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Fissile Material Cut-off Treaty Verification and Safeguards

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1. From Proliferation to Disarmament

1.1. Weapons of mass destruction

Two nuclear weapons have been used at the end the Second World War. Since then no nuclear weapons have anymore been used in war, but about 2050 test-explosions have been performed. The indiscriminate devastating effects, both direct and delayed, have classified the nuclear weapons as weapons of mass destruction. Hence their abolition has been requested continually. For many years they increased in number and performance.

The other weapons of mass destruction have been prohibited comprehensively by the convention on biological weapons and the convention on chemical weapons. Differently the nuclear weapons still have a certain legitimacy for use in extreme circumstances of self-defence of the State. Recently this point has been emphasized by the declaration of 8 July 1996 of the International Court of Justice in The Hague /1/. The security of nuclear-weapon States and allied non-nuclear weapon States depends on the possibility of a first use of nuclear weapons for their defence.

1.2. Reduction of the nuclear-weapon threat

More than fifty years of work to reduce the threat of nuclear weapons resulted in a number of repeating proposals for arms control and disarmament. Maintaining nuclear weapons however complicates, delays, and hampers the nuclear disarmament process. The Non-Proliferation Treaty (NPT) /2/ brought the horizontal proliferation near to a standstill. It recognized the five nuclear-weapon States as such. Additionally at least four non-NPT States have developed a nuclear-weapon capability. South-Africa abolished its nuclear-weapon programme before acceding to NPT. At least, in violation of NPT, another two NPT States made serious attempts to acquire a nuclear weapons capability.

The non-proliferation regime has been strengthened by international agreements on export of nuclear material, nuclear related material and equipment, and sensitive nuclear technology, and by the Convention on the Physical Protection of Nuclear Material /3/. Therewith the threat of proliferation to other States or entities reduced. But the so-called vertical proliferation continued with an incredible increase in number and performance of the nuclear weapons, combined with great advances of the related missile technology, the nuclear arms race.

1.3. Curbing of the nuclear arms race

The high costs of the nuclear weapons programs and the maintenance of the related missile technology were an incentive for the United States and the Soviet Union to conclude SALT /4/ and START /5/ agreements. Further improvement of their bilateral relations followed. For instance the INF-Treaty /6/ led to the destruction of a whole category of their missiles that could carry nuclear weapons.

More steps on the way to nuclear disarmament are taken by the five official nuclear-weapon States, sometimes together with other States. Mutual confidence has been increased recently by, unilaterally given, openness and transparency on nuclear weapon related matters. The bilateral disarmament agreed by the Russian Federation and the Unites States of America resulted in an amount of fissile material being declared as excess. The irreversibility of this disarmament step includes that the excess material will be placed under IAEA safeguards. Logically that requires also verified guaranties that the production of the fissile material for nuclear weapons has really stopped. The FMCT is therefore a necessity. Increasing co-operation in related fields of nuclear safety and physical protection have further improved the relations between the participating States.

1.4. The future course of action

The Principles and Objectives for Nuclear Non-Proliferation and Disarmament agreed at the Review and Extension Conference on the NPT /7/, held in New York in 1995, contain several steps to be taken. The first was the conclusion of the CTBT (Comprehensive Test Ban Treaty) /8/. Next came the publication of the Guidelines for the Management of Plutonium /9/, which give more insight in the policy and present situation of the stocks of civil plutonium in the world. The five nuclear-weapon States, and six other States with important unirradiated plutonium stocks participate. A similar arrangement for highly enriched uranium has been advocated by some of the participating States. The following step required by the NPT-conference is the start of negotiations on a Fissile Material Cut-off Treaty (FMCT).

In 1996 the Australian Government called together an “truly outstanding group of individuals to address the pressing question of how we can move to a world free of nuclear weapons”. Statesmen, scientists, diplomats and strategic thinkers participated /10/. On 14 august 1996 this “Canberra Commission on the Elimination of Nuclear Weapons” presented its report /11/. It proposes a number of steps of which already several have been realized, such as the agreed guidelines for the plutonium management, the CTBT, the taking off alert the nuclear forces, and the removal of warheads from delivery vehicles.

In Annex A of the Canberra report the subject verification is comprehensively dealt with. It clarifies an important aspect of verification:

> *“The elimination of nuclear weapons will not be possible without the development of adequate verification. A political judgement will be needed on whether the levels of assurance, possible from the verification regime, are sufficient. All existing arms control and disarmament agreements have required political judgements of this nature because no verification system provides absolute certainty.”*

As examples where the political judgements have been made it refers to the NPT and IAEA safeguards, the CWC the CTBT and the bilateral INF-Treaty /6/. Remarkable in the CTBT is the allowance to use information from

national technical means, as far as it will not be based on espionage /12/. The verification arrangements of the INF, and experiences with them, have been described in reference /13/.

1.5. Nuclear weapon free zones

The Antarctica Treaty of 1959 is the first disarmament agreement after the Second World War. In effect it declares Antarctica to a Nuclear Weapon Free Zone (NWFZ). In 1967 followed the Treaties on Outer Space, and, the Tlatelolco Treaty for Latin America. This last Treaty came into force in 1990 when 32 Members, out of the 33 States in the region, had ratified it. In 1971 the Treaty on the Seabed and Subsoil of the Oceans put a ban upon nuclear and other weapons of mass destruction in its area of application. Then came treaties for the Southern Pacific Ocean NWFZ (Rarotonga 1985), the African NWFZ (Pelindaba 1996), and the South East Asian NWFZ (Bangkok 1997). Other areas have been proposed like the Middle East, South Asia, the Korean peninsula and (parts of) Europe. The conclusion of NWFZ treaties is a step by step approach to nuclear disarmament, coupled with inspections by the IAEA for verification of the peaceful character of the nuclear activities in the region.

The NWFZ treaties contain, in several cases, more stringent obligations than are usual in the IAEA's nuclear safeguards agreements. Also the bilateral disarmament agreements between Russia and the United States of America are based on stringent verification. When a NWFZ for the Middle East should become a reality, this will undoubtedly also include very stringent verification arrangements that should be capable to detect any attempt to manufacture or introduce otherwise weapons of mass destruction in the Middle East. On the Korean peninsula exists already an agreement between the DPRK and the Republic of Korea, not to operate enrichment or reprocessing facilities. The adversary attitudes may be a stabilizing factor in these regional treaties, but the economic and political situation in the region can change. What once were opposite interests can change to mutual benefits. If the IAEA safeguards arrangements are dependent on these local differences, a provision to adapt it also to these eventual changes should be included.

1.6. Negative points

Apart from the slow but persistent progress of the disarmament process, also negative points have to be mentioned. The nuclear tests of India /14/ and Pakistan are the most outstanding ones, with quite some political reactions. The official Indian statement that the fusion weapon also has no secrets anymore for them, is not comforting at all. It can be assumed that all presently known States with a nuclear-weapon capacity, also are capable to ignite a hydrogen bomb.

Also some politically less radical points of the present time have to be noted:

- In Russia the opinion is aired that miniaturization of nuclear weapons could remove the odium of being a weapon of mass destruction.
- In the US, the plan to use civil power reactors for the production of tritium for weapons marks a break in the carefully maintained borderline between civil and military nuclear activities /15/.
- Only China has given a no first use declaration for their nuclear weapons; the other States will not exclude the option that nuclear weapons will be used to retaliate for an attack.
- In anticipation on the CTBT, computer programs have been developed, and investments have been allocated to test laboratories, which can replace the banned test explosions.
- The series of French and Chinese test explosions before the CTBT was agreed, emphasize the strong beliefs in the importance of their nuclear weapons.
- States that are allied with the nuclear-weapon States rely also on these weapons for their ultimate security needs.

Therewith it becomes difficult to convince India, Israel and Pakistan that they should not include the nuclear weapons option as an essential factor in their national security doctrine.

2. A Future FMCT

2.1. FMCT's possible achievements

Four nuclear-weapon States have already officially declared the cessation of the fissile materials production. China has not given such an official declaration. Open source information indicates however, that the installations, which could produce these materials in China, are not doing so /16/. A typical Chinese answer to the question whether the production has stopped, is "You may think so".

The political wish is to start negotiations on a treaty to ban the production of fissile materials for nuclear weapons. Such a cap on the amount of the material may be the first step to contain the vertical proliferation. For its credibility, a comprehensive verification of the treaty obligations is essential. The verification of the irreversibility on the excess fissile material from nuclear weapons makes sense, when also an assurance on the cessation of the production can be obtained.

Codification of the unilateral announced production stop in a treaty, with appropriate verification is a logic step to limit the vertical proliferation. But most important is to get also the three hold-out States India, Israel, and Pakistan to join this treaty. So they will emphasize their support for the limitation of the number of nuclear weapon possessors, and subsequently they support the non-proliferation regime /17/. India and Pakistan have claimed to need, for their national security, only a restricted nuclear arsenal, as a limited deterrent. Hence it may be expected that also these States with a nuclear-weapon capacity, can stop the production of the fissile material quite soon.

It is hoped that under the FMCT all States, including the eight that are not yet covered by full-scope safeguards on all their peaceful nuclear activities, will at least assume, like all the other NPT-States did already, an obligation not to acquire, produce, or recover /18/, additional fissile materials for nuclear weapons. IAEA verification, akin to safeguards, should give a high detection probability for an eventual resumption of the proscribed production.

2.2. FMCT achievements

The FMCT shall give a verified assurance that not more fissile material will be produced for nuclear weapons. But the FMCT shall, most probably, not address the military developments. The weapons are maintained and improved outside the area of the FMCT application, and work on the weapons continues. The glut of fissile material for nuclear weapons is obvious, hence also the number of weapons could again increase considerably, without additional production of fissile material. And it is not absolute impossible to develop much stronger explosives, than the conventional ones. It might be possible that these could enable the start of a fusion reaction with less, or even without use of fissile material, by the inertial confinement approach.

All real non-nuclear weapon States, with significant nuclear activities, have already accepted verification according to the IAEA safeguards system. Their verified compliance warrants that declared nuclear material has not been diverted, and declared facilities or equipment has not been misused. When the Additional Protocol to the Safeguards Agreement will be implemented, the IAEA will be enabled to provide increased assurance about the absence of undeclared nuclear material and activities /19/. For cut-off verification in non-nuclear weapon States this application of strengthened safeguards should be necessary and sufficient.

2.3. FMCT and non-proliferation

The present non-proliferation regime has been build up gradually according to necessity during the last thirty years. The possibility of armed conflict over genuinely vital issues remains real. The nuclear weapon can not be "disinvented", and therefore the nuclear weapon is always within reach for a State with a strong technological base. States with a nuclear-weapon capacity may fall into pieces, the threats may come from terrorism, unrecognized States, "rogue States", or the growth of organized crime /20/. The present non-proliferation regime should be maintained.

It is also in the national interest of the three hold-out States, to limit the number of States, or other entities, with a nuclear-weapon capacity. This goal of the non-proliferation regime could be incorporated in an FMCT. FMCT verification in non-nuclear weapon States can be accomplished in first instance by strengthened safeguards. When the nuclear weapons have fully disappeared out of the FMCT States the application of safeguards can (and probably should) become in all States identical to the present full-scope strengthened safeguards for non-nuclear weapon States.

To reach that point, which seems an universal desire, the NPT has the appropriate articles, including the long term obligation to negotiate complete disarmament /21/ under international control /22/. It is not unrealistic to expect that all (eight) States with a nuclear-weapon capability will join in an FMCT that incorporates the same objectives. In view of the remaining threats, the non-proliferation regime could be strengthened by the FMCT States, when they all recognize the necessity of all the measures of the present non-proliferation regime as essential to avoid further proliferation.

NPT has been considered by non-signatory States as a discriminatory treaty because it distinguishes between nuclear-weapon States and non-nuclear weapon States. Universal adherence to the FMCT is only possible if that discrimination is not repeated in the FMCT. Hence it is not possible to recognize the threshold States as a kind of nuclear-weapon States in a non-discriminatory FMCT. The discrimination they contested cannot be reinstated. The FMCT will have to circumvent this paradoxical situation, which shall be removed in the end when the Article VI obligation of NPT has been fully accomplished. In that way it may be possible to accept the existence of a nuclear-weapon capacity as a temporal defect.

In the past, many States wanted to acquire experience with nuclear techniques, that possibly could serve in a nuclear-weapon programme. Signing NPT became a necessary step to acquire this. Today the 187 parties to NPT set an international norm not to manufacture nuclear weapons. Most States that intended to develop a nuclear-weapon capability have abandoned these plans. Nevertheless, standing under the NPT obligations, and IAEA safeguards, two States succeeded to proceed in the direction of the proscribed manufacture of nuclear weapons. Recently strengthened safeguards should warrant that such a development will not go anymore undetected. It is to hope that political unanimity will allow the United Nations to decide an appropriate reaction to such a detected event.

3. Technique and Policy

The negotiators of an eventual FMCT need a good technical insight in its possibilities and limitations. Many technical factors will have to be considered carefully. At the time NPT, and its related safeguards agreement, were negotiated, clear scientific ideas about the verification possibilities existed. The IAEA was regarded by its most active Member States as a purely technical organization. The Director General was himself a highly respected physicist /23/. Industrial and political support for the research in the nuclear area stimulated the development of new ideas, and the testing of their practicability /24/. In this favourable climate the IAEA safeguards system matured.

Today, the low prospects for nuclear energy have their repercussion on the research and development community. Industry has its economic objectives, and safeguards is considered as a liability, more than an asset. Independent expertise, like could be found in the R&D area during the early years of safeguards, is needed to mediate between political wishes and technical realisations, in particular when new objectives are pursued. Today this expertise is quite scarce.

Political responsibility for the final judgement should not push aside thorough consideration of modern technical tools, that can support the judgement process. When the IAEA reports that no indication of activities, facilities or items has been found, that does not mean there is none. The probability that "no indication" corresponds to "non existence" depends upon how intrusive, extensive, systematic and skilful the investigation was that gave such result. *Judging that probability is not a technical matter. Even less so deciding what level of probability is required* /25/. But the technical experts could at least give an indication, or a measure, of the level of the parameters like intrusiveness etcetera, the weight of the indications found, and their synergies, which all have to be considered in the assessment /26/, that should be as technically objective as possible.

In view of the long time it takes to conclude and ratify treaties, the drafting of the FMCT should be based on principles that will allow to maintain the FMCT for a long time. Therefore consideration should be given to future technical developments that are perhaps not realizable today, but that could be predicted as a future possibility. Also a merging of NPT and FMCT verification, by the appropriate design of the related safeguards, should be considered. When serious negotiations in the Commission on Disarmament in Geneva starts, it could prove useful to foster a parallel process of technical discussions on FMCT verification matters, to make an optimal use of the scarce safeguards technical resources. In these discussions different options and consequences could be evaluated technically /27/.

4. The Non-Proliferation Regime

4.1. The Non-Proliferation Treaty

The Non-Proliferation Treaty specifies nuclear *energy* as the object that should not be diverted to weapon purposes /28/. Therewith safeguards is aimed at more than only the nuclear material, but it includes all that is needed to generate nuclear energy /29/. The main aim of the treaty is to proscribe the manufacturing of nuclear weapons by non-nuclear weapon States (horizontal proliferation).

Safeguards is an instrument to verify the compliance with NPT obligations, but the definition of verification /30/ includes much more that the IAEA could do under the nuclear material oriented safeguards, as defined in INFCIRC/153. The Model Additional Protocol gives more rights to the IAEA, e.g. to safeguard nuclear activities, which not per se need the presence of nuclear material /31/. Also that does not mean that the strengthened safeguards is sufficient for the comprehensive verification of the NPT obligations, but it has developed as an objective and internationally accepted tool, as basis for a political judgement.

4.2. Export rules and physical protection

The NPT obligation, not to help non-nuclear weapon States to acquire a nuclear-weapon capacity, implied the need for an agreed definition of the items, that should be placed under the export restrictions. The Zangger list gives this definition of the materials and items that should not be exported without safeguards being applied in the receiving State /32/. However that was not considered sufficient.

Theft and sabotage may lead to proliferation, either as a disguise, or as a real fact. The disappearance of nuclear material to unknown purposes violates the basic assumption of the INFCIRC/153 safeguards, namely to have a nuclear material accountancy that allows a verification of the actual inventory against the book inventory. Hence internationally agreed, and regularly updated, standards of physical protection, against misappropriation and sabotage, supplemented the safeguards since 1972 /33/. The physical protection of international transports of nuclear material required international agreement on the responsibilities during the transport, the rules for international co-operation on the eventual recovery, and reduction of the threats that the nuclear material could encounter. Regrettably military nuclear material had not been included in this scope of the Convention on Physical Protection of Nuclear Material /3/.

Commercial competition could lead to allow for negotiable levels of safeguards or physical protection, to be applied in the receiver State. To avoid the weakening of the non-proliferation regime, a set of uniform minimum requirements have been agreed between all main nuclear supplier States. Safeguards according to these Nuclear Suppliers Guidelines was triggered by either nuclear material, equipment or nuclear technology /34/. These guidelines require guaranties against transfer of these goods to third parties without consent of the first supplier, application of adequate physical protection, and the exercise of restraint on the choice of customers. It lasted for many year before all States of the Nuclear Suppliers Group agreed on full-scope safeguards in the receiving State, agreed updates of the lists of sensitive goods, and complemented it with a list of dual use goods /35/.

The present non-proliferation regime requires even more attention for the physical protection in view of real threats. The increasing stocks of, e.g. nuclear weapon material from dismantlement, require increased efforts for a safe, secure, and transparent nuclear material management. However the verification of the adequacy of the measures is a national prerogative. To assure internationally, in a credible way, that uniform levels of prevention of horizontal and sub-national proliferation have been reached, more guaranties on the compliance with the protection rules have been advocated.

