# IAEA safeguards in the 1990s: Building from experience

## *A key element of the NPT, the IAEA's verification system will be enhanced to strengthen its efficiency and effectiveness*

**by Bruno Pellaud and Richard Hooper**

When Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) meet in New York beginning in April 1995 to decide the Treaty's future, one point of focus will be the IAEA's nuclear safeguards and verification system, the world's first on-site international inspectorate. Among its provisions, the Treaty requires each State Party to conclude a comprehensive safeguards agreement with the IAEA covering all nuclear material in all peaceful nuclear activities within the State.

Since the NPT came into force in 1970, the IAEA has been applying safeguards under "NPT-type" agreements in a growing number of countries. Today, most of the IAEA's safeguards agreements are of this type, making the outcome of the NPT Review and Extension Conference of major importance to the IAEA and the international community.

Throughout the 1990s, extensive efforts have been directed at reinforcing elements of the IAEA's safeguards system. During 1991-93, for example, the IAEA Board of Governors confirmed the right of the Agency to use special inspections; took decisions regarding the early provision and use of design information of facilities under construction or undergoing changes; and endorsed a reporting scheme on imports and exports of nuclear material and exports of specified equipment and non-nuclear material.

The case of Iraq underscored the importance of following up these initial steps. During 1992, the IAEA carried out technical studies of specific areas of safeguards application that might be improved, and to identify mechanisms and activities through which improvements could be achieved. In July 1993, the IAEA launched a programme — known as "Programme 93+2" — to develop a solid proposal for a strengthened and more cost-effective safeguards system. As intended, the proposal is being submitted to the IAEA Board of Governors in March 1995, in advance of the NPT Conference itself.

This article summarizes major elements of that proposal, while allowing for an overview and an assessment of possible trade-offs and synergies in what should be a comprehensive and integrated approach for strengthening safeguards and improving their cost-effectiveness. Implementation of the overall approach will, of necessity, be incremental over time.

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### Main areas of emphasis

Ideas and proposals in "Programme 93+2" are broad in scope and diverse in nature. They deal with both declared and undeclared nuclear activities. They include possible new measures for strengthening safeguards; further efficiencies in how current safeguards activities are carried out; and alternative procedures and techniques that may be more effective in carrying out safeguards or that maintain the effectiveness of safeguards but require less effort and lower cost.*

Three main areas of reform are tackled:

**Access to information.** Measures already taken in this area in recent years are early provision of design information on declared facilities; greater use of data on nuclear activities that are available publicly, in-house or otherwise; and the reporting scheme on export and import of nuclear material, non-nuclear material, and specified equipment.

The major new elements contemplated for this area are:

**Effectiveness* reflects the extent to which IAEA verifications achieve non-proliferation objectives. *Efficiency* reflects the productivity of IAEA safeguards, i.e. how well available resources (staff, equipment, money) are used to fulfil stated objectives.

- broader information on States' nuclear activities, resulting in greater nuclear transparency; and
- the use of environmental monitoring techniques.

**Access to sites and the effectiveness of the access.** Measures already taken are the IAEA Board's expressed positions regarding special inspections; and voluntary offers by some governments to accept Agency visits "any time, any place".

New developments may comprise proposals regarding:
- routine access at nuclear-related sites beyond "strategic points";
- expanded right to prompt access on short notice or no notice; and
- "managed access" to sensitive sites under a scheme of expanded access.

**Rationalization and administrative streamlining.** Measures already taken include the expanded regional use of the IAEA's two safeguards offices in Toronto and Tokyo; the partnership agreement with the Euratom Inspectorate; and the proposal for simplified designation procedures for inspectors.

Further measures might be:
- greater use of unattended, remote readout equipment in lieu of some inspections;
- additional regional safeguards offices to save travel costs and facilitate short notice/no notice safeguards;
- multiple-entry visas for inspectors;
- expanded capability for inspectors to freely communicate with headquarters;
- retraining of inspectors; and
- joint use of equipment and laboratories by the IAEA and State Systems of Accountancy for and Control (SSAC) of nuclear materials.

## Access to information

**Expanded declaration.** Currently, the State submits a declaration covering only nuclear materials, associated processes (to the extent that process-related information is needed to safeguard the nuclear material), and nuclear facilities containing or expected to contain declared nuclear material within a State's territory or under its jurisdiction or control. A broader declaration is considered in "Programme 93+2". This declaration, in combination with certain verification activities, would make a State's nuclear fuel cycle and associated activities more "transparent". "Transparency" would result from a high level of co-operation between the State and the IAEA.

