signatory states to give access for IAEA inspectors to all their facilities. In connection with the treaty, an agreement called 'safeguards agreement' was signed in Brussels on 5 April 1973 to set forth a safeguards system based on nuclear material accountancy. This system is built on the same principles as for Euratom controls.
IAEA and Euratom inspectors visit the nuclear facilities of the signatory states to verify that nuclear material has not been diverted for undeclared military purposes. On basis of the existing agreements, strengthening measures were developed in subsequent years within the competences assigned by the above-mentioned agreements in order to increase the efficiency of the controls.

The Iraq crisis issue in 1991 and the difficulties with North Korea made it evident that it was necessary to strengthen the safeguards system by providing the IAEA with broader rights of access to information and by expanding physical access to locations where nuclear material is stored or can be found.
The model Additional Protocol, resulting from the decision taken in 1992 of strengthening safeguards, aims at completing general safeguards agreements and strengthening previous measures in this field. It intends to provide the IAEA with more efficient means to collect information related to the nuclear activities and projects of a state. The ultimate goal consists in providing assurance that no undeclared nuclear material or activities exist within a state.
The main characteristics of the Additional Protocol are: possibility to collect more information on material, activities or projects and broader right of physical access to every site in order to verify that no undeclared nuclear material or activities exist and that the information provided to the Agency is correct.
The law of 1 June 2005 ensures the implementation of the Additional Protocol and completes the law of 20 July 1978 introducing the inspection and verification activities performed by the IAEA inspectors.
With this law, the information that must be provided to the IAEA can be collected through different channels: the Ministry Of Economic Affairs, the European Commission and the Federal Agency for Nuclear Control. The Belgian state - and not the operators on individual basis - is responsible for the declaration.
This law also settles complementary access as it enables IAEA inspectors to access locations in complement of those specified in the law of 1978 such as any location of a site, any decommissioned facility or any place outside decommissioned facilities where nuclear material were commonly used.
The inspectors are allowed to carry out a.o. the following activities: visual observation; item counting of nuclear material; non-destructive measurements and

sampling; utilization of radiation detection and measurement devices; application of seals; examination of records relevant to the quantities, origin and disposition of the material; collection of environmental samples.
Finally the law governs the prosecution of violations:
The FANC nuclear inspectors are responsible for the identification and observation of the violations.
They have free access at all times to all places and data and to all physical and legal persons specified in the law.
As far as the identification and observation of violations are concerned, they have the same competences as the other judiciary police officers and they even have precedence over them, to the exception of the judicial magistrates who have the status of judiciary police officer.
Violations of the legal provisions are punished with a sentence of 8 days to one-month jail and with a fine of 2.5 to 2,500 euros or with one of these sentences only.
In the event of a second offense in a two-year period, the sentences may be doubled.
In the event of non-compliance with the obligations resulting from this law by a physical or legal person specified in articles 3, 4, 7 and 8, the Minister of Home Affairs can submit a request to the President of the Court of First Instance of Brussels for enforcement of the aforementioned obligations. The request is submitted in accordance with the summary procedure rules. The Court shall take a decision within 8 days notwithstanding any other prosecution of an offence based on the same facts before the penal jurisdiction.
The sentence is provisionally enforceable notwithstanding any appeal.

As a result of the implementation of the Additional Protocol, different *sites* were established and a representative was appointed for each of these *sites*. In cooperation with the European Commission, the Federal Agency for Nuclear Control helped Belgian operators to fix the limits of those sites according to their specific features. It also ratified the appointment of a representative for each site and it helped them prepare the first declaration. Subsequently, the Agency centralized the declarations to achieve harmonization and greater consistency, and sent them to the European Commission, which converted the information in the adequate format before sending to the IAEA.

Complementary access has been implemented in most of the Belgian sites. The Federal Agency for Nuclear Control was present during these activities. It let the operators know that IAEA inspectors' were coming to visit their facilities when the complementary access did not take place during classic inspections, and it informed the operators of the IAEA's motivations and of the activities that the IAEA was willing to perform. The FANC contributed to the respect of both parties' rights and obligations in that field.
Conscious that Belgium bears responsibility at this level, the Federal Agency for Nuclear Control monitors the effects of every activity related to the Additional Protocol.