The international co-operation on physical protection is increasing. States are willing to accept advice and support in this area. The IAEA has issued voluntary guides, and gives advisory service /36/. Confidence increases when the State, in an internationally accepted way, proves to have a proper functioning system of its national nuclear material control with preventive measures, in addition to the safeguards proof of its correctly declared accountancy. Safeguards can only detect a diversion after it has occurred. The role of the IAEA could be expanded further by making the physical protection rules mandatory. And more generally, the role of the IAEA in promoting peaceful nuclear energy could be expanded to include assuring the safety, security and transparency of all operations involving nuclear material /20/.

4.3. Complementary steps to NPT

The conclusion of the CTBT and the publication of the Guidelines for the Management of Plutonium, which include annual publication of the civil stocks of unirradiated plutonium /9/, are further complementing the non-proliferation and disarmament regime. Several nuclear-weapon States made unilateral and detailed declarations of their past production, policies, and stocks of fissile material for nuclear weapons. And they took measures like detargeting, removing warheads from missiles, and reduction of nuclear arsenals. Confidence in these declarations is also supported by publications of independent assessments on the amounts of weapons usable nuclear material /37/.

As a consequence of the weapon reduction agreement, START-I, between the Russian Federation and the United States, large amounts of fissile material from dismantlement of nuclear weapons will be converted, and put under IAEA safeguards, in order to verify the irreversibility of this process. The progress in that area takes time, and also a lot of technical development is needed, in order to avoid that classified weapon information will be exposed to the observation by safeguards inspectors.

In 1993 the President of the United States announced the intention of placing the excess nuclear weapon material under international verification. In 1996 the President of the Russian Federation made a similar offer. The material is intended to be introduced in the civil fuel cycle, or being disposed off definitively. These processes will take about 20 to 30 years for the present amounts of excess material.

The irreversibility requires safeguards to be continued. For the plutonium this means the application of safeguards on the conversion to mixed oxide fuel, until the material has been fissioned in reactors. Highly enriched uranium will have to remain at least under safeguards until it is down-blended to low enriched material. A trilateral working group with the IAEA has been established to investigate the technical, legal, and financial issues of the safeguards required.

Initially it was suggested that safeguards on the excess material could be applied under the voluntary offer safeguards agreements of the nuclear-weapon States. However these agreements assign to the State a right to withdraw material from safeguards, and the ordinary information necessary for safeguards can not be given in view of the classified character of this information. Hence another IAEA verification arrangement has to be made. Technical and legal instruments have to be developed and the problem of the related costs still has to be solved. IAEA participates in a verification experiment from December 1997 onward.

5. Some Other Relevant Nuclides

5.1. Tritium

The nuclear-weapon States have shown to be capable to realize quite a reduction in the amount of fissile material per nuclear warhead, while the explosive power of the warheads has been boosted by the use of tritium. In the seventies the Director General S. Eklund asked the IAEA General Conference, whether tritium should be subject to safeguards. In 1989 the American NRC formulated its view on this problem in response to questions posed in Congress /38/. It stated that:

> *"for the ignition of a hydrogen bomb a fission explosion is necessary. As tritium is widely used for a variety of peaceful purposes, safeguards on tritium should become quite a burden. The safeguards on nuclear material should be sufficient, and tritium should not be incorporated in the definition of special nuclear material".*

Safeguards is not exclusively based on a regular and comprehensive verification of the mass balance. Material accountancy is the safeguards measure of fundamental importance, but the role of containment and surveillance as important complementary measures is open for a wider interpretation. This allows for additional measures as laid down in the Additional Protocol. Nuclear material, or nuclear activities that don't involve nuclear material of a high strategic value, can be less stringently safeguarded. A right of access to information and related locations is needed for removing eventual suspicion, but this does not necessitate a disproportionate burden of related material accountancy /39/. The Additional Protocol offers a possibility to keep trace of what is happening with e.g. research and development, decommissioned facilities, non-nuclear materials, ore concentration, source material, exempted material and middle and high active waste /40/.

Similar arrangements could be worked out for tritium, as a step to remove suspicion about the non-proliferation *bona*

fides of large tritium consumers. The doubts that eventually may arise can not be removed on basis of a sharp accountancy verification scheme for tritium alone, because its verification is technically quite difficult and inaccurate. Openness and transparency contribute to a not exact quantifiable confidence. Military use of tritium for non-nuclear weapon purposes may be classified, which complicates the possibility to give sufficient openness on this issue. Clear formulation of what can be achieved by application of safeguards is necessary to avoid false feelings of security.

Canada followed this prudent way for the tritium that it supplied to the European Union for its research on the fusion reactor. The tritium has been put under Euratom safeguards on Canadian request. Similarly the United States of America have to build their own installation for the production of tritium for military use, because it cannot be bought abroad. Recycling of tritium from dismantlement is presently a sufficient source for the US needs /41/. Non-proliferation also implies some constraints on tritium production, trade, and use.

Perhaps a more futuristic consideration is the following one. When a breakthrough in the, per definition classified, research should result in very powerful explosives, based on other forces than the known chemical reactions, the fission reaction is not anymore needed for ignition of a hydrogen bomb. Also in order to avoid future surprises some measures of control and eventual safeguards verification on tritium should be considered.

5.2. Other fissile actinides

Similar prudence can be exercised with respect to the separation of fissile material that is not covered by the current definition of nuclear material. Several actinide nuclides have remarkable good neutronic characteristics /42/, this regards the elements neptunium, americium, curium, and californium. But in some cases intense alpha-activity creates a heating problem when thick metal pieces of these materials should be made. But it is difficult to prove that a creative solution of that problem is impossible. Not all of these nuclides give such severe decay heath problems. Neptunium has the right nuclear weapon characteristics /43/. In the Atomic Energy Law of the United Kingdom e.g. neptunium is cautiously included in the definition of prescribed substance, which is material that can be used to produce or use nuclear energy /44/.

Without applying international safeguards in full strength, it could be prudent to do something for some weapon candidate actinides. Safeguards measures additional to the current practices of design re-verification, observation, and monitoring could probably assure that those nuclides are not singled out from irradiated fuel during reprocessing or from the waste treatment for fissioning or transmuting the higher actinides /45/. Provisions for such qualitative safeguards measures may be sufficient at the present stage of technology and of disarmament, the option should be kept open to adapt the safeguards measures when the chances increase for weapon use of some of these actinide nuclides.

6. FMCT Verification and Safeguards

6.1. NPT verification in non-nuclear weapon States

For non-nuclear weapon States the compliance with the NPT includes the non-production of fissile materials for nuclear weapons. The strengthened safeguards system of the IAEA includes measures to detect an undeclared production. In most cases non-nuclear weapon States have little or no reason to develop a capacity to produce pure uranium metal, or plutonium metal. Their acquisition of the sensitive items of the nuclear suppliers guidelines has to be reported. Reported such activities can give rise to doubts, unreported they are an indicator that could be detected. In the strengthened safeguards system also indicators of a less technical nature can be taken into account.

Many elements of a programmatic mismatch between the actual status and the declared future programme of the civil nuclear activities of the State are detectable. The strengthened safeguards makes it possible to make country wide assessments that are aimed to detect the eventual programme to make nuclear weapons, over the years. It is only possible to escape the detection of the physical parts of the programme by use of methods and techniques which are not present in the physical model which the IAEA uses to identify and interpret indicators.

There is a large budget needed for a nuclear-weapon programme, and it will take a long time to build it up from zero. Connection with the declared, and safeguarded, civil fuel cycle, only enhances the detection probability. The programme should be set up fully independent and hidden from the normal nuclear activities. The variety of small indicators that should not be present in a honest non-nuclear weapon State, allows in every respect a reasonable level of detection probability for a nuclear-weapon programme, when these indications are integrated over time. This strengthened system is designed for the situation of horizontal proliferation. Under the strengthened safeguards, combined with political support via the United Nations Security Council, there is no reason to suppose that a case like Iraq could be repeated in a non-nuclear weapon State under strengthened full-scope safeguards.

6.2. Verification in States with a declared nuclear-weapon capacity

Taking FMCT literally, the verification of the compliance with the FMCT will at least have to include verification on all possible production capabilities of fissile materials for nuclear weapons. The present development of the verification of the irreversibility of the excess fissile material, which originates from the dismantlement of nuclear weapons, shows how difficult this is due to the classified information involved. And in this case verification is limited to declared material only. This material will be presented to the inspectors.

To prevent dissemination of classified weapons information, States with nuclear-weapon capabilities will have to declare some military area's as inaccessible for IAEA inspectors. Within those area's, where work on the existing nuclear weapons will continue, proscribed production facilities of fissile materials could be hidden. This will give rise to serious doubts on the completeness of the declarations on enrichment and reprocessing (or other unknown production) facilities, because the verification is not sufficiently comprehensive /46/. The possibility to select only inspectors originating from States with a nuclear-weapon capacity, could be helpful to prevent horizontal proliferation, however the continuing anxieties about espionage by other States with a nuclear-weapon capacity /47/ indicates the impossibility of such an arrangement. Besides, such a selection of inspectors introduces again the contested element of discrimination.

For States that use today their nuclear-weapon capability, many indicators of a nuclear-weapon programme, that could be used in non-nuclear weapon States, are nearly of no relevance. The ongoing activities in the nuclear weapon domain, with its, for inspection inaccessible parts, make it very difficult to distinguish an eventual production of new fissile materials for nuclear weapons from the declared and allowed nuclear weapon activities that belong to a stockpile and stewardship programme.

Further, these States are presumably not researching and developing well known production techniques, with all the related pitfalls that give rise to a detection chance in beginner-States. Known is for instance the advanced plutonium isotope separation by lasers, that had been well developed in the US-Special Isotope Separation project. Many other techniques, known and

unknown could be used. At least the possibility of such new processes has to be taken into account as scenarios that should be made detectable. Also the powerful environmental sampling will be confronted with an unknown background of the allowed military activities, and possibly also environmental monitoring may encounter interpretation problems when strange and unknown signals may be detected.

For this kind of States there is no time to loose between detection of the fabrication of any fissile material and the necessary alarm, because these States know how to make a nuclear weapon. The large expenses those States have made to acquire nuclear weapons, and their long standing efforts to keep those weapons operational, emphasize that no technically remote possibility may be excluded in the design of the safeguards system for FMCT.

Verification of the absence of something is already a problem with an open end. For the absence of any production of fissile materials for nuclear weapons in States with a declared nuclear-weapon capacity, which is inaccessible, this is even more problematic. The fabrication of the fissile material forms the single step to be verified because the production of nuclear weapons is continuing. Should also the rapid resumption (or start) of the production of fissile materials for nuclear weapons (break-out) have to be detected, verification of non-production with appropriate criteria for timeliness and significant quantity will presumably become an impossibly frequent, intrusive and expensive task.

6.3. Verification of military peaceful use

Production of fissile materials of weapon quality for non-weapon use is allowed. This implies that strict safeguards has to be applied, for instance, on the highly enriched uranium for military ship propulsion from the moment it has been made, continuing until it has been consumed. The nuclear material that belongs to the retained nuclear weapons stockpile can be subject legitimately to all possible processing, which may include reprocessing and enrichment. It does not make much sense to detect only qualitatively from the outside that these processes are going on. It will be impossible to detect from the outside for the whole military domain that they are not going on, or cannot be performed at all. To verify that no nuclear material is introduced, that does not belong to the (undeclared?) retained nuclear weapon stockpile material, requires that a distinction can be made according to the origin of these materials. It will be quite difficult to make this distinction, even with intrusive inspections inside the military domain to verify all facilities that possibly could be used for the proscribed production.

The necessary inspections become problematic in view of the demands of protection of sensitive information, even for a “peaceful use” like the reactor fuel of naval propulsion reactors. For these fuel elements the shape, and the enrichment, of the reactor fuel is classified. Therewith the essential verification measures are becoming as complicated as the measures for the irreversibility verification of nuclear weapon material. In principle it may be possible to design a safeguards system for the fuel of military reactors. Containment and surveillance measures should be capable to assist in meeting the verification goals for the sensitive information containing part of that fuel cycle. Only for the completeness verification of the initial inventory declarations about the “peaceful use” fissile materials located in the military domain, it looks nearly impossible to realize inspections that will not compromise sensitive information.

Possibly there could be designed an approach by which the amount of new nuclear material introduced into in the production is exchanged for an equivalent amount of used nuclear material that will be submitted to safeguards. The problem of the peaceful military use material may be solved gradually when the spent fuel is put under safeguards, and will only be replaced by fresh fuel that will remain under safeguards. Also the military nuclear material that will, or has been declared as excess, has in the irreversibility context to remain under safeguards, even when it will be used to fuel military reactors. Further this may touch upon the sensitive question in the FMCT negotiations of declaring stockpiles. It should be hoped that the stockpile problem may diminish with the ongoing development of nuclear disarmament, in sequel to the unilateral openness and transparency measures taken already by some States.

IAEA inspections in a military environment to prove the non-production of fissile materials for nuclear weapons could be challenged as a non-peaceful activity, incompatible with the spirit of its Statute. However in practice the IAEA has for instance measured the environmental pollution of nuclear weapon test sites, some of these when they were still in use /48/. However IAEA safeguards inspections have been limited to “peaceful” nuclear activities, and inspections on military “peaceful” (interpreted as non explosive use), have not been reported. Also verification of the irreversibility of excess material that left the military domain definitively, can thereby not be called safeguards on the military activity. Whether the IAEA will be allowed to apply safeguards in the military domain is a policy subject.

6.4. Separation of civil and military nuclear activities

Assuming that States with a nuclear-weapon capacity within their inaccessible military domain don’t agree with the intrusive inspections necessary to prove that within that domain no production of fissile materials for nuclear weapons is going on, or no production capability is located there, and recognizing that there will be (unsafeguardable) stocks of nuclear material that are declared to belong to the military nuclear weapon stockpile, the only remaining assurance that can be obtained is that no new (civil) nuclear material is introduced in the military domain unless its exclusive non-explosive use can be verified. Only the material that has initially been declared as military stock is allowed to be used for the production of fissile materials for nuclear weapons. For an FMCT that will be verifiable by use of international safeguards, an, as strict as possible, separation has to be made between peaceful non-explosive nuclear activities and nuclear weapon activities.

Safeguards has to be applied on civil material that enters the military domain. An innocuous possibility is the use of depleted or natural uranium in the fabrication of armouring or armour penetrating ammun-ition.

More problematic can be the use of highly enriched uranium in fuel for naval or other military reactors, which was already considered as a loophole of NPT /49E/. Another borderline problem can be generated by excess weapon plutonium, included in mixed oxide reactor fuel. In particular when the reactor is engaged in a military production of isotopes, like tritium. It can be supposed that the data on burn-up of the used fuel are of a particular sensitivity because of their relation to the amount of tritium produced. The required safeguards probably need some alternative measures.

In several States with a nuclear-weapon capacity, the separation of civil and military activities has still to be made, or improved. Particular problems can arise in combined civil/military plants, which have not been built for the application of safeguards, and which are perhaps not even equipped for a correct nuclear material accountability. When any fissile material is produced that could be used for nuclear weapons, this material has, under the rules of the FMCT, to remain under safeguards, during its allowed peaceful use. When dual use facilities produce nuclear material that can not directly be used for nuclear weapons, either the input material belonged to the civil domain, and the product has to remain under safeguards, or the input belonged to the military domain, and so will the output /50/.

6.5. Limiting safeguards to peaceful use material

The NPT requires non-nuclear weapon States to accept safeguards on all peaceful nuclear activities. This wording can be interpreted to exclude the stationed nuclear-weapons in those States, as was the intention of NPT /51/. In the NPT article III context, the governing objective of preventing the manufacture of nuclear explosives gave new meaning to an old word: peaceful can sometimes mean non-explosive rather than non-military /52/.

Keeping in mind the desires for universality and the non-discrimination aspects of FMCT the logical consequence is to apply full-scope safeguards to all *peaceful* nuclear activities in all States. So the experienced safeguards authority that applies strengthened safeguards at least can derive an assurance that no peaceful nuclear material can enter the military domain without keeping trace of it in under FMCT safeguards. Because this material will in principle never be used for nuclear weapons, the application of this safeguards on the declared material inside the military domain will be less intrusive as the thorough inspections needed for verification of the absence of any capability, or activity for the production of fissile material for nuclear weapons.

Some of the States with a nuclear-weapon capacity, that not yet have full-scope safeguards applied, will have difficulties implementing a State System of Accountancy and Control (SSAC). In any case the material will be covered by military supervision of the nuclear activities. This type of control can continue, and even has to remain as part of the SSAC control, while the civil approach of accounting and regular reporting has to be introduced additionally. A transition period might be necessary for the full implementation of a SSAC, as required for safeguards.

When the States with a nuclear-weapon capacity still possess large stockpiles of fissile materials for weapons, it is not realistic to assume that they will risk to challenge the FMCT obligation for a relatively small amount of material. But the treaty should be universal and non-discriminating. And it should last for long during (and after?) the arms control and disarmament process. Further it is a very difficult point to include today the stockpiles of fissile materials for nuclear weapons under the treaty. Hence indications of the size of these stockpiles cannot be used as guiding principle in this Treaty.

Nevertheless, in view of the practical difficulties to implement full-scope safeguards in the States with a nuclear-weapon capacity, during a transition period these considerations could be temporarily be used in order to allow a start with a limited safeguards application. In a gradual way it may grow to the full-scope safeguards. Parallel with that process of implementation, the IAEA can smoothly increase its inspection capabilities. The universal application of one kind of safeguards in all States has been advocated because it will also strengthen the regime, it may lead also to enhanced credibility, and stimulates efforts to realize cost reductions /53/.

7. Cheaper FMCT Verification

7.1. A focused approach for FMCT safeguards

The verification of the obligation not to produce new fissile materials for nuclear weapons is essential. Hence it has been proposed to focus FMCT safeguards /54/ on reprocessing and uranium isotope separation and other ways to acquire the fissile materials for nuclear weapons /55/. Also the diversion possibility from the civil fuel cycle, implies that at least all material with a high strategic value has to be under safeguards from the beginning. When a production starts, which output could be fissile material that can be used for nuclear weapons, safeguards on the output should continuously be applied from the beginning. All output should remain under safeguards until there are accepted reasons for exemption or a temporarily deferring of the application of safeguards.