A broader or expanded declaration of a State's nuclear activities should provide — in addition to information on *all* nuclear material — information on all other nuclear and nuclear-related activities of the State. This information would include a description and the location of all nuclear-related processes; production; research and development; and training. In addition, the industrial, commercial, and military installations in close proximity to nuclear installations would be identified in the expanded declaration. Within the scope of "Programme 93+2", a model expanded declaration is evolving in the course of field trials being hosted by a number of States.

**Information sources.** Effective verification depends on the availability of reliable information about nuclear activities in the countries being inspected. Information could come from IAEA databases and from open sources, e.g. media reports and scientific publications. Internal sources comprise safeguards inspection data; information received on imports and exports of nuclear material and exports of specified equipment and non-nuclear material; and the expanded declaration referred to above. Regarding open sources, the IAEA has established a computerized system for storage and retrieval of safeguards-relevant information. The system incorporates selected information from existing IAEA databases on power reactors, research reactors, and nuclear fuel cycle facilities. It also contains a broad spectrum of information on States' nuclear regulations, energy requirements, production and resources, nuclear and nuclear-related programmes, international co-operation, and companies, firms, and organizations working in the nuclear field. The system also considers public commercial information on nuclear material, technologies, facilities, and equipment, including dual-use items.

**Environmental monitoring.** Environmental monitoring techniques could crucially enhance the IAEA's ability to detect undeclared nuclear activities. Therefore, "Programme 93+2" devotes much attention to this promising avenue. Through field trials in 11 countries (among those having invited the IAEA for that purpose) during 1993-94, substantive progress has been made in:
- evaluating the practicality, effectiveness, and cost of the use of environmental monitoring under a range of representative conditions;
- establishing and documenting environmental signatures associated with a variety of nuclear activities (with an emphasis on uranium enrichment, reactor, and reprocessing operations) at both long and short range;
- establishing and documenting sample collection and analytical procedures and quality control requirements; and

- establishing a "clean room" sample handling and screening capability at the IAEA's Seibersdorf Laboratories*; extending the existing network of analytical laboratories to include the capabilities for the analysis of environmental samples; and establishing certification requirements for laboratories added to the network.

Any production or manufacturing process loses some small fraction of the process materials to the immediate environment. The extent of the losses depends on a wide variety of things including the nature of the process, the material, the control measures to limit losses, and the migration of losses beyond the immediate environment. The processing of nuclear materials is no exception, and even though losses are limited to a level well below that of health and environmental concerns, they inevitably occur. Still, nuclear materials have specific physical properties (e.g., radioactivity) that make it possible to detect and characterize extremely small quantities. This capability — together with the possibility that specific signatures can be unambiguously correlated with specific nuclear processes — is why environmental monitoring is seen as having promise with respect to the detection of undeclared activities. The goal of the environmental monitoring field trials is to demonstrate and, where possible, calibrate the utilization of these methods for safeguards application.

Typical sample media are swipe samples from inside and outside buildings, vegetation and soil samples, and hydrological samples (grab water, high-volume water, sediments, and biota). In field trials under "Programme 93+2", the emphasis was on short-range monitoring; that is, most samples were collected in the immediate vicinity of nuclear facilities. Currently planned field trials do not foresee the collection and evaluation of high-volume air samples or the sampling for gaseous effluents.

As part of the field trials, a sample distribution and reporting protocol has been developed to protect the identity of the samples. All samples distributed to the expanded network of laboratories are coded in a way that does not permit tracing of the original sampling point. The samples from the field trials carried out so far have been distributed to specialized laboratories in several IAEA Member States, including Australia, Canada, Finland, Hungary, the Russian Federation, United Kingdom, and United States. IAEA Member States hosting environmental monitoring field trials have been invited to participate in the analysis of parallel samples.