THE BELGIAN NON-PROLIFERATION POLICY

Werner Bauwens
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BIOGRAPHIES

TOM SAUER

Born in 1969 in Antwerp, is professor at the University of Antwerp in the Department of Politics (International Relations). He has the following teaching tasks:

- at the University of Antwerp: Diplomacy; Theories of International Relations; International Security; History of International Politics (from the academic year 2007-2008 onwards)
- at the KU Leuven: Theories of International Relations; Strategy (threat assessment; arms control); Seminar on Current Issues in International Politics (debating class); Seminar in International Relations; Multilateral diplomacy and negotiations skills (simulation); European Security and Conflict Management (history module).
- at the Royal Higher Institute for Defense (Ministry of Defense, Brussels): Chemical, Biological and Nuclear Arms Control

He published several books and more than 40 academic articles. Additionally he wrote more than 40 op-ed articles for national and international newspapers.

His research areas are proliferation of weapons of mass destruction; (nuclear) arms control, and disarmament; catastrophic terrorism; coercive diplomacy; European security and defense.

Ane Håkansson

Born 1959, is associate professor at the Department of Neutron Research at Uppsala University, Sweden. As an experimentalist, he has previously performed research within basic nuclear physics and especially to the development of detector technology.

Since 1989 he has devoted himself to build academic competence within the area of safeguards technology at Uppsala University. This work has evolved in such a way that he today leads a research group that is focused on a variety of problems encountered in nuclear technology and which can be solved by nuclear methodology.

Besides research and development, the research group is heavily involved in education directed to undergraduate and graduate students as well as personnel from the nuclear industry in Sweden.

Bernd Richter

Diploma and PhD in experimental nuclear physics of Bonn University, Germany;
post-doctorate studies at the Weizmann Institute of Science, Israel;
as of 1976, at the Jülich Research Centre, Germany;
as of 1978, R & D in the field of international safeguards;
as of 1985, coordination of the German R&D programme in support of the IAEA;
chairman of the ESARDA Working Group on Containment and Surveillance;
member of the ESARDA Executive Board, Steering Committee, and Editorial Committee;
Associate Editor of the Institute of Nuclear Materials Management, USA.

Arlette ETIENNE

She works in the nuclear sector since 1985 dealing with security and clearance aspects, physical Protection of the nuclear facilities and Safeguards for the Department of 'nuclear

Security' under the Belgian Ministry of Justice.
From 2001 these responsibilities were transferred to the Federal Agency of Nuclear Control and she became Nuclear Inspector for this Agency. She works in the Department of Control and Surveillance.

Klaus Mayer

Obtained his Ph.D. work in 1987 in the field of radiochemistry and analytical chemistry from the University of Karlsruhe.

After that, he worked on a variety of subjects, like the transmutation of minor actinides, the development of U/Pu robotized separation, on the preparation and characterization of Am containing superconducting perowskites and on the analysis of dissolution residues from reprocessing of spent nuclear fuels.

From 1990-1996, he was working for the European Commission at IRMM. His work included actinide isotopic reference materials, high accuracy mass spectrometric measurements of U, Pu and Th, the organization of the interlaboratory measurement evaluation programme, and the coordination of support activities to Euratom and to the IAEA.

In 1996, he started to work at ITU as the project leader for the development, installation and commissioning of safeguards analytical on-site laboratories. As the Section Head “Measurement Methodology”, he is responsible for the development and improvement of analytical methods for nuclear material and the coordination of support activities to Euratom Safeguards Office and IAEA. The current focus of his work is in the area of nuclear forensics and in combating illicit trafficking.

Olli Heinonen

IAEA Deputy Director General and Head of the Department of Safeguards
Mr. Olli Heinonen was appointed as the Deputy Director General, Head of the Department of Safeguards, at the International Atomic Energy Agency, in July 2005. The Department of Safeguards is responsible for verifying that nuclear material placed under safeguards is not diverted to nuclear weapons or other nuclear explosive devices and that there is no undeclared nuclear material or activities in non-nuclear weapons States party to the NPT.

Before joining the International Atomic Energy Agency in 1983, Mr. Heinonen was a Senior Research Officer at the Technical Research Centre of Finland, Reactor Laboratory.

From 1999–2002, Mr. Heinonen was Director of Operations A and from 2002-2005, he was the Director of Operations B in the Department of Safeguards.

Mr. Heinonen studied Radiochemistry and presented, in 1981, a Ph.D thesis in Radiochemistry at the University of Helsinki, Finland.