This focused approach of safeguards could lead to reductions of safeguards effort in comparison to the full-scope safeguards under NPT. When FMCT safeguards and NPT safeguards will converge, it is foreseen to reduce or even stop safeguarding on non-weapon useable fissile material in States without enrichment or reprocessing capability. Of course this has to be verified. The possibility to withdraw plutonium from mixed oxide fuel should imply that this material will be safeguarded. Application of the new measures of the strengthened safeguards system should give the required assurance of the absence of undeclared enrichment or reprocessing activities.

7.2. Comments on a focused approach

With a focused approach several risks are taken. The strengthened safeguards system is developing, and its technical safeguards capabilities are not yet clearly settled. It supposedly gives a credible assurance on the absence of undeclared activities for States without a nuclear-weapon programme. Time is for that case an important factor, because it is assumed that a long time is needed to set up a nuclear-weapon programme in those States. In States with a nuclear-weapon capacity the nuclear-weapon programme is ready, and operational, and possibly they have also other, well advanced technical capabilities. Hence a thorough theoretical and practical assessment of the remaining value of safeguards techniques, like environmental sampling, has to be made in view of the possibilities of such an advanced State.

There has to be a complete declaration of all facilities of the State that could be used for the production of the fissile materials for nuclear weapons. As production and research of nuclear weapons will continue, safeguards should give assurance that no research, pilot, or production facility in the less, or even not accessible military domain, will be used anymore for the production of old or new kinds of fissile materials for nuclear weapons. One consequence of the focused approach is that an assurance of completeness of the declaration on the production capabilities only can be obtained by intrusive verification of the military domain.

With regard to the States without an official nuclear-weapon capacity it has to be realized that a focused approach relies strongly on the new safeguards measures, that could probably be insufficient to detect attempts to set up equipment for the production of fissile materials for nuclear weapons. Where the technical barrier between diversion of the material, e.g. LEU be diverted for secret enrichment, and production of the desired fissile material is reduced, more safeguards efforts are necessary to create a relatively equal detection probability.

In an attempt to reduce the cost of safeguards, there are acceptable possibilities to reduce e.g. the inspection frequency for irradiated low enriched uranium fuel in situations where the risk involved in a diversion is low. That can be the case with high burn-up fuel in States with good non-proliferation credential without any facility for reprocessing. The concentration of safeguards on “direct use material” in such a non-nuclear weapon State has to be seen against the detection vulnerability of an eventual nuclear-weapon programme in that State. Where little information is available to make a good assessment of the intentions and capabilities of the State more safeguards efforts should be justified.

For the unambiguous proof of the occurrence of a significant diversion, one has to rely on nuclear material accountancy and its verification, like in the classical safeguards. Strengthened safeguards is a valuable addition, it can direct safeguards to the points that need extra attention. But this addition cannot replace the hard evidence of the quantitative

safeguards, which can be obtained directly, in contrast to the additional measures of the protocol, which are subject to procedures that can lead to misleading explanations and lengthy debates, before a conclusion can be drawn.

If it should be decided that a focused verification approach is sufficient, this would confirm old argumentations against the Non-proliferation regime, namely that its heavy safeguards burden, as this has been experienced for so many years by the nuclear advanced non-nuclear weapon States, was overdone, or was made with even worse intentions relating to economic competition. In that way confidence in the non-proliferation regime will be undermined.

By a gradual implementation of safeguards, the focused approach is an option for the start, but it should not be institutionalized for ever /56/. The non-proliferation regime became what it is today by necessity. The long term objective of the NPT is that all States will become equal non-nuclear weapon States, hence its discrimination can disappear. For the time being the nuclear weapons are a reality, and a FMCT could help to, at least, remove the NPT discrimination for the civil part of the nuclear activities. But to reach a full convergence of FMCT and NPT, it is necessary to have a political engagement towards a total abolishment of the nuclear weapons. For this development it is essential that an effective IAEA safeguards is applied as universally as possible, to begin with the civil nuclear material, followed by the excess nuclear weapon material. Probably the unilateral openness of some States on their production of fissile material for nuclear weapons, could be followed by other States, preparing grounds for confidence building and towards the future inspections.

7.3. The political decision ahead

In 1982 the IAEA Board of Governors showed little enthusiasm to oblige States under NPT safeguards to report the indigenous production of uranium /57/. The main reason not to insist on this kind of obligation was the high estimated workload involved in the full application of safeguards inspections to the large amount of material of low strategic sign-ificance. In this political decision the cost argument prevailed over the wish to strengthen safeguards, even in States of which there were indications that they have had a nuclear weapon ambition, like Iraq. In the following years several States had enough information to support the hypothesis that Iraq had a nuclear-weapon programme, but no consequent action had been enabled for the IAEA safeguards, like posing further questions or demanding a special inspection.

Also in relation to the safeguards for FMCT the technical world can only formulate options and consequences. It is a policy decision to define at which point safeguards will be strong enough. But it must be sufficient to create confidence that safeguards for the FMCT may not encounter a similar loophole as it did in Iraq. It is the responsibility of the safeguards experts to indicate this kind of weaknesses and risks involved in the system design.

A loophole has been identified in an article that gives a technical outline of a focused FMCT verification regime based upon the experience with the IAEA safeguards system. Also that evaluation reaches the essential dilemma. States with a nuclear-weapon capacity have under NPT Article I the obligation not to disclose any sensitive information on manufacturing nuclear weapons. They also have defence and security considerations that may inhibit a full declaration of all production facilities of fissile materials for nuclear weapons. This may lead to a significant loophole in the FMCT verification regime /58/. The negotiators should be made aware of such technical problems. A working group on FMCT verification should be formed as early as possible, to form a technical basis for an eventual solution to this problem.

The strength of an FMCT will be dependent upon many policy factors. When the treaty is only signed by NPT States, it only codifies what the five nuclear-weapon States, nearly all, already have declared unilaterally about the production of fissile material for nuclear weapons. It is a much greater challenge to get also the other three States with a nuclear-weapon capability, to join the non-proliferation regime. In the discussions ahead, undoubtedly the policy and technical arguments will be intermingled. A pure technical discussion could help to increase the mutual understanding and appreciation of the technical difficulties. Probably also technical solutions can be found to overcome straight policy inhibitions, which are based mainly on political grounds. A verifiable cut-off can become the foundation of the further steps in the multilateral nuclear disarmament process /59/.

7.4. Safeguards, a valuable asset

One of the reasons for the proposed focused approach is the expectation of a cost reduction for safeguards. If one should take the benefits of a good safeguards system into account, these costs are negligible. International nuclear trade and co-operation is only possible on basis of good guaranties that the received items are not misused. The costs are minimal:

1. Compared to the value of the total amount of nuclear electricity produced, the cost of safeguards amount roughly 0,1 per cent. The Uranium Institute calculated that a similar amount of money is spent on safeguards by the nuclear industry /60/.
2. In 1998 Stephen Schwartz of the Brookings Institute concluded a four years study on the cost of the U.S.A. nuclear armament. In the period 1940 to 1996 5,8 T$ was spend. About 7 per cent was needed for the fabrication, and double of that amount for the maintenance of nuclear weapons. The cost of safeguards are again in the order of 0,1 per cent of that amount.
3. The annual IAEA safeguards budget of 80 M$ compares with the annual budget of the American “Defense Threat Reduction Agency” of 1,5 G$ as quite small.

How much is spend worldwide on these issues can only be guessed. To be confident in the verification of the FMCT by the IAEA is a valuable asset. It deserves a comparable budget.

8. Concluding Remarks

1. By the Chemical Weapon Convention and the Biological Weapon Convention two categories of weapons of mass destruction are being abolished. A nuclear-weapons free world is an objective, which is still far ahead.
2. The nuclear weapons option is an essential factor in the national security strategy for States with, and for many States without nuclear weapons. Hence the abolishment of the nuclear weapons is a complicated and time consuming process which has to involve both the “have” and the “have-not” States.
3. The verified cut-off of the production of fissile material for nuclear weapons means a important step forward on the long way to nuclear disarmament. As long as national security denies inspection access to military (nuclear weapon) complexes, and it may be assumed that there are nearly unlimited financial, technical and scientific resources for military purposes, the risk of a break-out remains. Only when FMCT includes a strong obligation to reach a verified complete disarmament, the risk of a break-out may be considered acceptable, during the limited period where still a nuclear arsenal is maintained.
4. The FMCT has to become an universal and non-discriminating treaty. It offers a possibility to integrate the whole non-proliferation regime into one treaty for the future, which should not only be acceptable for all States, but this time also all States should adhere to it.
5. The States without nuclear weapons prove that they are not producing fis-

sile material for nuclear weapons by means of the accepted strengthened full-scope safeguards.

6. The credibility of the measures of nuclear-arms reduction, taken by the States with nuclear weapons, can increase by a verified cut-off.
7. Cut-off verification is a logically required complement to the irreversibility verification on the excess-nuclear weapon material.
8. The reality of today is that the possibility of armed conflict over genuinely vital issues remains real. The nuclear weapon can not be "disinvented", and therefore the nuclear weapon is always within reach for a State with a strong technological base. States with a nuclear-weapon capability may fall into pieces, the threats may come from terrorism, unrecognized States, "rogue States", or the growth of organized crime /20/. There is no reason to weaken the non-proliferation regime of the last thirty years, that has been build up gradually according to necessity.
9. An active stockpile and stewardship programme for nuclear weapons implies an inaccessible area for verification of the cut-off. The consequence is incomplete verification that cannot give any credible assurance on the non-production of new fissile material for nuclear weapons.
10. Strengthened IAEA verification, in analogy to the strengthened full-scope safeguards, on all civil, and all non-explosive military, nuclear activities can at least give the assurance that no nuclear material is added to the declared nuclear-weapon programme.
11. The effectiveness of an FMCT will depend on the willingness of the States to provide adequate funding for the compliance verification by IAEA safeguards. This willingness will be the true "litmus test" of the desire for an effective FMCT, and the dedication to a true nuclear disarmament. By lack of funding for the application of safeguards in States with a nuclear-weapon capacity, equal to that in the NPT non-nuclear weapon States, it will be difficult to establish an equal confidence in their peaceful applications of nuclear energy.
12. Finally the value of IAEA safeguards and verification relates also to the political follow up that it can generate when a diversion has been detected. The IAEA access to the UN Security Council is unique. But its value depends also strongly on the consensus between all the Members of the Security Council.

9. References

/1/ The International Court of Justice declared that the threat or use of nuclear weapons is generally unlawful. The Court also declared that it could not definitively conclude whether the threat or use of such weapons would be lawful or unlawful in an extreme circumstance of self-defence, in which the very survival of a State would be at stake. The judges unanimously concluded: "There exists an obligation to pursue in good faith and to bring to a conclusion negotiations leading to nuclear disarmament in all its aspects under strict and effective international control". Bull At Sci Sept/Oct 1996 pp. 39-40.

/2/ NPT was opened for signature on 1 August 1968. On 31 December 1997 the required safeguards agreement with the IAEA was in force for 123 States.

/3/ "The Convention on the Physical Protection of Nuclear Material", IAEA document INFCIRC/274/Rev. 1.
The Convention on the Physical Protection of Nuclear Material was signed at Vienna and at New York on 3 March 1980. It obliges Contracting States to ensure during international nuclear transport the protection of nuclear material within their territory or on board their ships or aircraft. The Convention provides an appropriate framework for international co-operation in protection, recovery and return of stolen nuclear material and in the application of sanctions against persons who commit criminal acts involving nuclear material.

/4/ SALT, Strategic Arms Limitation Talks, started on 17 November 1969 at a time where the Soviet Union and the United States of America had reached a nuclear parity. It resulted in agreement on a ceiling in the number of intercontinental ballistic missiles, and a limitation on the missile defence systems SALT-I. The SALT-II agreement of 1979 never came into force.

/5/ START, Strategic Arms Reduction Treaty, is a treaty on the reduction and limitation of strategic offensive arms. Discussions started 29 June of 1982 in Geneva, and resulted in the signature on 31 July 1991 of a treaty that reduced the strategic nuclear armament with one third. In June 1992 deeper reductions were agreed, however this START-II agreement has not yet been ratified.

/6/ INF Treaty, Intermediate-Range Nuclear Forces Treaty between Russia and the United States of America, which led to the controlled destruction of all missiles for nuclear weapons with a range between 500 and 5000 km. The destruction was completed mid 1991, some inspections will continue until the year 2011.

/7/ "1995 Review and Extension Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons", IAEA document INFCIRC/482, 23 August 1995.

/8/ The CTBT was signed at the UN in New York on 24 September 1996. On 26 May 1999 it has been signed by 152 States. In order to come into force 44 States are named that have to ratify the treaty, 21 of them did so. India, North-Korea and Pakistan should also ratify, but they have even not yet signed the Treaty. The text-file can be found on the Internet at http://www.unog.ch/frames/disarm/distreat/ctbt.pdf

/9/ "Communication Received from Certain Member States Concerning their Policies Regarding the Management of Plutonium", IAEA document INFCIRC/549, 16 March 1998, and the subsequent documents. Belgium, China, Germany, Japan, Russia, Switzerland, the United Kingdom, the United States of America, and France will adhere to the Guidelines for the Management of Plutonium, that include the publishing of a description of the policy for the civil material and an annual listing of the stocks of civil plutonium.

/10/ The Commissions members include Professor Joseph Rotblat, the winner of the 1995 Nobel Prize for Peace, Mr Michel Rocard, the former Prime Minister of France, Mr Robert McNamara, the former United States Defence Secretary and President of the World Bank, General George Butler, the former Commander of the United States Strategic Air Command, Dr Maj Britt Theorin, former President of the International Peace Bureau, Field Marshal the Lord Carver, the former Chief of the British Defence Staff and Professor Robert O'Neill, the eminent Australian strategic thinker who is Chichele Professor of the History of War at Oxford University and Captain Jacques-Yves Cousteau, the distinguished environmentalist, and former President of the French Council for the Rights of Future Generations.

/11/ The report can be found on the Internet at http://www.dfat.gov.au/dfat/cc/cchome.html

/12/ CTBT Article IV. A. 5. For the purposes of this Treaty, no State Party shall be precluded from using information obtained by national technical means of verification in a manner consistent with generally recognized principles of international law, including that of respect for the sovereignty of States.

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ceedings, Los Angeles CA July 15-18 1990, p 76. INMM, Northbrook IL (1990).
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/15/ NuclearFuel 28 dec 1998, p. 3.
/16/ NuclearFuel 13 November 1989, p. 1, China stops production of military HEU. Similarly it is assumed that at that time-frame China stopped the production of plutonium. Chinese Research reactors will be converted to LEU, but NuclearFuel of 13 January 1997 published that the reprocessing of HEU in Lanzhou (Province Gansu) will start in 2000.
/17/ Lawrence SCHEINMAN, "Engaging Non-NPT parties in the Nuclear Non-Proliferation Regime", Programme for Promoting Nuclear Non-Proliferation, Issue Review No. 16, May 1999.
/18/ e.g. from nuclear test sites, or weapons and other nuclear material lost by accident, which has not yet been recovered.
/19/ IAEA, "Annual Report 1998", part of the safeguards statement reads:
"In fulfilling the safeguards obligations of the Agency in 1998, the Secretariat did not find any indication that nuclear material which had been declared and placed under safeguards had been diverted for any military purpose or for purposes unknown, or that facilities, equipment or non-nuclear material placed under safeguards were being misused. All the information available to the Agency supports the conclusion that the nuclear material and other items placed under safeguards remained in peaceful nuclear activities or were otherwise adequately accounted for.
Protocols Additional to Safeguards Agreements ... , when implemented, will enable the Agency to provide increased assurance about the absence of undeclared nuclear material and activities".
/20/ Richard LATTER, "The Continuing Threat of Nuclear Proliferation", Summary of the Wilton Park Conference on the Threat of Nuclear Proliferation of 14-18 December 1998.
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/28/ NPT article III: "... accept safeguards ... 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".
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/35/ "Communication Received from Certain Member States Regarding Guidelines for the Export of Nuclear Material, Equipment and Technology, Nuclear-related dual-use transfers", IAEA document INFCIRC/254/Rev.3/Part 2, this list has been updated in 1998.
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/40/ IAEA document INFCIRC/540(Corr.), see for example articles 2.a.5-2.a.8, article 3 on reporting, and article 6.b on inspection access including examination of production and shipping records.
/41/ NuclearFuel 8 September 1998, p. 3., Under START-I a new production has to start in 2005. When Russia signs START-II this can be postponed until 2011.
/42/ Sümer SAHIN, Roland CALINON, "Criticality of Curium Assemblies", Atomkernenergie-Kerntechnik Vol. 46 (1985) No.1 p. 45-49.

/43/ The critical mass is about forty kg. Two nuclear test explosion seems to have been made with a neptunium device.

/44/ Atomic Energy Act 1946, Revised to 30th September 1977, Article 18.

/45/ NuclearFuel 3 July 1995 p 22 "France: CEA awards prize for cesium-separating molecule". In this news item can be read that:
"Calixarenes are capable of selectively separating a specific element from a waste solution by forming a compound with it, and then releasing it outside the solution, e.g. caesium-135. Other calixarenes can be used to selectively extract minor actinides, in particular americium and curium. This family of molecules, synthesized at the University of Mainz, was also patented early this year".

/46/ INFCIRC/153, article 46 b (iv) states: "If the State so requests, a special material balance area around a process step involving commercially sensitive information may be established".
This has been intended by the negotiators as a small area where for proprietary information inspection access could be limited. This article has never been implemented, even not in the internationally discussed HSP arrangement, for commercial centrifuge enrichment facilities, by which arrangement the inspectors got a Limited Frequency Unannounced Access right to the cascade halls.

/47/ J. RISEN and J. GERTH, "China Stole Data on Atom Warhead, U.S. Report Finds", New York Times, 21 April, 1999; and the allegations of espionage by UNSCOM members in Iraq, that came into the news by the Washington Post, the Boston Globe, the Wall Street Journal, around 7 January 1999, and the declaration by Scott Ritter at the Australian radio on 7 January.