The results for some field trials have been reviewed with representatives of the respective Member States. Some findings can be reported here:

***Field trial in Sweden.*** In mid-September 1993, water, sediment, and biota samples were collected in Sweden's coastal waters in the vicinity of five nuclear facilities. A total of 30 locations were selected for sampling. The sampling locations were chosen to extend from the outfall of each facility to 20-30 kilometers in each direction along the coast. Results from the trial showed that the nuclear operations in this coastal area can be detected in water and sediment samples up to 20 kilometers from the facility depending on local transport and mixing conditions. Nuclear reactor operations could be detected by the presence of activation products. A minute quantity of plutonium ($\sim 10^{-15}$ grams/liter) isolated from a high-volume water sample taken near a research facility showed high burn-up isotopes consistent with spent fuel characterization studies being conducted there. Sediments from other locations showed only fallout plutonium and were clearly distinct from those collected in the vicinity of the facility.

***Field trial in South Africa.*** In early 1994, an extensive environmental sampling field trial was carried out at the Pelindaba site in South Africa. During this trial, soil, vegetation, and hydrological samples were collected in and near the facilities. Swipe samples were taken inside and outside the main process buildings of the shut-down prototype enrichment facility (which earlier produced highly enriched uranium), from the semi-commercial low enrichment facility, and from related process buildings. The various types of vegetation collected showed, at very low levels, evidence of uranium enrichment activities. The swipe samples gave clear signatures of the uranium enrichment processes and enrichment levels. In particular, the results obtained on small particles showed comparable distributions in uranium-235 enrichments in samples from the process area, auxiliary rooms, and outside the buildings.

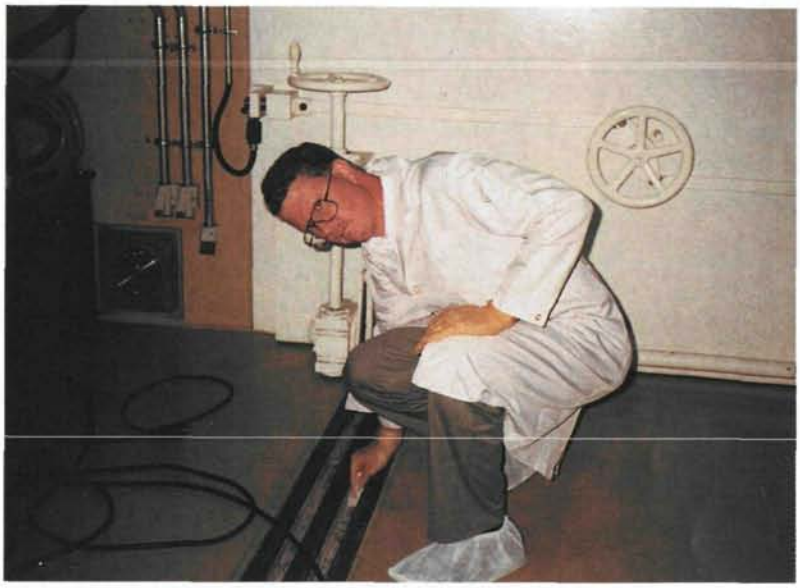
***Field trial in Australia.*** In April 1994, environmental samples were collected at the Australian Nuclear Science and Technology Organization's Lucas Heights Research Laboratories in Australia as part of a field trial. Swipes taken in laboratories related to the production of the radioisotope molybdenum-99 gave clear indications of the different target materials used and of the resulting irradiation products. Swipes from laboratories involved in metallurgical work showed uranium-235 signatures of the different

*See "Environmental monitoring and safeguards: Reinforcing analytical capabilities", by David Donohue, Stein Deron, and Erwin Kuhn in the *IAEA Bulletin*, Vol. 36, No. 3 (1994).

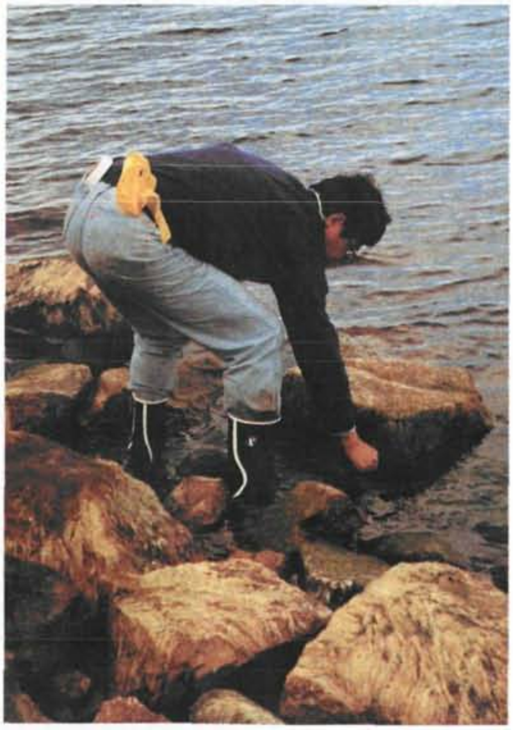
types of source materials processed. Swipes collected in a building that housed R&D installations for centrifuge enrichment dismantled 14 years ago clearly revealed the presence of such activities.