/48/ After closure, the environmental effects were measured for the test sites on the Marshall Islands, and at Semipalatinsk. Before the test sites were closed, and after their closure, measurements were performed by the IAEA at Mururoa and Fangatauga.

/49/ L. SCHEINMAN, "Political Aspects of NPT Safeguards", in R.B. Leachman and P. Althoff (eds), Preventing Nuclear Theft: guidelines for industry and government, Symposium of Implementing Nuclear Safeguards, October 25-27 1971, Kansas State University (New York: Praeger, 1972).

/50/ The classified information that can be disclosed inside the dual use facility, or the technical impossibility to apply proper safeguards there, could lead to opt for the exchange of equivalent amounts of output material for civil input material.

/51/ See /29/, Endnote 39.

/52/ See /29/, p.12.

/53/ W.-D. LAUPPE, G. STEIN, R. GERSTLER, H.-H. REMAGEN, "The Context Between a Fissile Materials Cut-off and NPT-Safeguards", International Atomic Energy Agency Symposium on International Safeguards, Vienna, Austria, 13-17 October 1997, IAEA-SM-351/79.

/54/ There is not yet a clear distinction made between safeguards and verification. Part of the problem is related to the colloquial meaning of verification in INFCIRC/153, and the more extensive meaning of verification in the context of arms control and disarmament/30/. Might safeguards be a technical measure applied by a technically competent organisation, verification of Treaty obligations can be based on safeguards results together with other information. Decision on criteria for safeguards, and judgement of the outcome in connection with eventual other information is a political matter.

/55/ V. BRAGIN, J. CARLSON, J. BARDSLEY and J. HILL, "Focussed Approach to Verification under FMCT", Proceedings from the Fissile Material Cut-off Seminar in Stockholm, June 1998, FOA Hasseludden, 1998.

/56/ In ref./55/ there is suggested to draft a special treaty for the application of safeguards under FMCT.

/57/ R.J.S. HARRY, "The Starting Point of IAEA Safeguards, Aspects of Safeguards on Ore Concentrates", 15th Symposium on Safeguards and Nuclear Material Management, Augustinianum, Vatican City, Roma, Italia, 11-13 May 1993, EUR 15214 EN, ESARDA 26, pp. 153-160.

/58/ KINJI KOYAMA, "What the verification regime under a fissile material cut-off treaty could be like: a preliminary view", Journal of Nuclear Material Management, Vol. XXVII, 2, Winter 1999, Institute of Nuclear Materials Management, Northbrook IL U.S.A.

/59/ Ms Katharine C. Crittenberger, "Statement of the U.S. Delegation to the Third Preparatory Committee Meeting for the 2000 NPT Review Conference, Fissile Material Cutoff Treaty (FMCT), 13 May 1999: "A cut-off, in short, is the foundation for further steps in the multilateral nuclear disarmament process. If eventual nuclear disarmament is our objective, a cutoff in the production of fissile material for nuclear explosive devices is a step that should be taken. We should not let this opportunity slip away."

/60/ G. Clark, "International Safeguards, An industry perspective, The civilian nuclear industry has long backed the need for an effective system of nuclear verification", IAEA Bulletin 38/4; 1996.

Installations for the Storage of Spent Fuel
Conditioning Facilities
Geological Repositories

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1. Introduction

In safeguards, there is a clear shift towards the back-end of the fuel cycle in terms of inspection effort, investments and R&D needs. Industrial scale reprocessing, the build-up of Pu-stocks, re-use of Pu in MOX elements, the medium and long-term storage of spent fuel and, last but not least, a trend towards its direct disposal in geological repositories, with or without prior conditioning has generated a number of challenges with regard to a more efficient use of resources and a minimisation of the interference of safeguards measures with operations. These will have to be solved in a way specific to the conditions of a site and may be achieved for instance by the use of unattended and/or remote safeguards equipment and the application of sophisticated and reliable C/S systems.

Within ESARDA, the need for a dedicated forum for the back-end of the fuel cycle was identified which, as a supplement to the discipline oriented working groups (NDA, DA, C/S), would cover issues of a more general nature and could have some coordinating role in the subject area.

As questions concerning reprocessing were sufficiently covered by the ESARDA Working Group for Reprocessing Input Verification (RIV), and MOX fabrication is dealt with by the ESARDA MOX Fuel Fabrication Working Group, the new Working Group for the Back-end of the fuel cycle focuses mainly on the long term storage of spent fuel, spent fuel conditioning plants and final geological repositories for the direct disposal of spent fuel.

It intends to represent a European forum for companies and organisations involved in the research, design and operation of installations of the back end of the fuel cycle. It is used to discuss all questions related to safeguards approaches and their implementation, in particular focusing on the methods and techniques to be applied. The Working Group aims to provide independent European input in this field and maintains contacts with other initiatives in this area such as SAGOR and Member State Support Programmes to the IAEA (MSSP).

This document has been prepared with the support of all the Members and Special Members of the BFC WG and it includes also the comments as received by the Convenors of the ESARDA NDA and C&S WGs. It outlines the existing trends in the European Union, it summarises the current safeguard requirements, and it contains recommendations for the optimisation of safeguard approaches and for their implementation in above installations and identifies particular needs in this field.

The objectives of the BFC WG, as a follow up of this document, is to undertake a joint task with the discipline oriented ESARDA working groups (NDA, C/S) with the following scope:

- Identification and evaluation of past and current R&D projects in this field.
- Identification of topics not covered so far.
- Proposal of possible innovative solutions.
- Definition of R&D priorities.
- Identification of possible actions and time schedules.

2. Activities and Trends of the Back End of the Nuclear Fuel Cycle within the EU

Within the EU there are different strategies for the Back End of the nuclear fuel cycle and the situation in this field is very sensitive to political changes. Delays, or the complete abandonment, of the spent fuel reprocessing option in some countries, and delays in the foreseen operation of geological repositories, have led most of the nuclear countries to increase both their spent fuel storage capacity and the duration of storage.

In order to have a picture of the present situation and trends on the different policies an overview of the spent fuel management in the European countries has been performed.

Belgium

In Belgium, nuclear power is provided by seven units on two sites. The back-end policy has been the subject of numerous debates in Parliament, the latest of which took place in December 1993. This debate concerned reprocessing and the use of MOX fuel in two of Belgium's nuclear power plants. The Parliament endorsed the use of MOX fuel and approved the continuation of the existing reprocessing contract signed in 1978. Following the decision taken by the Government, based on the recommendations of the Parliament, the direct disposal option is henceforth placed on the same level as reprocessing. As a consequence, additional interim storage capacity had to be provided at the nuclear power plant sites.

The electric utility adopted two solutions: dry storage in dual-purpose metal casks in a concrete building at Doel site and wet storage in pools in a bunkered concrete building at the Tihange site (2000 tHM of spent fuel).

Both installations are currently in operation.

Finland

The Finnish power utilities operate four units at two sites. Over 15 years, based on the 1983 Decision in Principle by the Council of State, Olkiluoto nuclear power plant (BWR) made domestic arrangements (site selection, technical plans and safety assessments) for final disposal of the spent fuel. Until 1996 the Loviisa nuclear power plant (VVER) returned spent fuel to the Russian fuel supplier. After the amendment of Finnish nuclear legislation prohibiting export of nuclear waste, the two utilities signed an agreement to co-operate in the management of spent fuel and formed the waste management company Posiva for the planning and later implementation of a final disposal in the Finnish bedrock.

Approximately 75 tonnes of spent fuel removed annually from the reactors is

stored at wet storage facilities at the power plants. The capacity of the Olkiluoto interim storage facility (KPA) is now 7200 assemblies (ca. 1200 tHM) and the Loviisa storage is being expanded to 4200 assemblies (ca. 610 tHM). Some 2600 tonnes of spent fuel will accumulate during the projected 40 years of operation of the Finnish reactor units. Both storages could still be extended.

According to the Decision in Principle, the disposal site will be selected at the end of 2000 and the encapsulation plant and repository will be designed in the 2000-2010. The construction is planned to be carried out after 2010 and the disposal of spent fuel will start in the 2020s.

France

Reprocessing of spent fuel discharged from the French nuclear reactors and recycle of plutonium and uranium is done on an industrial scale. Of the 1200 tHM per year discharged from the 57 EDF nuclear units, 850 tHM are reprocessed and since 1987 the recovered Pu has been used for the fabrication of MOX fuel. Up to year 2000, 28 units could be refuelled with MOX assemblies.

Considering the existing storage capacity at La Hague reprocessing plant, the short term and medium term storage of spent fuel is carried out there, under water. However, the law of December 1991, related to waste disposal, provides that alternative solutions to reprocessing (direct disposal) should be explored. Studies are underway to examine and evaluate the various possible nuclear fuel cycles as well as the corresponding technical solutions. The above mentioned law schedules that the concluding investigations will be presented in 2006 in Parliament, which could possibly then change the trend of national politics on the back-end of the fuel cycle.

Germany

The concept of spent fuel management in Germany provides for both options, either reprocessing or long term storage, followed by final disposal in a geological repository.

The contracts for spent fuel reprocessing with COGEMA and BNFL in France and UK include the provision that the waste which is separated during the reprocessing of the German fuel has to be returned to Germany.

At present two industrial-scale intermediate storage facilities for spent fuel are in operation and a third is under construction:

- The Ahaus facility has been in operation since June 1992. Spent fuel assemblies (THTR and LWR) are contained in transport/storage casks of the CASTOR type. The capacity of the storage facility is at present 3960 tHM.
- The Gorleben facility has been in operation since April 1995. It is of similar design to that of the Ahaus facility and is at present licensed for the storage of LWR spent fuel and vitrified waste from the reprocessing of spent fuel in CASTOR type casks. The total capacity is 3800 tHM.
- The Greifswald facility is planned to go into operation in 1999 and will store the spent fuel assemblies (LWR) of the Greifswald and Rheinsberg nuclear power plants also in CASTOR type casks. The capacity is 620 tHM. At present the majority of the spent fuel assemblies of the two nuclear power plants mentioned are stored in a wet storage facility at the Greifswald nuclear site with a capacity of 560 tHM.

It has to be mentioned that the spent fuel from the High Temperature Research Reactor AVR in Jülich is also stored in CASTOR casks in an intermediate storage facility at the site of the Jülich research centre.

Since 1990 a Pilot Conditioning Facility has been under construction at the Gorleben site (throughput 35 t HM/a). It is primarily designed for consolidation and packaging of spent fuel into final disposal casks suitable for underground final disposal in rock salt.

The Gorleben salt dome is currently being investigated at a depth of about 840 m with respect to its suitability as a final disposal repository for spent fuel assemblies and all types of radioactive waste including heat generating waste. The capacity of the repository is assumed to be sufficient to store all this type of heat-generating material existing now and generated in the future up to a maximum heat capacity of 2500 GWyear.

Italy

Most of the spent fuel produced during the Italian nuclear energy programme, which was abandoned in 1987, has been reprocessed at the BNFL facilities. As far as the remaining spent fuel is concerned, 192 tHM were stored at reactor pools, 81 tHM in the AFR wet storage facility Avogadro, and 4 tHM in pools at the ENEA pilot reprocessing (Eurex and Itrec). The current strategy is the on site dry cask storage. Facilities for the storage of dual-purpose (transport/storage) metal cask will be realized at the two NPP sites Trino and Caorso.

The Netherlands

The spent fuel produced by the two nuclear power plants (15 tHM/a) is reprocessed at the COGEMA and BNFL facilities.

However, a centralised dry interim storage facility, both for the High Level Waste from the reprocessing and for the spent fuel from research reactors, is foreseen and also, not excluding a future rethinking to the open cycle option, for the long term storage of LWR spent fuel. The storage facility, a bunkered concrete vault similar to the CASCAD concept, has been realised at the HABOG site.

Spain

Spent fuel management in Spain is based on direct disposal. Since at least 40 years may be necessary before the operation of a final disposal, additional storage capacity will be needed. Current strategy contemplates either to increase the capacity of the existing reactor pools or to use dual-purpose metal casks in on-site facilities. With the aim of providing the power utilities with about 100 casks, ENRESA has developed, in co-operation with NAC, a metal cask for 21 PWR fuel elements (NAC-STC).

A centralised interim storage facility will be realised by 2010 and different solutions are being evaluated.

Sweden

According to the Swedish choice for the back end of the nuclear fuel cycle, the spent fuel will be disposed of at about 500 meters depth in bedrock.

Since 1985, the spent fuel is stored in the interim storage facility CLAB. The storage is of the wet type, comprising large water pools located in crystalline rock about 25 m below the surface. The store has the capacity of 5000 tHM and, by 2004, will be extended, through the construction of further pools, to 8000 tHM.

Extensive research is going on how the spent fuel will be disposed of. It is foreseen that the spent fuel will be placed in canisters at an encapsulation plant. The canisters will then be transported to a geological repository. The capacity of the repository will cover the amount of spent fuel created by the Swedish nuclear programme. The final sites for the encapsulation plant and the geological repository have not yet been selected.

United Kingdom

Different spent fuel management strategies are currently pursued in UK:

- MAGNOX fuel - All fuel will continue to be reprocessed at the Sellafield site.
- AGR fuel - Agreement has been reached between Nuclear Electric and BNFL to reprocess 3000 tHM of spent fuel arising up to about the year 2005, but no decision has been made by NE for later arising of AGR fuel. Scottish Nuclear Electric has reprocessing contracts with BNFL for 1700 tHM of spent fuel, the arisings from the AGRs up to about 2007. The remaining lifetime arisings of SNL AGR spent fuel will be sent for storage at Sellafield

with the option to reprocess or condition for direct disposal.
- PWR fuel - The reprocessing and direct disposal options remain open. The current UK design of PWR provides for 18 years at reactor wet storage and, by adopting higher burn-up and/or rod consolidation, full use will be made of the storage capacity available at the reactors.
- Prototype Fast Reactor - Fuel from the Prototype Fast Reactor (PFR) is being reprocessed by the UKAEA at Dounreay.

3. Safeguards Requirements in Spent Fuel Management

In the European Union, all plants handling nuclear material designated for civil uses are under Euratom Safeguards. The IAEA safeguards all the installations in the Non-Nuclear Weapon States and certain designated facilities in the Nuclear Weapon States France and United Kingdom.

3.1. Inspection goals

For installations handling spent fuel, the inspection goals are currently defined as follows:
- Confirmation, that there are no inconsistencies/ shortcomings in the operator's accountancy system.
- Confirmation, that there are no inconsistencies between declared and physical characteristics and operation of the plant.
- Confirmation, that there was no diversion of nuclear material.

For nuclear material verifications, the inspectorates use the following quantitative goals:
- Goal quantities: IAEA - 8 kg of Plutonium, Euratom - the smaller of 8 kg of Plutonium or one fuel assembly or the corresponding amount in pins.
- Timeliness goal: 3 months.
- Detection probability: IAEA - 50 percent, Euratom - 90 percent (for gross and partial defects).

However, these working tools can only be applied where nuclear material is accessible.

3.2. Generic verification activities

In the fuel cycle facilities, where nuclear material is accessible, the inspectorates achieve their goals with an appropriate combination of verification methods, specific for the material type subject to inspection.

If the material is easily accessible, such as in many wet stores, the inspectorates consider it sufficient to regularly re-verify the spent fuel assemblies by visual checks and Non Destructive Analysis (NDA). The verification requirements may be reduced by applying a single C/S system (e.g. optical surveillance or seals) to maintain the continuity of knowledge on the material between inspections. As in case of system failures the inspectorates might decide to re-establish the continuity of knowledge using NDA, which is extremely time consuming and costly in the case of big stores, the inspectorates aim to have some redundancy within the C/S system.

The situation becomes different, when the spent fuel elements become inaccessible for a long time or even forever. In this case, the conventional methods of verification are being followed until the last possible point. From this point onwards, the information of the operator's accountancy is being followed by using a multiple C/S system with a high level of reliability.

The term *"multiple C/S system"* is not always understood correctly. In particular, the term is often confused with the term *"redundancy"*, which in fact has a different meaning.

A *"redundant"* C/S system consists of a duplication of equal components to make it more reliable, e.g. by installing two completely independent camera systems. Normally, only one of these components is evaluated for verification purposes. Only in case of system failures, the back-up system is used to obtain the necessary information.

A *"multiple"* C/S system consists of a number of components which are functionally independent, are not subject to a common tampering or failure mode and therefore provide diverse and independent assurance. Examples are a seal plus video surveillance, or two different types of seals.

As a consequence, the inspectorates evaluate both layers of the multiple C/S system at the inspections. When only one layer is found to be intact the situation is being evaluated and further verification activities may be considered on a case by case basis to make sure that no nuclear material has been diverted.

3.3. General requirements

The inspectorates are interested in ensuring that all safeguards methods and techniques considered for application will be approved for inspection use (environmental qualification, acceptance and implementation testing, authentication, European EMC - Electro-Magnetic Compatibility - standards).

4. Wet Storage of Spent Fuel Elements

4.1. Installation types, techniques

Wet storage represents, up to now, the most widely used technology, with a positive and consolidated experience. Water pool storage technology is quite simple and provides ready access to the fuel allowing easy verification.

Water pools associated with the power reactor are the most common types of spent fuel storage. With arising problems in storage capacity, the first solution adopted by operators was the implementation of various in-pool measures (e.g. neutron absorbers and compact storage racks).

Nevertheless these measures still could not provide sufficient capacity, particularly in those countries where the strategy of direct disposal (or "wait and see" option) has been chosen for the closure of the nuclear fuel cycle. In this case separate wet interim storage facilities had to be realised. It has been demonstrated that wet storage can provide safe storage of spent fuel elements for periods of 50 years and more.

Typical examples of interim wet storage facility in EU are the CLAB interim storage facility in Sweden, the TVO-KPA store in Finland and the Tihange installation in Belgium.

4.2. Safeguards concepts and activities

The main safeguards concern in this installation type is the removal of irradiated fuel assemblies from the wet store or from transport casks when or after they leave the installation.