***Field trial in Argentina.*** Results are available for swipe and vegetation samples taken in May 1994 during a sampling field trial in and around the Pilcaniyeu enrichment plant in Argentina. During this field trial, the following samples were taken: soil and vegetation samples at nine locations; water, sediment, and biota samples from a river up- and downstream of the facility; and swipes in five locations inside process and general purpose buildings. Results from particle analyses on swipes, vegetation, and soil samples clearly showed the presence of depleted, natural, and low-enriched uranium consistent with the operation of the facility.

The findings based on these results are consistent with the activities declared by the States for these facilities. The results from environmental monitoring field trials show that these techniques constitute a powerful tool to confirm declared activities or to detect the presence of undeclared nuclear activities. It should be noted that the sampling methods have proven effective




**Scenes from field trials of environmental monitoring activities for safeguards purposes. Trials have been conducted in co-operation with a number of States, including Sweden, Argentina, Australia, and South Africa.** *(Credits: D. Beals; E. Kuhn, IAEA)*



in preventing cross-contamination of the samples. Furthermore, the analytical techniques available in the expanded network of laboratories have demonstrated their capability to carry out extremely low-level radiochemical and isotopic measurements. Data reported by laboratories from the analysis of splits from the same samples are consistent and the results from "bulk" or whole analyses of samples are also consistent with the particle results from the same samples. The consistency between the results from "bulk" sample analyses and the more detailed particle analyses is important. It indicates that "bulk" analyses can be effectively used to screen samples before committing to the more detailed and expensive particle level analysis.

**Proliferation critical path and associated rules.** As more information becomes available for systematic analysis, the IAEA should be in the position to find out at an early stage any instance in which the State's nuclear activities become inconsistent with the State's declaration. With expert assistance from several of its Member States, the IAEA is developing a proliferation critical path — which is designed to include all known pathways for the production of weapons-usable material and subsequent weaponization — to structure both the requirements for information and for analysis. The path can be represented graphically as a series of increasingly specific and detailed levels of all processes for the production of weapons-usable material and weaponization. The first and top level contains the main steps, e.g., enrichment, reprocessing, etc. Each block in this level is broken down into more specific routes or processes. For example, the enrichment block is broken down into nine possible processes (gas centrifuge, electromagnetic, aerodynamic, gaseous diffusion, molecular laser, atomic vapour laser, plasma separation, chemical exchange, and ion exchange), which form in this case the second level of the proliferation critical path model.

Each process is then characterized by indicators which would be associated with the existence or development of the process, such as specialized equipment, dual-use equipment, nuclear and non-nuclear materials, training, and environmental signatures. These indicators represent the third level of the proliferation critical path. As an example, some of the indicators related to gaseous diffusion enrichment would be diffusion barriers, gas blowers, uranium hexafluoride, chlorine trifluoride, fluorinated compounds and heat releases in the environment, and large power lines. The weaponization-related activities, which appear in the top level, comprise such processes as the production of tritium, enriched lithium and alpha-emitting radionuclides, and the procurement of high technology equipment such as X-ray flash photography.

With the help of experts, the proliferation critical path is being formulated as logically connected "if-then" rules. The primary purpose of this formulation is to recognize and place information (e.g., export data) in the appropriate place(s) of the critical path structure. The critical path takes into account the possibility that any of the pathways to weaponization might be shortened through external procurement (e.g., procurement of source material, uranium hexafluoride ($UF_6$), enriched uranium, etc.).

## Access to sites

Inspector access has been a key issue since the beginning of safeguards. For routine inspections under a comprehensive safeguards agreement, access is provided to specific points (called "strategic points") deemed necessary to enable the IAEA to meet its safeguards obligations related to material accountancy. Wider access is a key for a strengthened safeguards system. It would represent an improvement over the current practice with respect to increased assurance regarding the absence of undeclared nuclear activities.