In wet storage, the nuclear material normally is easily accessible for re-verification. The safeguards approach therefore normally comprises counting, identification and NDA (passive techniques and Cerenkov Viewing Device, CVD) of the items in the wet store in order to check consistency with the pond loading plan.

In addition, C/S systems might be applied, such as seals or continuous surveillance of the wet store in order to keep the continuity of knowledge.

If spent fuel assemblies are being loaded into transport casks for transport to and further storage in a long term dry store, they are verified by the inspectorates before loading for gross and partial defects. At present, this verification is performed normally under wet conditions with passive techniques.

After loading, the casks are sealed with one or two seals to maintain the continuity of knowledge on the cask contents.

4.3. Technical safeguards requirements

The main technical needs are underwater measurement devices for the non-destructive analysis of spent fuel assemblies. The equipment has to be reliable and robust, easy to use and should provide sufficient measurement

accuracy to detect gross and partial defects within a reasonable measurement time and minimum interference of the verification activities with operations and without jeopardising the safety of the installation.

The system should be easy to handle and should allow the quantitative characterisation of spent MTR and LWR fuel under wet conditions, if possible without the need to move the fuel in the storage pond.

There is also a need for small and easy to use detectors to replace CVD, for the characterization of the spent fuel with long cooling time and/or low burnup.

5. Dry Storage of Spent Nuclear Fuel

5.1. Overview

Apart from wet storage also dry storage technology is being considered by several countries for the longer term.

There are two main routes in EU for the dry storage of spent fuel:

a) storage in vaults with prior unloading of assemblies from the transport casks (and possibly repackaging into storage canisters).
b) shielded metal casks. Normally, the same casks are used for transport and storage such that no re-loading becomes necessary (dual-purpose casks).

There are outside the EU other solutions of dry storage for spent fuel like concrete dual purpose casks (Canada and USA) or concrete horizontal modules (USA), but they will not be discussed in this document.

5.2. Vault storage

5.2.1. Installation types, techniques

A vault is an above ground reinforced concrete building containing arrays of storage cavities suitable for containment of one or more fuel elements.

The fuel is stored in metal tubes in a shielded vault through which air passes by natural convection.

The installations might comprise hot cells for rebatching operations.

Typical examples of vault storage facilities are the CASCAD in France and the HABOG facility in the Netherlands.

5.2.2. Safeguards concept

In vault storage plants the material normally is not, or not easily, accessible and therefore cannot be verified by visual checks and measurements. Therefore, the nuclear material has been verified before loading of the transport cask for gross and partial defects and is afterwards put under a multiple C/S system to keep the continuity of knowledge (see point 3.2 above). However, the inspectorates maintain the possibility to perform a verification upon reloading in the storage facility in case the Continuity of Knowledge was lost or in case the material was not sufficiently verified before.

The applied C/S systems normally consist of the following elements:

- optical surveillance to follow all operations from receipt of the shielded transport casks up to the loading of the assemblies or canisters into the vaults;
- monitoring and logging of neutron emissions on the transport route to detect movements of filled casks and canisters and to distinguish between full and empty casks;
- two different types of seals (e.g. metal plus optical seal) on the lid of the storage vaults during the dynamic phase of operations;
- two different types of seals on doors leading to the vault area during the static phase.

5.2.3. Technical safeguards requirements

During handling of the nuclear material, optical surveillance forms the main element of the safeguards concept. Therefore, there is a need for:

- Optical surveillance systems allowing for:
  - front end triggering;
  - short review times;
  - automatic documenting and archiving of images;
  - incorporation into integrated systems;
  - encryption of data;
  - image authentication;
  - data reduction;
  - high reliability;
  - high performance;
  - cost efficiency;

  by using as far as necessary customized components and as much as possible commercial off-the-shelf components.
- Transmission of state of health signals (light situation, recorder status etc.). If complete video scenes could be transmitted to headquarters this would allow early reaction on the part of the inspectorates avoiding the need for re-verifications.
- In addition, the inspectorates are interested in applying reliable sealing systems allowing quick and easy placement and verification. Normally, there is no problem regarding the dose uptake such that there is no need for remote interrogation of the seals. However, to increase the efficiency and effectiveness of the safeguards system, remote interrogation of the seals from headquarters could be an interesting option.
- For installations with hot cells the inspectorates are also interested in applying NDA systems which allow measurements on the fuel assemblies under dry conditions and which can be used to re-establish the Continuity of Knowledge. The NDA systems should be as less intrusive and as compact as possible.

5.3. Storage in casks

5.3.1. Installation types, techniques

Storage casks are passive devices requiring no active systems to ensure proper cooling of the contained spent fuel and only limited surveillance and maintenance by facility personnel. The spent fuel, after few years of cooling time, is loaded into the cask at the pool of the power plant. The number of fuel elements loaded per cask is ranging from a few units to more than 50 depending on the fuel type and the cask design. The cask is sent to the storage site without the need to reopen the cask throughout the storage period. A typical metal cask used for long term storage of spent fuel and also licensed as transport cask is the CASTOR cask used in the storage facility in Gorleben and Ahaus, Germany as well as the TN cask used at Doel in Belgium.

Storage facilities used for metal casks are normally made up by the following common features:

- the installation is made up by a handling corridor, a maintenance area and one or more storage halls;
- the spent fuel elements are stored in specifically designed storage casks (e.g. CASTOR or TN casks);
- the casks have to be prepared for dry storage (e.g. fitting of protective lid, connection to leak detecting system);
- movement of casks is done using cranes;
- normally, there are no hot cells allowing the removal of spent fuel assemblies from the transport cask.

Differences mainly result from:

- different frequency of operations;
- different radiation levels;
- storage of casks in one or more layers;
- storage of spent fuel casks only, or mixed storage together with waste and/or empty casks; sometimes, it is difficult to distinguish casks visually.

5.3.2. Safeguards concept

At present, there are no established methods for quantitative measurement of the contents of storage casks. Since the safeguards approach in dry storage installations builds on maintaining the continuity of knowledge through multiple C/S systems, the spent fuel arriving at the storage installation has been verified by the inspectorates before loading for

gross and partial defects and the continuity of knowledge has been maintained up to the receipt of the cask.

In some installations, the safeguards approach has to take account of an increased radiation level in the storage hall which excludes time consuming verification activities in this area.

The multiple C/S system might comprise the following elements:

- optical surveillance in the corridor, the maintenance area and, where appropriate, in the storage halls;
- monitoring/logging systems along transport routes and in the maintenance area to confirm the declared use of the casks;
- sealing of storage casks with diverse types of seals (e.g. combination of electronic and optical seals), if possible in groups;
- sealing of storage hall doors in the static phase.

5.3.3. Technical safeguards requirements

Due to the fact that, in case of C/S failures, a re-verification of the nuclear material in the storage casks is, at present, not feasible, the applied multiple C/S system must be very reliable and its components backed-up whenever regarded necessary. It is furthermore important that the dose uptake for inspectors and operators as well as the interference with operations be kept to a minimum. Thus, C/S techniques which allow verification without a need to approach the storage casks are the preferred route.

Optical surveillance systems

For optical surveillance systems, the requirements are identical to those provided already for vault storage installations, i.e.

- Allowing for:
  - short review times;
  - automatic documenting and archiving of images;
  - incorporation into integrated systems;
  - encryption of data;
  - image authentication;
  - data reduction;
  - front-end triggering;
  - high reliability;
  - high performance;
  - cost efficiency;

  by using as far as necessary customized components and as much as possible commercial off-the-shelf components.
- Transmission of state of health signals (light situation, recorder status etc.). If complete video scenes could be transmitted to headquarters this would allow early reaction on the part of the inspectorates avoiding the need for re-verifications.
- Camera systems independent from lighting.

Sealing Systems

In all cases where the multiple C/S system is made up by seals applied on the storage casks lids or their protective plates, it is important to find solutions which minimise the dose uptake during placing and verification. It is therefore of primary interest that advanced seals are used which satisfy the following requirements:

- easy and quick placement;
- easy and quick verification, if possible by remote interrogation;
- minimised maintenance requirements (no change of batteries, remote power supply);
- option to seal a large group of storage casks.

Other systems

In the storage hall and the maintenance area, surveillance systems could be applied to confirm the operator's declarations.

In the future, integrated safeguards systems based on multi-modal sensors (e.g. optical, electronic sealing, infrared, laser, radar, sound, etc.) and related data retrieval/review techniques (possible use inside storage halls to replace or supplement sealing systems) could be helpful in this regard. Such systems have to comply with EU regulations (e.g. electromagnetic compatibility).

Additional integrated measures could be monitoring systems mounted at the doors and inside the maintenance area.

The mixed storage of spent fuel casks and waste casks renders it difficult to distinguish the casks by visual checks or radiation patterns. It would be useful to identify unique radiation patterns, heat emission or other features which could allow the distinction via monitors.

Finally, small size electronic tags could be used which are attached to each storage cask and allow their remote identification during storage (e.g. using a reading device installed on the crane) or during transport, i.e. when passing doors.

Non destructive measurement techniques

As said before, it is not possible so far to re-establish the inventory by NDA measurements after a loss of the continuity of knowledge has occurred, i.e. after a failure of the installed multiple C/S system.

Quantitative measurements of the cask contents may be difficult and might not yield the accuracy needed. However, it should be investigated whether radiation "fingerprints" could be used to confirm that the cask contents have remained unchanged. It is of particular importance that also the diversion of fuel elements from inner basket positions could be detected.

In addition, it would be useful to identify a NDA technique for the distinction of spent fuel and waste casks, as outlined above.

6. Conditioning Plants

6.1. Installation types, techniques

Conditioning of spent fuel consists of all processes for packaging of fuel in a form suitable for disposal, in general it may involve:

- unloading of spent fuel elements;
- disassembly;
- rod consolidation;
- cutting of fuel rods;
- loading entire spent fuel elements or the consolidated fuel rods into the disposal cask;
- embedding of the fuel in a matrix material;
- sealing of the disposal cask and transport out of the facility.

There are several conditioning facilities in the planning stage and one, the Pilot Conditioning Plant at Gorleben, Germany, is under construction. At present only this facility under construction is designed to dismantle fuel assemblies and consolidate the entire fuel rods. For the other planned facilities the integrity of the spent fuel elements will be maintained during the conditioning process.

In the Pilot Conditioning Plant, LWR fuel assemblies will be unloaded from storage casks. Subsequently, the fuel will be disassembled and the pins transferred into particular bins which again are loaded into specific casks with welded lids ("Pollux" casks).

6.2. Safeguards concept

Conditioning facilities are throughput facilities which will be safeguarded effectively by a wide application of safeguards instruments in unattended mode. These safeguards measures comprise:

- multiple C/S systems to keep the continuity of knowledge on the nuclear material;
- seals on transport casks with the capability to be removed or attached by the operator;
- optical surveillance of the safeguards relevant handling operations;
- Monitoring Logging Systems (MLS) to verify movements and the loading status of casks;
- NDA systems to verify spent fuel assemblies and filled cans in case the continuity of knowledge was lost or the fuel was not sufficiently verified before;

- seals on exit routes from the disassembly/rebatching cell not used frequently by the operator;
- branching of operator's measurement systems as appropriate (e.g. monitoring off gas releases);
- weld seam sealing of disposal casks.

6.3. Technical safeguards requirements

Part of the safeguards measures to be applied to conditioning facilities are the same standard instruments and systems as for the storage facilities. These are optical surveillance, seals and monitoring logging systems for which the requirements are similar to those outlined in points 5.2.3 and 5.3.3.

Additionally, new plant specific instruments and systems are envisaged for safeguarding such type of facility. These measures may include the above mentioned NDA monitors in the hot cells, gas release monitoring of the hot cells and weld seam sealing of disposal casks. However, new equipments and methods must be tested; they could be applied for conditioning facilities once proved capable to meet the Safeguards objectives.

7. Direct Disposal of Spent Fuel in Geological Repositories

7.1. Installation types, techniques

When the once-through option has been chosen for the closure of the fuel cycle, it is foreseen that the spent fuel will be transferred to a deep (several hundred meters) geological repository. Geological repositories are also the destinations foreseen for the High Level Waste from reprocessing.

As different geological conditions exist around the world a series of different media are being considered (e.g. clay, salt, rock).

At present, there are no operational geologic repositories in the EU for the direct disposal of spent fuel. In Gorleben, Germany, the investigation of the suitability of a salt dome as a final repository is underway. In Sweden an underground laboratory is investigating the deep disposal in igneous rock. In Belgium, direct disposal in clay is being investigated.

The installation itself will be normally made up by the following main parts:

- receiving area including buffer stores;
- preparation area;
- shafts or ramps leading to the underground disposal area;
- tunnels and drifts for the emplacement of disposal canister or casks;
- borehole emplacement.

Concepts at present generally foresee backfilling of the tunnels and drifts with bentonite or salt, however, for various reasons there might be trend to keep the retrieval option open as long as possible or even to foresee adequate retrievability in the design of the repository.

In general, geological repositories will undergo three different phases:

- pre-operational phase (construction);
- operational phase (emplacement of disposal canisters or casks);
- post-closure phase (after complete backfilling of the repository).

In addition, it should be mentioned that the pre-operational phase is preceded by investigatory mining; i.e. a mine is constructed which, however, will not necessarily result in a geological repository for spent nuclear fuel.

7.2. Safeguards concept

It is quite obvious that it will still take quite a considerable time before the first repository will become operational. The emplacement itself will again take several decades before the repository is closed for an indefinite period, may be for ever. Thus, safeguards approach and required safeguards techniques will undergo a constant development, based on the technical progress and adopted new safeguards requirements. Due to these reasons, discussions on the safeguards concept are not yet finalised. There exist several initiatives to formulate recommendations and to work out detailed approaches along with the technical needs (ESARDA BFC Working Group, MSSP's, IAEA Consultants and Advisory Group meetings).

It is also evident that the final safeguards approach will have to be tailormade for each single repository, depending on the operational and especially the geologic conditions. Generally, the safeguards approach is based on the following assumptions:

- The retrieval of nuclear material during or after the operational phase cannot be ruled out completely.
- Safeguards do not terminate after the closure of the repository.
- Similar to long term dry stores, there is no possibility for a re-verification of the nuclear material once it is placed in the storage canisters or casks. Therefore, the spent fuel to be disposed of must have been sufficiently verified before it becomes inaccessible.

In addition, it has to be taken into account that:

- There has been already major work going on over years in the pre-operational phase (investigatory mining); therefore, the safeguards authorities should be informed already in this phase. Upon implementation of the new Model Protocol INFCIRC/540 there may arise a legal basis for providing specified information.
- The nuclear material in canisters or casks normally will not be accessible anymore for verification, such that the safeguards concept will have to be based on a multiple C/S system.
- Due to the harsh environmental conditions and safety reasons it may be difficult to apply C/S systems underground.
- The design might change continuously during pre-operational and operational phase.
- There will be indefinite storage of canisters or casks after emplacement unless there will be a decision for a retrieval.

Based on these assumptions, the following major elements of a safeguards concept have been identified.

Pre-operational phase

The pre-operational (or design and construction) phase starts with a decision to construct a geological repository for spent fuel. Although in this phase, there is no legal basis for inspection activities, the safeguards authorities might seek to get early information, e.g. on site selection and characterisation including exploratory excavations. The inspectorates might also seek access to the site at an early point in time to identify potential issues of safeguards relevance.

Operational Phase

In this phase, it will be of utmost importance to verify the nuclear material flow. The inspection goals for this activity will be:

- the timely detection of diversion of spent fuel from disposal casks before they enter the repository;
- the timely detection of undeclared removal of spent fuel from the repository.

To achieve this goal the following safeguards means might be used:

- In general, as spent fuel is not accessible anymore for direct re-verification, the application of appropriate design verification techniques and a multiple C/S system on each credible diversion path to maintain the continuity of knowledge on the nuclear material will be required.
- Video surveillance in the receipt facilities and at the shaft entrances.
- Seal/weld seam verification immediately before disposal canisters or casks enter the shaft(s) of the repository (if possible in unattended mode).
- Monitoring equipment at or near shaft entrances to:
  - detect the movement of radioactive materials;

- distinguish between empty, waste and spent fuel casks;
- identify the disposal canisters or casks;
- identify radiation "fingerprints", if applicable, as confirmation that cask contents are unchanged.

In addition, due to the steady change of the repository design (backfilling of drifts, opening of new ones), there will be a need for re-verification of the design on a continual basis. It will also be necessary to verify the absence of undeclared operations. Inspection activities therefore might aim to confirm the absence of:

- undeclared shafts/drifts/cavities;
- undeclared rebatching operations;
- undeclared reprocessing activities;
- undeclared drilling/mining activities.

The safeguards means to achieve these goals might consist of :

- visual checks;
- mobile equipment, if applicable;
- monitoring of site surroundings (aerial photography, satellite imagery);
- taking of environmental samples (HPTA);
- monitoring of the ventilation system.

Post Closure Phase

The inspection goal will be to confirm the integrity of the repository (detection of undeclared mining operations).

Depending on the geologic conditions of the whole repository and its environment, safeguards measures to achieve this goal might be:

- aerial photography;
- satellite images;
- seismic techniques, if applicable;
- other applicable techniques.

7.3. Technical safeguards requirements

Although safeguards for geological repositories could be implemented with available methods and techniques, further R & D is required to enhance efficiency and cost effectiveness at the time when the first repository becomes operational.

Regarding the definition of priorities, one might distinguish between near-term, medium-term and long-term needs. Any method has to assure that the operational and especially the long term safety of a repository will not be compromised.

Near-term needs

Near-term needs are mainly determined by the provision of information at an early stage.

In the pre-operational phase, equipment and methods might be:

- mobile equipment, if agreeable;
- aerial photography and/or satellite imaging for the monitoring of the site surroundings;
- in addition there may be a need for sufficiently developed techniques to perform baseline environmental sampling/HTPA in and around the repository.

Medium-term needs

The medium-term needs will be determined by the activities to be performed in the operational phase of a repository. Needs will mainly arise concerning the C/S system to be applied, i.e.