Increased physical access is being assessed in the field trials to a number of different types of locations. Firstly, there is access beyond the "strategic points" in safeguarded facilities to any location on the facility site. Secondly, there is access to locations included in the expanded declaration which do not contain nuclear material, or contain only small amounts exempted from safeguards, but which contain or have contained nuclear-related activities. These first two types of locations include all nuclear and nuclear-related locations identified in the expanded declaration. Thirdly, as an important contribution to increased co-operation and transparency, the State would seek to facilitate access to other locations on the expanded declaration, i.e. industrial, commercial, or military installations in the immediate vicinity of nuclear installations. Finally, there is access to locations other than those identified in the expanded declaration; the request for access would be prompted by specific information or by the need to implement a technical measure, e.g. environmental monitoring.

A concept somewhat similar to that of "managed access" in the Chemical Weapons Convention is also being tested. This would allow IAEA access to sensitive locations while recognizing the State's right to protect sensitive information. Measures such as shrouding of equipment, dials, and electronic systems are included.

For effectiveness, this broader access being investigated in the field trials should to the extent possible be without prior notice to the State. "No notice" is taken to mean no advance notification regarding the timing, activities, or locations of an inspection. In practice this means that the State is informed of the IAEA's intention to perform such an inspection when its inspector arrives at the entrance to the site in question. A requirement for the effective implementation of such no-notice inspections is that States require no visas, or grant multiple-entry visas, for IAEA inspectors while on inspections.

An issue closely related to the "notice" is the time taken, from arrival at the site, to get to the specific location to be inspected. In most circumstances this time period is not critical. There are some circumstances, however, in which the IAEA may need to reach a location quickly in order to meet its objectives. In testing the procedures for these circumstances, a maximum time of two hours was used as a target in most trials.

## Rational use of resources

**Cost analysis of present safeguards.** "Programme 93+2" includes an assessment of the costs of implementing safeguards as a function of the magnitude of the technical safeguards parameters (timeliness, significant quantities or SQ, and probabilities of detection). The specific implementation costs associated with current values of these parameters and the cost sensitivity to changes in the values have been determined. A reasonable range in the value of each parameter has been defined for this cost assessment. In parallel to these studies, the technical cases are being considered for changes in these parameters, e.g., for changing the timeliness goal for metallic plutonium/highly enriched uranium and for changing the conversion time/timeliness goal for depleted, natural, and low-enriched uranium. The financial aspects, as well as the inherent technical merits, are being addressed.

**Potential cost savings.** The programme also deals with the identification and evaluation of a number of technical and administrative measures that have the potential to reduce costs associated with the current implementation of safeguards.

Major cost sectors associated with the implementation of safeguards, and thus the areas targeted for potential cost savings, are staff, equipment, and travel. As the number of facilities and the quantities of nuclear material under IAEA safeguards continue to increase, reduction in trained staff is not realistic. However, more efficient use of staff and travel resources may be achieved through use of modern technology, through economies in the way safeguards operations are carried out, by enlarging existing field offices or establishing new ones, and through efficient use of office automation equipment. Cost savings in the equipment sector may be achieved through greater standardization and by sharing with the operator the use and costs of equipment and analytical services. Two examples may be illustrative:

***Equipment in unattended mode.*** The use of advanced technology, assay, and monitoring equipment that can be operated in an unattended mode offers the possibility of reducing the physical presence of inspectors in facilities. As a result, reductions can be realized in terms of inspection effort; the radiation exposure of inspectors; and the level of intrusiveness of inspections in the daily routine of the operator. Examples of such cases include the use of bundle counters, core discharge monitors, video surveillance, a system known as Consulha (Containment and Surveillance for La Hague), and non-destructive measurements at mixed oxide (MOX) fuel fabrication facilities. Other cases where similar measures might be applied include the verification of inter-bay transfers of spent fuel in on-load reactors; verification of transfers of spent fuel to dry-storage canisters; verification of receipts, storage, and shipments of nuclear material at MOX fuel fabrication facilities; verification of feed to and production from enrichment plants; and tank monitoring and sampling at reprocessing plants.