- Optical surveillance systems as outlined in this paper before (see point 5.2.3.).
- Seal/weld verification techniques which can work in unattended mode.
- Monitoring equipment running in unattended mode allowing to:
  - detect the movement of radioactive materials;
  - distinguish between empty, waste and spent fuel casks;
  - identify the disposal canisters or casks (e.g. electronic tags);
  - identify radiation "fingerprints" as confirmation that cask contents are still unchanged.
- Techniques supporting the design verification of the underground structure of the repository.

Long-term needs

Long-term needs will be those techniques required in the post-closure phase of the repository, which is still far from now. They will heavily depend on the technical developments taken place in the meantime, which are difficult to predict.

In general, techniques will be required which are able to confirm the integrity of the repository without posing an undue burden for the future use of the site. These techniques might be based on optical surveillance (aerial photography, satellite images), or other methods still to be identified and qualified, including seismic techniques.

Integration and Synergy - Keys to the Future

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World is changing a lot - in economics, politics, societies, informatics, techniques and in safeguards. Old structures can not guarantee success; revisions and replacements are needed and inevitable. In international safeguards the most important success-factor is the rate at which states sign and ratify the Additional Protocol. Second in the line is the *true* implementation of the Protocol. Implementation that brings *added value* to the Signatory. For success, timing and tempo are becoming more and more important.

1. Bright and Challenging Future for ESARDA

ESARDA is, to my mind, in a good position. By open thinking and dynamic activities ESARDA can tackle the important new direction. In addition to the classical and Additional Protocol safeguards, challenges and bright possibilities cover areas such as other verification regimes, new candidates states for joining the EU, non-EU European countries (such as Norway and its important activities in North-West Russia in European context) and challenges in NIS-states.

The key factor, to my mind, is how we, ESARDA, manage be part in designing and demonstrating true integration and implementation of the new safeguards. Preferably in a proactive way.

In European context, as well as globally, the true implementation of the Protocol is vital.

It must not introduce an additional layer of controls but by integration with classical safeguards be implemented in a manner which increases assurance in state-as-whole level with lower cost.

True integration is possible because by increased assurance that there is no undeclared nuclear activity in a state as a whole, the assurance of non-diversion of declared material becomes less critical. In other words, the classical safeguards can be relaxed.

For true integration it is important to recognize certain main elements in and differences between classical and new safeguards.

2. Mechanistic Safeguards should be relaxed

Classical safeguards concentrates on the non-diversion of the nuclear material that a State has declared. The rational was that it was considered too difficult to construct reprocessing, enrichment and other facilities needed for nuclear weapons in secrecy. And if in the very unlike event that a state manage to get these facilities, the activities would be revealed by detecting the diversion of nuclear material from the safeguarded facilities. To run a nuclear program entirely outside safeguards system was considered impossible.

Based on this, the classical safeguards system is designed and operated in a systematic and mechanistic way. Non-diversion of declared material emphasizes facility-oriented approaches.

This implied strict safeguards criteria, inspecting repeatedly same material in same locations, using routine-use-approved methods and equipment (C&S, NDA, DA).

3. Higher State-as-whole Assurances

As the Iraq case demonstrated, it was indeed possible to have a nuclear program, facilities and materials, entirely outside the safeguards system.

The bottom assumptions of the classical safeguards were reconsidered. An extensive political effort resulted in a framework, Additional Protocol, which opens us a new dimension for our safeguards work: to focus also to undeclared nuclear activities in a state-as-whole perspective.

And here some most important factors, to my mind, include the following. The IAEA shall not mechanistically or systematically seek to verify the new information it receives from the member States (Article 4 of the Protocol). In other words, here inspectors can not visit repeatedly same places for same purposes with same justification to carry out same activities.

Information review plays a key role and guides operations. Basic information is collected by “expanded declaration” (Article 2). In addition, important information can be received from open sources, satellite imagery, wide area environmental sampling etc.

Other crucial, but also qualitative-type, information include the State’s openness and transparency, competence and willingness to co-operate of the SSAC, other possibilities to use advanced technology (for example remote monitoring), etc.

The review results of these, with the assessment of the dependency of a State’s fuel cycle on foreign services and State’s scientific and technical capabilities to go nuclear weapons, guide further plans including complementary access.

Complementary access i.e. new inspections cannot, however, be carried out systematically or mechanically.

4. Integration & Synergy - the way ahead

Integration of old and new safeguards will result in increased affectivity and deceased costs. Dreams or true?

Possibilities exist, for example in use of advanced technologies (including wide area monitoring, satellite imagery, remote monitoring), improved co-operation between IAEA-State-facility levels with sharing resources (such as training).

It is important to remember the lessons learned from the ESARDA 1998 Helsinki meeting: there are many other verification regimes that have similar objectives as we have and where synergy gains can be reached. These regimes include Chemical Weapons Convention, Comprehensive Nuclear Test Ban Treaty and Nuclear Suppliers’ Group.

To my knowledge, these regimes do not have a forum like ESARDA.

Possibilities for true implementation are obviously state specific, but non-discriminative.

In States with simple and small fuel cycles (power reactor with fuel storage) countries depending heavily on other integration can be larger than in States having large domestically developed and maintained nuclear programs including reprocessing and/or enrichment capabilities.

Non-discriminatory, in broad context, means to my mind that the “law is the same for everyone”. That implies that rules and methodologies are not state dependent. But the “more criminals you have, the more police you need”.

Nuclear and safeguards will also make headlines in the future. Their sensitiveness will stay. Modern technologies are available also for others.

I would not be surprised if, for example, some interest group presented in media surprising environmental samples supported by satellite information from commercial companies.

And there, I would definitely not like to see us in the safeguards community to respond that we have not been able to come up with proper modern technological solutions to provide a state-of-the-art answers.

Today, concrete proposals for safeguards integration and synergy are few. Innovative thinking and new proposal for integrated safeguards are needed from ESARDA.

These are not limited to technical issues. Also at system studies are needed.

The needs and the customers for ESARDA are clearly increasing. The future is full of opportunities for ESARDA.

Avoiding Useless Quantification: Impressions from the 21st ESARDA Symposium

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The IAEA Safeguards Protocol INF/CIRC 540 /1/ has introduced new, "qualitative" elements into international safeguards. These new elements have been the subject of considerable discussion over the last several years, beginning with the "93+2" Program and continuing most recently at the 21st ESARDA Symposium in Seville, where an entire plenary session was devoted to the subject. During this session a statement was repeated which has been made in one form or another on several occasions before, namely that "useless quantification" of the new measures within the overall safeguards regime should be avoided /2/. At the same time the additional measures are generally seen by those concerned as a means to "improve safeguards effectiveness and efficiency".

For the systems analyst this is a rather absurd situation, as "improvement" or "optimization" without some sort of quantifiable objective are vacuous concepts. It is this lack of definition of terms that has contributed to the long, difficult and at times cross-purposeful discussions that have characterized the debate between member States and the IAEA on the subject of the new Protocol. To be sure, the situation is not improved with "useless" quantification, a good example being the introduction of equations involving "additive factors" /2/. However we would like to illustrate in the following short contribution how one can, by means of "useful" quantification, identify the problems associated with the new system and discuss them in a more meaningful way.

1. The Old System

The discussion is not new. In fact the problem of quantification lurks within the "old" safeguards system defined in INF/CIRC 153. We can illustrate this with the paradigmatic example of a storage facility consisting of N sealed items of nuclear material.

Suppose a sample of n items is checked by an inspector. Then his probability of detecting at least one falsified seal is given approximately by:

$$1 - \beta = \frac{n}{N}. \qquad (1)$$

Just how large should n be for "effective and efficient safeguarding" of the storage facility? *Technically,* one solves the problem by allowing the inspector to work for T hours. If the time needed to check one seal is t hours, he can check $n = T/t$ seals. His *effectiveness,* expressed as the probability of detecting illegal activity, is then a function of purely technical quantities:

$$1 - \beta = \frac{T}{Nt}. \qquad (2)$$

But is this *efficient?* Is the inspector wasting some of his time, or should he be investing more of it? The obvious - and only - answer is that the inspector should invest that amount of verification effort which *will deter* the facility operator, through the risk of timely detection, from illegally breaking a seal, no more and no less. And herein lies the dilemma. In order to treat the question of efficiency we are forced to introduce the subjective aspects associated with perceived risk, namely the utilities of the inspectee in the case of legal and illegal behavior.

We might just stop here and say, "No, we are not willing to do this". Instead, we could, together with the IAEA, take the standpoint that $1-\beta$ is an, exogenous variable to be determined bureaucratically. Typically some *ad hoc* value for $1-\beta$ such as 95% can be set down, which then determines the "required" effort T from (2) according to

$$T = 0.95 \times Nt. \qquad (3)$$

But in doing this we are begging all questions regarding efficiency, and any further discussion of the matter will be sterile.

Therefore, rather than throwing in the towel in this way, let's try to do some useful quantification and see where it leads us. We'll order the facility operator's preferences as follows:

$-b$ for detected illegal behavior,
0 for legal behavior,
$+d$ for undetected illegal behavior.

(The normalization to zero for legal behavior is convenient and thoroughly consistent with the meaning of utility.) The operator's *expected* utility, if he decides to behave illegally, is accordingly

$$-b\,(1 - \beta) + d\beta,$$

and he will be inclined to behave legally if he perceives this to be less than zero:

$$-b\,(1 - \beta) + d\beta < 0$$

or equivalently if

$$\frac{d}{b + d} \cdot \frac{1}{1 - \beta} < 1. \qquad (4)$$

Combining equations (2) and (4), the condition for an efficient inspection is

$$T > Nt \cdot \frac{1}{1 + b/d}. \qquad (5)$$

The larger the ratio b/d of perceived sanctions to perceived gain (in the case of illegal behavior), the smaller is the maximum amount of effort T that should be invested by the inspector to achieve his goal.

This way of looking at things has often been criticised on the grounds that it is impossible, or worse, impolitic, to estimate b/d. But all we have really done is to relate, via inequality (4), the thoroughly technical result (2) to the *reality of the situation* to which it is being applied. If for example the operator's incentive d to break a seal is *known* to be much smaller than the consequences b of detection, a good inspection plan would be to make T very small. Then just a single token seal check would be both efficient and effective. If on the other hand b/d is inaccessible or tabu, then at least we know *why* we cannot achieve efficient verification. In either case quantification has helped us.

2. The New System

In the additional safeguards measures defined under INF/CIRC 540, explicitly qualitative elements like the "motivations" of States are to be taken into account /2/. What can this be if not a recognition of the fact that different States may have different motivations? The sort of analysis just undertaken should therefore be all the more relevant.

Extending our previous paradigm to two "States" each possessing one storage facility, these motivations are

$-b_i$ for detected illegal behavior,
0 for legal behavior,
$+d_i$ for undetected illegal behavior,

for the ith State, i = 1,2. If the corresponding detection probabilities are denoted $1-\beta_i$, i = 1,2, then one can show under reasonable assumptions that both States are deterred from illegal behavior when the following condition is satisfied:

$$\frac{d_1}{b_1+d_1}\cdot\frac{1}{1-\beta_1}+\frac{d_2}{b_2+d_2}\cdot\frac{1}{1-\beta_2}<1. \quad (6)$$

This is just a generalization of (4). But now the required detection probabilities for *each* State are inextricably bound up with *both* States' utilities. The bureaucratic "solution" (3) is even more arbitrary and unjustified than before and the inclusion of subjective preferences seems unavoidable.

Thus a simple, self-consistent quantification reveals the often-heard statement that safeguards regimes must be completely non-discriminatory to be in logical contradiction to the equally often repeated requirement that the measures be made effective and efficient. Any discussion of effectiveness and efficiency of verification which does not explicitly address States' motivations, preferences, utilities, or whatever one cares to call them, is of little meaning.

Perhaps we shouldn't confuse "avoiding useless quantification" with avoiding thinking about the true nature of the problem.

3. References

/1/ Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INF/CIRC 540, IAEA, Vienna, 1997.

/2/ W. GMELIN, W. KLOECKNER, H. NACKAERTS AND J. PATTEN, ISS - Concepts based in Proliferation Risk, Invited Paper, 21st ESARDA Symposium, Seville, May 1999.

The Application of Multimedia Techniques in Safeguards

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1. Introduction

This paper reflects the discussions of the ESARDA Working Group on Containment and Surveillance regarding the application of multimedia techniques in safeguards. Conclusions are drawn on the usefulness of multimedia in the safeguards area and recommendations are provided regarding its possible application.

2. What is Multimedia?

For discussion purposes, multimedia was defined as any combination of different single media, such as, voice, sound, text, graphics, photographs, film or video, animations, 3-D, etc. Many people are familiar with the use of multimedia from presentations, training courses or even tourist information centres which have taken advantage of multimedia to present information on the local tourist attractions. Multimedia can also be defined from the user's perspective in that the user can select which media best suits his needs for the assimilation of the information provided. Obviously, this aspect of multimedia applies only where the user of the multimedia module has control over the choice of which media he would prefer.

The inclusion of 3-D as one of the media introduces the application of virtual reality as a multimedia tool.

3. Multimedia Techniques in Non-Safeguards Application

Because the use of multimedia techniques in safeguards is relatively new, the Group examined the application of multimedia techniques in other areas.

3.1. Public relations

An example of the use of multimedia in a public relations application was a CD ROM prepared by British Nuclear Fuel Limited (BNFL) for their reprocessing facility. The CD ROM uses a number of media, including voice, photographs, video, text, and graphics. The navigation tools were simple and easy to understand. They allowed the user to choose his own path in the module thereby facilitating the assimilation of the information in a way best suited to the user. The use of different media was found to reinforce the message. A significant advantage, over the use of videotape or film to provide the same information, is that the user can proceed at his own pace and the interactivity provides enhances the absorption of the information.

Included in the public relations category is the use of multimedia in tourist information centres or kiosks. With respect to tourist information centres it is important that the navigation tools are intuitive or self-explanatory. The users must also have the ability to make their own selections of where to proceed next. Appropriate choice of media is important to attract the user's attention, to maintain interest in the subject and to facilitate the assimilation of the information.

3.2. Construction of computer 3-D models from Computer Aided Design (CAD)

The design of modern facilities is often done using CAD. The digitized CAD data can be used to construct computer models of the facility. These models can then be used to verify that there are no conflicts between different design groups. For example, the model can confirm that the proposed piping routing does not conflict with civil structures, such as support beams. The models can also be used to confirm that the layout of plant facilitates the movement of personnel or material. Such models are often used to perform "walk-throughs" or "fly-throughs" whereby one is able to obtain a feeling of being inside the actual facility and walk through it from room to room. This is very helpful to optimize the layout of the facility even before construction begins.

The existence of these types of computer models would be useful for determining the location of safeguards equipment for installation in the facility. For example, the location of radiation detectors to monitor the movements of nuclear material could be selected with the aid of the model as well as the cable routing from detectors to the data collection hardware. The selection of positions for surveillance cameras could be chosen using the model. The angle of view and appropriate lens for the camera could be determined. In addition, one could ensure that there are no obstructions that would limit the field of view of the chosen location.

3.3. Development of computer models as input to detailed CAD drawing

This approach is the inverse of section 3.2. The visualisation provided by the computer model is a great facilitator of communication between the various design engineers and operations groups. Benefits include the assessment of multiple viewing angles, the review of the whole rather than individual parts of the design far earlier than traditional methods would allow and at less cost than building full-scale mock-ups. The three-dimensional real-time models enable project teams to assess design decisions by "flying" around the virtual environment, either freely or as a human model. These virtual reality models can have the look and feel of real facilities through the use of colours, textures, panel screen designs, etc. Because the model is computer-generated it is relatively easy to institute design changes and examine their effect on the overall design.

An example of this approach was provided in the application of virtual reality (VR) in the design of the central control room for the BNFL Sellafield MOX Plant. The VR model was demonstrated to the Working Group using a Pentium laptop computer. The experience of BNFL was that the design process was significantly enhanced by the use of VR. Without it, the development of the central control room design would have been relatively cumbersome, involving more design iterations, and consuming more of the project teams time. It gave a wide range of people a common visualisation and understanding of the central control room design and future operation. The ability to have instant visualisation of proposed changes facilitated rapid decision-making which improved the design process.

The development of the computer model provided additional benefits since it could be used to demonstrate design to customers, inspectors and the general public and plant operators also used the model as part of their training program for staff before and after the completion of the facility.

3.4. Training

Development of computer-based training modules using CD-ROMs, intranets/internets or dedicated computers has been gaining popularity in recent years. Such modules are employed to cover a range of applications such as: how to use certain software packages, how to operate equipment, how to perform certain manufacturing processes, etc. There are a number of advantages to producing such training modules that are elaborated in section 4, with respect to the development of computer-based training modules for safeguards purposes.

3.5. Virtual Reality (VR)

There are number of definitions for VR which range from the "traditional" CAD 3-D interactive modules, discussed in sections 3.1 and 3.2, to 3-D models which provide interactivity in real-time. Using the latter definition one normally uses head mounted displays which provide some tracking. Tracking technology can be implemented using electromagnetic, ultrasound, mechanical or optical techniques. Interaction with the system is through devices such as 3-D mice, joysticks, space balls, force feedback devices or data gloves. The latter work well when studying human kinetics and ergonomics.

VR is good at:

- Human-human communication. 3-D is a natural, intuitive and universal language. There are no ambiguities; everybody sees the same 3-D model.
- Understanding of tri-dimensional data and processes. Moving in space interactively helps to build 3-D mental maps faster. One can also learn through experimentation with the model without the fear of breaking or damaging anything.
- Human-machine communication. VR can facilitate the computer not-so-literate to use it. It facilitates the management of large arrays of data and the visualisation of the data. It is important that the user interface is well done, which is not always easy.

The following pitfalls or bottlenecks were identified regarding the application VR to different projects:

- It is easy to be seduced by false good ideas. That is, one must be certain that VR is the right tool to solve the problem.
- It is very simple to get things to half work but exponentially difficult to get them to work well.
- Getting the models right can be difficult. With respect to CAD conversion there is often too much detail which can require a lot of computing power.
- For full interactivity, wires, cables, calibration, electromagnetic perturbations on trackers and settling issues on something supposed to be a user-friendly interface can be problematic.

In the field of VR it was recognized that there is often more hype than real applications. For example the press, technical papers and commercial brochures can report prototypes pretending to be everyday applications. However the number of VR CAD visualisation programs available off-the-shelf is increasing. The next phase for off-the-shelf software will include 3-D direct manipulation.

Projections for the future indicate that there will be generalized low-cost real-time 3-D platforms, more use of large flat screen displays, maturing technologies and techniques, less expensive force feedback devices and better and cheaper tracking devices.

Several examples of the use of VR by industry were demonstrated and discussed:

- Airbus Industrie developed a very complex and realistic model for use as a communication and marketing tool by providing a walk-through of the future double decker aircraft.
- Aerospacial developed a tracking tool for aircraft system architects providing an intuitive user interface aimed at CAD illiterates to be used for concept development. The model is displayed on a computer screen and uses medium range computing power (Indigo2 computer from SGI).
- Bechtel uses VR models derived from CAD to facilitate project reviews, both internally and with customers. The VR models are used to determine design scale and to resolve human interaction issues.
- TRW has developed VR models from photogrammetric data, taken by humans or telerobots, for planning of nuclear facility decontamination for the U.S. Department of Energy. These models employ walk-throughs and have proven useful for planning the size and type of each tool to be used in the decontamination.

4. Application of Multimedia Techniques in Safeguards

The first application of multimedia techniques in safeguards was in the development of computer-based training modules for inspectors on how to operate equipment or how facilities were operated. Development work has also been undertaken on the application of VR for inspector training and DIV.

4.1. Inspector training

Multimedia computer-based training has been proven to have many advantages over the standard classroom setting for training:

1. The training is not dependent on the particular ability of the instructor nor on instructors availability (training is available on demand).
2. The users can proceed at their own pace.
3. The interactive nature of such modules involves more human senses, maintains interest and facilitates better understanding of the material.
4. In addition to higher comprehension levels, retention periods are longer.
5. The training time is considerably shorter than classroom-based training.
6. It is simple to track progress and to provide feedback to the user or to developers of the module for future improvements.
7. If the modules are structured appropriately, changes and additions are simple to incorporate.
8. It is easy to add additional languages for text or narration if the module is structured appropriately.

Demonstrations of computer-based training modules under development were provided to the Group. One, being developed by JRC Ispra, was for gamma and neutron measurement equipment. Another, being developed in Canada, was for radiation monitoring equipment. Both developments emphasized the need to have a multidisciplinary team in order to produce a good product.

A key member is the instructional designer who has a pedagogical background and a knowledge of the applicability of the various media to convey the information. His role is to produce the instructional design or program map for the training module. This is produced by consulting subject matter experts who can include instrument developers and inspectors. The module is then created by a team of media specialists including script writers, interface designers, graphic artists, animators, programmers, etc.

The JRC CBT module demonstrated a user-friendly intuitive navigation system for moving around the module and the use of multilingual text and narration. Tests were designed into the system to measure the comprehension and understanding of the subject matter by the user. The tests provide feedback to the user immediately when wrong answers were provided. This was particularly well demonstrated in a simulation for the

connection of cables to the electronics module. At present there was no implementation of a tracking system to record results because of negative feedback from Euratom Safeguards Directorate, the end-user.

Information from the IAEA indicated that they would track user scores to verify results of performance-based training. Performance will be measured to determine the success of the instruction. Performance checks will be tied to the course objectives. A record of training performance will be maintained and trainees will receive immediate feedback to indicate success or failure as they progress through each section of the module.

4.2. Cost considerations

There are a number of considerations that must be weighed in undertaking the development of interactive multimedia computer-based training modules, such as:

What are the alternative methods to give the training?

What is the availability of trainees to take a traditional course at a fixed time? This will involve considerations of workload, amount of duty travel, etc.

How often will the course be given? Traditional courses require expenditure of resources for giving the course each time, while most of the effort for CBT is expended in producing the module.

How often would refresher training be required?

How much material already exists that can be incorporated into the module, for example photographs, illustrations, text, videos, etc.

How critical is it that the trainee be able to perform the tasks for which is being trained?

In deciding on an approach to develop a training program to meet specific objectives all of these items must be considered. It should be remembered, however, that interactive, self-paced multimedia, computer-based training modules have been demonstrated to provide increased understanding of the subject matter, faster absorption of the material and longer retention periods. It is not possible to give a rule of thumb for production costs of CBT modules. Depending on the objectives of the training, and the amount of material to be absorbed by the trainee, the cost can vary from tens of thousands of dollars up to a few hundred thousand dollars. Each case must be examined on its own merits when deciding to use more traditional approaches or to develop a CBT module.

4.3. Virtualised reality

The concept of virtualised reality arises from the construction of 3-D models to represent physical reality. The modules are constructed based on distance measurements, for example using laser rangefinders. Distance information lets the system “know” about spatial relationships. The 3-D models provide a good “feeling of being there”. The 3-D models can then be used similarly to the VR models described previously to provide safeguards training for inspectors where spatial relationships are important, such as to provide a good understanding of a complex facility prior to inspections.

Another application is in design information verification to indicate the differences between the design of a plant and the “as built” plant. In addition changes between subsequent inspections can be determined when the system is used to scan the relevant regions of the plant at subsequent visits.

Development work using virtualised reality is currently being undertaken at JRC, Ispra. The development of 3-D virtualised reality models to represent actual physical constructions has shown promise. The next steps will be to demonstrate practical implementation and cost-effective application.

5. Conclusions and recommendations

After examining the use of multimedia techniques in safeguards and more general applications, the Working Group suggested that multimedia techniques had promise in the following areas:

- The use of 3-D models would facilitate the introduction of safeguards equipment into the facility design even before construction of facility begins. This would be most easily accomplished where the facility designer developed a 3-D module for his own use.
- Multimedia computer-based training modules are particularly suited to goal oriented instruction of safeguards equipment in order to maximize trainee learning and increase the retention period. The module should employ some mechanism to report scores to verify results of the performance-based training, both to provide feedback to the inspectors and developers who could then improve the module.
- The application of Virtualised reality in safeguards, particularly with respect to design information verification, has promise. More effort is required to demonstrate its use as a practical safeguards tool.
- Pre-inspection for complex plants.

6. References

/1/ J. REED, C. TUNLEY, “Application of Advanced Visualisation and Simulation Techniques in Control Room Design and Operator Training”, 1997 IEEE 6th Conference on Human Factors and Nuclear Plants, Orlando, USA, June 1997.

/2/ VR in Industrial Training, VR News, Volume 5, Issue 4.

/3/ VR in Education, VR News, Volume 5, Issue 6.

/4/ J.G.M. GONÇALVES, V. SEQUEIRA, F. SOREL, “Application of Virtualised Reality to Safeguards”, IAEA Symposium on International Safeguards, October 1997.

Activities of the Working Group for Destructive Analysis

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The ESARDA working group on standards and techniques for destructive analysis (WGDA) has been active in the area of analytical methods, quality control and reference materials for many years. The scope of work was defined in the group's terms of reference. Whenever needed these were adapted to the changing needs of the safeguards community. Throughout the years a definition of "destructive analysis" had never been formulated. In analogy to and complementary to the definition of "Non destructive analysis" as given in /1/, the following definition was formulated /2/:

Destructive Analysis involves a measurement technique which is operated in a way that the sample being measured is not returned to the batch it was taken from.

Hence, a destructive analytical technique introduces a significant change to the item which is subjected to a measurement. Historically mainly chemical methods of analysis like titration, coulometry, gravimetry or mass spectrometry were considered as being "destructive". However, active and passive radiometric measurement techniques have also been considered by the working group. Another area that has gained growing interest within the working group is the analysis of nuclear signatures, also known as high performance trace analysis (HPTA) or environmental sampling (ES).

1. Current Activities of the Working Group

The recent activities of the working group reflect the evolving needs of the safeguards community and the changing boundary conditions in nuclear material analysis. Increased efficiency, waste minimization, quality control and quality assurance, analytical performance and cost effectiveness are the key words that determine the agenda items and influence the discussions.

A compendium of destructive analytical techniques has been established. This document provides an overview of the measurement techniques currently applied for the analysis of nuclear material for accountancy or safeguards purposes, the associated uncertainties and the reference materials being used are quoted as well. The compendium will be published in the ESARDA Bulletin.

A compilation of nuclear reference materials is being established. Materials from several suppliers at different levels of certification and for various purposes have been included. This compilation shall help analytical laboratories to identify the most suitable material and the respective source.

The two external quality control programmes EQRAIN and REIMEP are supported by the group. The results are regularly discussed and participation is strongly encouraged. The uncertainty of the final measurement result comprises also a contribution which is due to sampling. These sampling errors may consist the most important part in the uncertainty budget. Sampling errors in MOX and input solution were discussed, an exercise on MOX pellets was organized. It was recognized that the problem does not arise from the actual measurement, but the sample taking is an integral part of the analytical procedure. Plant specific issues (sampling device, sampling procedure, homogeneity etc.) make it quite difficult to draw unambiguous and generally valid conclusions. The issue certainly deserves further attention and additional investigations.

The concept of "Target Values" for measurement uncertainty components had been conceived and promoted by the working group. These Target Values have evolved over the years /5/, the concept was adopted by the IAEA resulting in the "1993 International Target Values" /6/. The Target Values have proven to be a useful tool in assessing uncertainties achieved in nuclear material measurements. In a coordinated action between the DA and NDA working groups and the safeguards authorities of Euratom and IAEA these values are being critically reviewed. At the dawn of the new century new Target Values are being established.

The activities of the working group have been extended to cover also new areas like the analysis of nuclear signatures. The results of field trials and conclusions thereof were discussed. The working group acts as a forum for the exchange of experience and views on a scientific/technical level. Unnecessary duplication in research can be avoided and cooperations are encouraged.

2. Topical Meetings

Meetings on specific topics are organized by the working group whenever the need arises. Upon initiative of the ESARDA WGDA a workshop on measurement techniques applied for the identification of nuclear signatures was held at IRMM Geel /3/. The needs of the safeguards authorities were illuminated and the implications for analytical laboratories were discussed in a first instance. Furthermore, the different approaches were highlighted ranging from in-plant sampling to wide area monitoring. The analytical methodologies that are currently applied in this area cover radiometric techniques like low level alpha or gamma spectrometry, liquid scintillation counting, gas measurements also including stable isotopes (e.g. Xenon) and mass spectrometric techniques comprising ICP-MS (Inductively Coupled Plasma Mass Spectrometry), TIMS (Thermal Ionization Mass Spectrometry) and SIMS (Secondary Ion Mass Spectrometry). The lack of suitable reference materials and the need for (more) highly specialized laboratories with skilled analysts were underlined.

A joint DA/NDA sub-working group discussed the rather specific subject of using X-ray fluorescence for analyzing solid MOX pellets. This analytical approach is taken in some laboratories in order to reduce the amount of waste and to provide results in shorter delays. As the discussions showed, this method has a high potential although further investigations are required. Since the analysis is limited to the surface of the pellet (i.e. fractions of a millimeter), the question whether this thin layer is representative of the whole pellet needs to be answered /4/.

3. References

/1/ IAEA Safeguards Glossary, IAEA/SG/INF/1 (rev.1), International Atomic Energy Agency, Vienna, 1987.

/2/ K. MAYER, "Destructive" Analytical Measurement Techniques in Nuclear Material Safeguards, Seminar on Modern Verification Regimes: Similarities, Synergies and Challenges, Helsinki, Finland 1998, Report EUR 18681 EN.

/3/ Workshop on the Status of Measurement Techniques for the Identification of Nuclear Signatures, 25 – 27 February 1997, Geel, Belgium, Report EUR 17312 EN.

/4/ Minutes of the meeting, November 1998, Sellafield (UK).

/5/ K. MAYER, P. DE BIÈVRE, Target Values for Measurement Uncertainty Components, ESARDA Conference, May 1996, Bath (UK).

/6/ S. DERON et al., 1993 International Target Values, ESARDA Bulletin 23 (1994) 15-27.

Preparing for the Future Today

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1. Introduction

At the July 1998 Annual Meeting of the Institute of Nuclear Materials Management (INMM), a closed session was held in the framework of a topical session on the role of analytical laboratories for safeguarding nuclear material. The closed session was intended for the discussion of subjects of common interest and common concern in an atmosphere that would encourage an opportunity to speak openly on sensitive matters. Experts from nuclear analytical laboratories from many countries participated in the discussion, many of them also being members of ESARDA working groups.

The focus of the discussion was directed towards strategic aspects rather than on specific technical problems.

2. Current Challenges

On both a national and an international basis, safeguarding nuclear material involves providing adequate assurance that these materials are present in the amounts stated in the nuclear material inventory. This is achieved by analytical measurements determining both elemental and isotopic content for accountancy or for verification purposes. Performing these measurements to the required degree of accuracy and at the necessary level of safety, requires skilled and well trained scientists. International Safeguards verify that "nuclear plant and materials are being used for peaceful purposes only" /1/. After the Gulf War, a highly visible application of this principle occurred within the International Atomic Energy Agency (IAEA) and is described in "Analytical Chemistry in the Aftermath of the Gulf War" /2/. The combination of requirements for accurate and precise measurements in accountancy and verification, the need for development and implementation of environmental measurement techniques for safeguards application and the combat of illicitly trafficking nuclear materi-

als, requires state of the art analytical capabilities.

The participants noted that in all countries nuclear programs have changed, leading to cuts in funding and reductions of staff. Accompanying this, non-destructive on-line measurement techniques and remote sensors are increasingly being applied. However, the participants unanimously felt that analytical laboratory expertise is required to fully understand the chemical and physical phenomena linked to measurements relevant to the nuclear fuel cycle.

3. Discussion of Concerns

With the decreasing number and size of nuclear programs, the specific sector of nuclear material analysis also suffers from a reduced number of job opportunities and a lack of professional prospects. The special problems associated with working in "hot laboratories" and the current rather low standing of radiochemistry appear as constraints preventing recruitment in the field. In addition, public distrust in nuclear operations has become more vocal in recent years: as a consequence, working in nuclear analytical laboratories is becoming considerably less attractive. Young scientists and technicians are becoming more and more reluctant to undergo training and accept jobs in the highly specialised area of radiochemistry or nuclear physics. At the same time, the experienced scientists and technicians who have been working in these fields from the early days are now about to retire. A new generation of scientists is needed to take over.

These observations immediately lead to consequences which will have considerable long-term implications.

The lack of well qualified young people in nuclear analytical laboratories will render the transfer of experience extremely difficult. It will therefore be increasingly challenging to maintain the level of expertise that has been built up over many years. Not only will the proper operation of the laboratories suffer, but qualified advice will not be available to be given to safeguards or regulatory authorities. This prospect contrasts with the present and future challenges arising from the increasing amounts of excess weapons material, the growing capacities of reprocessing, waste conditioning and storage, the illicit dumping of nuclear waste and illicit trafficking of nuclear materials.

4. Recommendations

Taking into account the significance of the material involved, the environmental and the safeguards concerns, participants noted the situation with alarm. It was perceived that immediate, active steps must be taken to conserve the knowledge and skills resident in specialised facilities. In particular, the training and development of younger staff members should be fostered.

To ensure that the presently shrinking technical culture of nuclear material handling and analysis remains viable in the future throughout the world, these experts from the nuclear analytical laboratories recommend the following measures to be implemented in the very near future:

- improved communication among workers in the field. This can be achieved, for instance, by provision of funds to allow training at accepted centre of excellence and staff interchanges. In many cases only minimal additional funding is needed to cover small expenses such as travel;
- provision of scholarships designed to attract new workers into the nuclear field;
- public recognition of the needs and joint statements of concern from governments and extra-governmental organisations.

The participants recognised that supra-national organisations (e.g. the IAEA) have a key role to play in the realisation of these proposals but call at the same time on national authorities to recognise the gravity of the problem and to undertake steps along the lines outlined here to ameliorate the situation before it is too late.

5. References

/1/ IAEA Safeguards: Aims, Limitations, Achievements, IAEA/SG/INF/4, International Atomic Energy Agency, Vienna, 1983.

/2/ D. DONOHUE, R. ZEISLER, Analytical Chemistry, Vol.65, No.7, April, 1993, (359A-368A).

RMTC - the Russian Methodological and Training Centre

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1. Introduction

The Russian Federation has recently decided to transform and reinforce its State System of Accountancy and Control SSAC of nuclear materials.

At the basis of the new system, consistent with the example of other national or regional systems, a laboratory framework giving reference and traceability to international standards, methodological support and training is being set up.

The European Commission, in the framework of the collaboration with the Russian Federation, has proposed and initiated projects oriented to supporting the above plans. This includes the establishment of laboratories and facilities designed for the development, calibration, evaluation of the performances and training, which are the basis for the implementation of an objective and sound nuclear material accountancy and control system.

This paper presents the establishment of the Russian Methodological and Training Centre (RMTC) at the Institute of Physics and Power Engineering (IPPE) of Obninsk, Kaluga Region, in the Russian Federation. The project is financed by the TACIS programme.

A detailed study of the features of the Russian fuel cycle as well as of the SSAC has beeen carried out preliminarily /1/, so that detailed specifications of the project could be designed.

The RMTC is mainly oriented to the training of Minatom plant operators and Gosatomnadzor inspectors in the proper use, calibration and implementation of mass and volume determination techniques, non-destructive assay methods, sealing-identification, surveillance and monitoring techniques and the application of statistical methods for measurement and material balance evaluation. It is planned to conduct physical inventory exercises for training in the application of inspection procedures. The training activities are designed in such a way that the results can be readily used in real plant conditions.

The RMTC is now operational: the activities performed at present are listed in the following sections. Such activities are carried on today by RF officers, mainly IPPE staff, by US staff under the DOE cooperative support programmes and by JRC staff under the TACIS support programmes.