***Mail-in of data.*** Safeguards criteria presently require periodic verification of inventories of safeguarded nuclear material. In the majority of cases, the nuclear material, e.g. spent fuel, is kept under containment and surveillance. Routine inspections for timeliness are made to service the surveillance equipment; replace/verify seals; or retrieve non-destructive data collected over a period of time. Transmission of the safeguards data through mail-in by the SSAC/operator, or by remote transmission, offers possible reduction in the number of interim inspections and, hence, savings in inspection effort.

In 1992-93, the IAEA, through established safeguards support programmes of Finland, Hungary, and Sweden, successfully conducted field tests for SSAC mailing of surveillance video tapes to the IAEA for review and evaluation. In principle, this measure could be applied in all situations where Agency cameras are installed. Alternatively, the data could be retrieved electronically through remote transmission. In both cases, new equipment is required to protect data during transmission. Remote transmission is the preferred means for transfer of data between facilities and the IAEA or its field offices wherever, *inter alia*, modern telephone communication systems exist. Where this is not the case, the mail-in method can be used on an interim basis.

**Increased co-operation with State Systems.** Co-operation between an SSAC and the IAEA is a necessary condition for achieving effective safeguards implementation. Traditionally, the SSAC's role in such co-operation has mostly been limited to the provision of information required under the safeguards agreement with regard to inventories of nuclear material and their changes, the securing of access to facilities and to nuclear material, and the establishment of an accountancy system at facility and State levels.

As previously noted, a high level of co-operation between the SSAC and the IAEA will be needed to facilitate the measures implied by increased access and transparency. This co-operation could also permit reductions in the costs for safeguarding declared nuclear material, even though the IAEA would need to maintain its own ability to draw independent conclusions. The experience gained in developing the New Partnership Approach with Euratom has been useful in this regard. *(See related article, beginning on page 25.)* A model pattern of increased co-operation has been derived by identifying all candidate activities which an SSAC could perform, either by itself or jointly with the IAEA, in order to increase the efficiency of IAEA verification activities, and hence to reduce the IAEA's costs or the extent of its activities. These candidate activities are largely, but not entirely, related to inspections.

Finally, the issue of regional systems for accounting and control is being addressed. This includes the examination of criteria that could characterize a regional system in the context of increased co-operation and from which the international community could derive non-proliferation assurance. On this basis, guidelines are being developed for assessing the degree to which any particular system possesses these features. The features being considered include the existence of a binding non-proliferation agreement between the States concerned; the technical effectiveness of the relevant system; the number of States in the system; the independence of the States within the system; the independence and transparency of the system; and the legal powers of the system.

**Cost savings in traditional safeguards activities.** If an increased assurance about the absence of undeclared activities were to be achieved through some strengthening measures, would it not be possible for elements of the present safeguards system (e.g. timeliness inspections for irradiated fuel) to be done differently, less often, or not at all? The cost savings and impact on effectiveness of such approaches indeed deserve serious consideration, since such savings could possibly absorb the cost of the strengthening measures.

Approaches are being designed to be equally applicable in all States with comprehensive safeguards agreements, in terms of generic facility types or broad categories of nuclear material. Approaches are being tested in various field trials at light water reactors, fuel fabrication plants, irradiated fuel storage facilities, and research reactors which address more cost-effective safeguards on declared material and assurance regarding undeclared activities. The activities and effort required to achieve the same level of assurance of the absence of undeclared nuclear activities may vary among States due to, for example, differences in their programmes.

## Implementing the next steps

The findings of investigations carried out under "Programme 93+2" are being reported to the IAEA Board of Governors in March 1995. The report will combine into an integrated whole the strengths of the present system and the enhancements brought by new techniques, new information gathering, and new administrative measures. It will further address the technical, legal, and financial implications.

In this context, it is important to keep in mind that the fundamental legal document of NPT verification [INFCIRC/153 (Corrected)] was drafted in such a way as to leave to the IAEA Inspectorate many of the details of safeguards implementation. To that extent, the drafters intentionally built into the related agreements a certain flexibility of interpretation. Accordingly, many measures thus far identified under the programme may be interpreted as falling within the IAEA's existing authority. Such should be the case, for example, with the implementation of short-range environmental monitoring in the vicinity of locations declared by the State as containing nuclear material and nuclear activities, as well as with most of the cost-reduction measures outlined here. ❒