Training courses are routinely held by IPPE staff (with the support of European Commission and US-DOE staff) at a pace of about 30 courses/year (in 1998, see fig. 1), with an attendance of approximately 750 attendees.

The collaboration between Russia, the US and the EU has resulted in a fully equipped and successful Training Centre that is playing a critical role in reforming the SSAC of nuclear materials in Russia. The RMTC fills a key position in this system, providing the execution of all entrusted functions, including the training of specialists, development of scientific and methodological methods and the provision of advanced technical assistance to enterprises and organisations all around Russia.

2. Role of RMTC

The RF decided, in March 1994, to create the State Methodological and Training Centre, with the objective of being in support to the implementation of the new concepts of nuclear material accountancy and control (NMAC) in Russia.

The European Union accepted to support the project, through Commission TACIS funding, and the implementation was delegated to the Joint Research Centre.

The tasks of the RMTC were identified as:
– training and technology transfer;
– method development and testing;
– calibration and testing of NDA procedures;
– traceability of field measurements to primary standards.

The main initial steps of the project were:
– analysis of the Russian nuclear fuel cycle;
– technical requirements of SSAC and NMAC methods;
– preparation of the content and methodological materials of the courses;

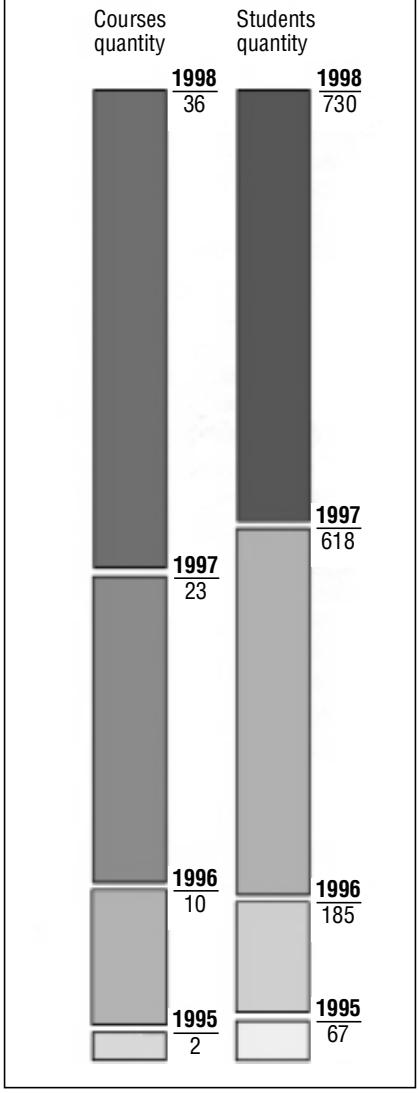

Figure 1: Dynamics of RMTC Courses

– definition of instruments and reference material standards necessary for training and calibration activities;
– training of RMTC trainers in JRC and EU member states;
– set-up of training and calibration laboratories;
– supply of NDA instruments, training modules in statistical accountancy, scale calibration models, computers and appropriate hardware and software.

The training "menu" was structured such to serve the maximum possible wide spread of staff, coming both from Minatom Institutes and facilities, as well as from GAN inspectorate: Table 1 gives the areas of RMTC training.

Table 1: RMTC Training.

1. training of specialists both in theoretical aspects of control and accounting of nuclear materials;
2. planning and carrying out of physical inventories;
3. non-destructive assay of mass and isotope composition of nuclear material;
4. control of mass and volume of Special Nuclear Materials (SNM) in solutions;
5. application of statistical methods and codes for accounting, evaluation and control of nuclear materials;
6. assistance to facilities in developing and in practical use of means and technical measures of accounting and control of nuclear materials;
7. control of solution mass and volume in process tanks;
8. densitometric analysis of nuclear materials samples by means of gamma- and X-ray radiation analysis;
9. arrangements of seminars and of meetings of nuclear facilities specialists, for exchange of experience.

3. RMTC Structures

The laboratories. To support the training and calibration activities, the European Commission has sponsored the realisation of six laboratories of the Training Center, which are being equipped with modern instruments and can provide methodological and technical support of training:

- *Computer accounting of nuclear materials.* The laboratory has two computer classes, modern computers and software.
- *Non-destructive methods and measures of control of nuclear materials.* The laboratory is equipped with different gamma-spectrometers for the determination of uranium and plutonium isotope composition; active and passive neutron coincidence counters for measurement of U-235 and plutonium mass in containers; a system for the assay of plutonium in waste drums; a system for non destructive assay of uranium in fuel pins and assemblies will be also installed.
- *Mass/Volume calibration facilities.* TAMSCA laboratory equipped with facilities (tanks, mass/volume sensors, computerised data analysis) for calibration of large tanks containing fissile materials in liquid form, as, eg, input accountancy tanks.
- *Calibration of balances.* The laboratory is equipped with electronic and mechanical balances, standard samples of mass, necessary hardware and software for the evaluation of systematic and random errors of balances.
- *Containment and Surveillance.* The laboratory will be equipped with surveillance systems and sealing identification tools, as well as with a demonstration station for ultrasonic sealing bolts.
- *Densitometry.* The densitometry laboratory will be provided with an hybrid (K-edge/XRF) densitometer

The education and training programme is made up of the following levels:

a. Introductory courses on the concepts of nuclear material accountancy and safeguards, the legislative framework, regulations for its implementation, practical obligations of the plant operators, role of nuclear material assay and containment and surveillance techniques.
b. Courses on basic principles of measurement techniques for the determination of the nuclear material content. These techniques include neutron detection measurements, gamma-spectrometry for the isotopic determinations of U and Pu, K-edge densitometry for U and Pu concentration, management of destructive analysis measurement results, weighing, mass and volume determination of liquids in tanks.
c. Courses on the basic principles of sealing-identification, surveillance and monitoring techniques to assure the continuity of knowledge of the nuclear material content in items and containers.
d. Statistical analysis of stratification and strata sampling, and evaluation of measurement data generated for material accountancy and for the estimation of the uncertainty on material balance data.
e. Plant-oriented courses, illustrating the material balance structure, key measurement points and the application of specific measurement techniques in the different parts of the plant, for the creation of accountancy data and for verification purposes and practical applications in physical inventory exercises for U and Pu bulk handling facilities, including the preparation of the necessary accountancy documents, the establishment of an inspector sampling plan, execution of verification measurements, evaluation of the data and comparison with operator-declared data and overall evaluation of the physical inventory verification.

The special nuclear material (SNM) standards. One of the main goals of the RMTC is to have available a number of plant-representative well-characterised U and Pu working standards to be used for the calibration of NDA instruments and techniques, which will be jointly applied by the operators and the Safeguards Authorities and for training.

It is planned to equip the RMTC with plutonium oxide standards of different burnups, HEU and LEU dioxide powder standards. mock-up fuel elements (VVER, RBMK, BN), powders, pellets and metals of different enrichments. Independent characterisation and certification of these reference materials by metrology offices and by several well qualified analytical laboratories will certify the uncertainty on estimated uranium and plutonium content and isotopic values, and will ensure full traceability to primary reference materials.

4. Training RMTC Trainers

An important role in the establishment of the RMTC is played by the training of Russian trainers in JRC laboratories and EU facilities. The first course for trainers was organised at the JRC, Ispra, in November 1995. Since then, several courses for RMTC Trainers have been given, both at RMTC and at the JRC Ispra.

The following is a list of courses for trainers, held by the JRC-Ispra:

1. Basics of nuclear materials control and accounting.
2. Methods of nuclear materials control.
3. Containment and Surveillance.
4. Methods and devices of non-destructive assay (NDA) of nuclear materials with gamma-spectrometry.
5. NDA Neutron-based methods and devices.
6. NDA Standards
7. Methods and measures of balance calibration.
8. Application of statistical methods for accounting and control of nuclear materials (basic).
9. Statistic methods for NMCA (advanced).

10. Application of statistical methods for determination and analysis of inventory difference.
11. Software for Nuclear Materials Balance Calculations
12. Software for Balance Calibration

5. Conclusions

The existing staff in the Russian nuclear facilities, whose jobs will be affected by the changes in the NMAC legislation, are at least 700 /1/. The number of jobs in Gosatomnadzor which will be affected by the changes is approximately 150 (mainly inspectors) and the expanded role for inspection under the new legislation means that at least 100 new inspectors will need to be engaged and trained over the next 3 to 5 years. It is estimated that the final number of staff to be instructed is at least 1000 people.

The RMTC has been designated by the Russian Federation Government to be one of the important tools in the process of training and education in the new concepts of NMAC. The RMTC has been designed taking into account the above figures: it is actually operational since few years.

The Centre has been recently inaugurated (November 1998), with a Ceremony which saw the participation of the Russian Minister of the Nuclear Energy, Mr E. Adamov, Mr G. Adam, member of the European Parliament and the Director General of the Joint Research Centre, Mr H. Allgeier (fig. 2, 3).

6. References

/1/M. Franklin, S. Guardini; “Russian Methodology and Training Centre: Final Report Phase 1”, EC Special Publication I.98.76 JRC Ispra, 1998

Figure 2: The Ceremony for Inaugurating the RMTC. From left: Mr. E. Adamov, Minister of Atomic Energy of the Russian Federation; Mr. V. Sudarenkov, Governor of the Kaluga Region of the Russian Federation; Mr. G. Adam, Member of the European Parliament; Mr. K. Shealey, Director of the Office of Control and Non-Proliferation of the US DoE.

Figure 3: Mr G. Adam, Member of the European Parliament, offering a Ceremony plate to the Minister of Nuclear Energy of the Russian Federation, Mr. E. Adamov. On the right, Mr. H.J. Allgeier, Director-General of the Joint Research Centre

News and Information

SKI is a new Party to ESARDA

In November 1999, the Swedish Statens Kärnkraftinspektion SKI (Nuclear Power Inspectorate) became a Party to the ESARDA Agreement.

The Nuclear Power Inspectorate is the competent Authority in Sweden, appointed by the Swedish Government, for all matters related to nuclear activities in Sweden. Apart from the regulatory, inspection and information activities, the SKI administrates an extensive research programme. Part of that programme is exclusively for research in the safeguards field. SKI is also responsible for the Swedish support Program to IAEA Safeguards, that has been active since 1987.

ESARDA warmly welcomes SKI among its Members. Mrs. Monika Eiborn will represent SKI in the ESARDA Steering Committee and in the Executive Committee. Mr. Göran Dahlin will be the ESARDA Scientific Co-ordinator for Sweden.

ESARDA Chair

In the year 2000 the ESARDA Chair will be taken by the European Commission. The Chairman of the association will be Mr. M. Cuypers, of the Joint Research Centre, Ispra, Italy. The Chairman of the Scientific Committee and Co-ordination Board wiil be Mr. S. Guardini, of the Joint Research Centre, Ispra, Italy.

Cooperation Agreement between the European Atomic Energy Community and ABACC

The European Atomic Energy Community and the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) have signed a Co-operation Agreement in March 1999, covering activities related to Nuclear Safeguards.

The European Atomic Energy Community is represented by the European Commission and the Agreement was signed by Mr. Herbert J. Allgeier, Director-General of the Joint Research Centre.

ABACC was represented by the Secretaries, Carlos Feu Alvim and Elias Palacios.

The objective of the Agreement is the co-operation between ABACC and the European Community on R&D topics and training in the field of safeguards of nuclear materials.

The areas covered by the Agreement are:

1. Training of Nuclear Safeguards Inspectors
2. Procurement and Characterisation of Nuclear Material Standards
3. Analytical Measurement (NDA, DA), Environmental Monitoring and International Intercomparison Exercises
4. Containment, Surveillance and Integrated Systems
5. Nuclear Material Accountancy.

In some of the above areas, the co-operation has already been started, giving preliminary but very promising results.

The 21st ESARDA Symposium on "Safeguards and Nuclear Material Management"

In 1999, the traditional ESARDA Symposium on "Safeguards and Nuclear Material Management" was organised in Sevilla, Spain, by the Joint Research Centre of the European Commission.

This Symposium marked the 30th anniversary of ESARDA - founded in 1969. It was the largest Symposium ever, both for the number of participants (230) and for the number of presentations (142). This is a tangible sign that the safeguards community needs, more than ever, to exchange information and experience, and that ESARDA is considered to be an appropriate forum for such an exchange. It has to be noted that the number of papers and participants coming from Eastern European Countries and from the CIS is on the increase.

Presentations covered the traditional spectrum of subjects, ranging from Safeguards Concepts to Safeguards Implementation Experience and to a number of technical and scientific issues.

The programme also included two special sessions on issues related to future developments of Safeguards. The first of these two sessions - "Other Verification Approaches" - speculated into possible synergies between nuclear safeguards and other verification regimes related to the reduction and control of weapons of mass destruction (CTBT, CWC, BWC, cut-off, etc.); it is worth recalling that ESARDA has already devoted a full Seminar to this subject ("Modern Verification Regimes: Similarities, Synergies and Challenges", Helsinki 12-14 May, 1998). The second session - "Consequences of INFCIRC/ /540 Implementation" - was related to the integration of the strengthened safeguards measures contained in the IAEA additional Protocol INFCIRC/540 with those of "traditional" safeguards, based on Protocol INFCIRC/153; here again, it is worth recalling that ESARDA will devote a full Seminar to this same subject in May 2000 (see announcement in this Bulletin).

Proceedings of the Symposium have already been published, and are available at the price of 50 EURO. Also the Proceedings of the Helsinki Seminar are available at the same price.

ESARDA on the Internet

From the beginning of the year 2000, ESARDA is present on the Internet with its own web site. At present, the web site contains detailed information on the objectives and the structure of the association, and announcements of coming events organised by ESARDA. The site will be progressively expanded to contain information on the ESARDA activities and their results.

The site can be accessed at the address: ***www.jrc.org/esarda***

Seminar on "Strengthening of Safeguards: Integrating the New and the Old"

Dresden, Germany, 9-11 May 2000

ESARDA will organise its 22nd Annual Meeting in Dresden, Germany, from 8 to 12 May 2000. This Meeting will include:

- activities of the ESARDA Working Groups - with participation restricted to the members and observers only - on Monday 8 and on Friday 12 May;
- a Seminar open to the public, on the subject of "Strengthening of Safeguards: Integrating the New and the Old"; it will last three days, from Tuesday 9 May to Thursday 11 May.

Objectives of the Seminar

Until the end of the 1980s, international safeguards was based on the verification of materials declared to the IAEA by Member States. The discovery of clandestine activities after the Gulf War, highlighted the need and raised the problem of how to deal with the possible existence of clandestine activities. In 1993 the IAEA initiated an examination of proposed measures intended to strengthen safeguards in this direction (known as "Programme 93+2"). This initiative culminated in the adoption in 1997 of the Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards (INFCIRC/540). This protocol has already been implemented in some Countries, and will be implemented in others, including those of the European Union, as soon as the necessary legal powers are in place to give legal effect to its requirements.

ESARDA has organised this seminar with the following objectives:

i) to inform operators and the safeguards community at large of the latest developments regarding the implementation of the measures of the Additional Protocol, as well as of the views of the Member States and of the Safeguards Authorities on the integration of these new measures with the classical nuclear material related activities;

ii) to provide to the Safeguards community a forum where the various parties can interact and exchange opinions on Safeguards Integration, so that they can prepare themselves to enter this new environment and also contribute to its development; and

iii) to co-ordinate initiatives and stimulate R&D for developing an effective and efficient modern Integrated Safeguards System.

The meeting will address the following topics:

- institutional aspects
- changes in safeguards approaches
- the rôle of information in new safeguards
- the rôle of satellites in new safeguards
- technologies for new safeguards (monitoring and measurements).

Presentations

The Seminar will comprise oral and poster sessions. The oral sessions will include more than 50 presentations, all of them invited by the Organising Committee. The poster sessions will run in parallel to the oral sessions.

Posters on matters related to the various aspects of Integration of Safeguards are desired. Authors wishing to present a poster are requested to submit an abstract in English of 500 words to the Selection Committee, by 31 March 2000, preferably by e-mail or fax, at the following address:

W.-D. Lauppe
Forschungszentrum Jülich, STE
D-52425 JÜLICH, Germany
Phone: +49-2461-614151
Fax: +49-2461-612496
e-mail: w.lauppe@fz-juelich.de

Attendance

Attendance to the Seminar will be limited to 150 participants only, based on the criterion "first come, first served"

Additional Information

Additional information can be obtained from the Scientific Secretaries of the Seminar:

W.-D. Lauppe (address above)
C. Foggi (address on the front cover).

3rd Joint ESARDA-INMM Workshop on "Science and Modern Technology for Safeguards"

Tokyo, Japan, 13-16 November, 2000

To promote the continued effectiveness of International Safeguards activities, ESARDA and the Institute of Nuclear Materials Management (INMM) have joined together to initiate a series of workshops on Science and Modern Technology for Safeguards. Thus far, two Workshops have been conducted: the first in Arona, Italy, in October 1996, and the second in Albuquerque, NM, USA, in September 1998 (proceedings are available for both workshops).

The 3rd Workshop of this series will be organised in Tokyo, from 13 to 16 November 2000. The co-organisers are:

ESARDA
INMM
The Japanese Chapter of INMM
The Korean Chapter of INMM.

These workshops bring experts in the physical sciences, in the social and political sciences and in the implementation of alternate inspection regimes together with safeguards experts, to examine the applicability of the fields of expertise represented by these experts to safeguards. More precisely, the purpose of the Workshops is:

1. to inform the safeguards community about research, experience and selected, advanced technologies that might become available in three to five years, and that could be used to support needed advances in International Safeguards; and
2. to stimulate application of research and advanced technologies to safeguards by providing an opportunity for technical interchange between experts in the various technologies and experts in safeguards.

The Workshop will take the format of four Working Groups dealing with:

1. Regional Systems and State Systems of Accounting and Control
2. Social and Political Aspects of Safeguards
3. Safeguards Challenges of Future Energy Technologies
4. Automation, Robotics and Expert Software.

More details about the programme will be available in May 2000. For more information, please contact the ESARDA Secretary, C. Foggi (address on the front cover).

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