Role of support programmes in safeguards

A review of R&D activities and future trends

by H. Kurihara

The successful implementation of IAEA safeguards consists of many elements. Safeguards are based on an agreement between the Agency and a State (in the case of NPT safeguards, based on INFCIRC/153), subsidiary arrangements, and facility attachments. Prior to the negotiation of facility attachments, the Agency develops a diversion path analysis and a safeguards approach relevant to the facility. This approach recognizes that the State must send to the Agency timely reports, such as ICRs (Inventory Change Reports) or MBRs (Material Balance Reports), and as a consequence the Agency has developed its own data processing system to handle these reports. Similarly, the Agency performs inspections at the facilities to verify the nuclear material therein and it must have inspection procedures relevant to each type of facility. The basic verification measure used by the Agency is nuclear material accountancy, with containment and surveillance as important complementary measures.

If nuclear material accountancy is to be effective, inspectors must make independent measurements so as to verify the figures presented in the accounts. Two basic types of techniques used are non-destructive analysis (NDA) and destructive analysis (DA). Containment and surveillance (C/S) techniques are applied in order to economize on safeguards inspection effort (e.g. by reducing the frequency of accountancy verification) and also to give assurance that nuclear material follows predetermined routes, that the integrity of its containment remains unimpaired, and that the material is accounted for at the correct measurement points. The Agency evaluates its safeguards activities and reports the results to the Board of Governors in annual Safeguards Implementation Reports (SIRs). Evaluation and quality assurance methods are essential to the preparation of these reports and are being developed for them. Thus the Agency's safeguards implementation activities require an ongoing developmental programme.

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Major parts of the necessary research and development (R&D) work have been done within the framework of Member State Safeguards Support Programmes rather than by the Agency itself. In this article, a brief history of the R&D activities of support programmes, the present situation, and future trends are described.

Early stages

Throughout the history of safeguards, the R&D work performed by the Agency itself has been very limited. Limitations on financial as well as human resources were imposed because Member States believe that the Agency is not intended to be a research establishment, but rather an implementation organization. Initially, the Agency relied for its R&D needs on the sporadic efforts of scientific institutions in Member States. Then, in the late 1960s a safeguards group was formed at the Los Alamos Laboratory, USA, which initiated R&D work on safeguards technology. Similarly, the Karlsruhe Research Institute of the FRG started a safeguards research project.

In 1970-71, the Safeguards Committee of the Board was formed and produced a document (INFCIRC/153) which is a model agreement between the Agency and a Member State under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). Throughout the discussion, the importance of spending more effort for safeguards R&D work was recognized. About this time, two associations related to safeguards work were established — the Institute of Nuclear Material Management (INMM) in the USA and the European Safeguards Research and Development Association (ESARDA) in Europe. The Agency also started its series of safeguards symposia.

The first Member State Safeguards Support Programme, that of the USA, began in 1976. Soon afterwards others followed: Canada (1977), Federal Republic of Germany (1978), UK, Australia (1980), Japan, European Atomic Energy Community (Euratom) (1981), USSR, Belgium (1982), France (1983), Italy (1985), and Sweden (1987).

The initiation of support programmes stemmed from the following two main reasons: (1) A decision by the Board that any development needs would best be met through Member State facilities rather than have the Agency develop its own in-house capability; and (2) the recognition by the Agency that certain safeguards deficiencies and needs could only be met by the development of new equipment and techniques.

The activities of support programmes have covered not only the development of NDA, DA, and C/S equipment and procedures, but also development of safeguards approaches, training of Agency inspectors, development of information treatment and safeguard evaluation methods, and the appointment of cost-free experts to the Agency.

A support programme is established by an exchange of letters between a Member State and the IAEA Director General. It is assumed that the support programme activity is a joint co-operative activity between a Member State and the IAEA and it requires close co-ordination. In these activities it is considered that both parties benefit.

For the Agency, benefits include a flexible source of funding and project management, focused on difficult areas; access to the varied resources of the world's leading nuclear facilities; realistic environments for testing, evaluation, and training; and valuable sources of information on trends in the nuclear industry and facility construction schedules.

For the Member State, benefits include assistance in preparing their facilities to cope with safeguards measures to be deployed; assurance that the equipment and techniques used would meet their safety requirements; provision of a forum through which they could ensure that the Agency is made aware of practical constraints imposed by particular facility environments and operating procedures; and information on state-of-the-art techniques and instrumentation, communicated via the Agency.

Status of support programmes

More than 10 years have passed since the first support programme was initiated. During this period many achievements can be attributed to the support programmes. The main achievements, however, can be summarized as follows:

- Virtually all the equipment presently used by the Department of Safeguards has been either developed, tested, improved or documented via support programmes.
- Cost-free experts have been provided in all areas of safeguards.
- Training equipment, facilities, lecturers, and entire courses have been provided.
- Assistance has been provided to help initiate or support many other safeguards areas. These include data processing, evaluation, management, maintenance, quality assurance, and system studies.

In short, Member State support programmes have assisted the Agency in nearly all matters related to its safeguards responsibilities to Member States. (Some of the safeguards equipment derived from support programmes is described in a following section.) At present 270 active tasks exist within 12 support programmes. *(See accompanying table.)*

As for financial assistance, it is believed that roughly US $12-14 million has recently been spent per year. A precise estimate is not possible in terms of a single currency, since there are substantial variations in the financial and operational modes of the various programmes.

Co-ordination between the Agency and the support programmes and also among support programmes has become an important matter in recent years. The Agency has several possibilities for co-ordination. In 1983, the Agency called a co-ordinators' meeting, which was attended by all support programme co-ordinators; the subjects of management and better co-ordination of support programmes were discussed. Co-ordinators' meetings were held in 1984 and 1986 and another meeting was scheduled for 1988.

With most support programmes the Agency has annual or semi-annual review meetings. On these occasions each task is reviewed and their effectiveness is evaluated; new proposals are also discussed. The Agency nominates project officers for all tasks and there is also a country officer for each support programme. In addition to these systems, the Agency has organized topical technical meetings from time to time; in 1987 two such meetings were held.

Every 2 years the Agency collects all information on the R&D work (mostly from support programmes) and issues the "Safeguards Development Report". This report contains an overall review of the R&D work in various areas in the past 2 years and also contains a short description of all active tasks under the Member States' support programmes. *(See table for summaries of meetings held in 1987 related to the co-ordination of R&D efforts.)*

Active tasks in support programmes

System studies	24
Measurement technology	100
Containment and surveillance technology	55
Information treatment	12
Safeguards evaluation	16
Training	28
Other	35

Some results of R&D activities

As described above, R&D work extends over almost the whole area of safeguards. In the equipment development area, it is impossible to introduce all activities in the support programmes, so only a few examples of equipment commonly used by the Agency are described here. In the area of nuclear material accountancy, NDA

Safeguards technical and review meetings in 1987

Technical meetings:	*Date:*	*Participants:*
Meeting on the analysis of plutonium milligram-size samples	July 1987	Representatives of the Network Laboratories CEN-Belgium, CCL-CSSR, CEA-France, ECN-Netherlands, NBL-USA
Advisory group meeting on methods and techniques for NDA safeguards measurements of power reactor spent fuel	November 1987	Participants from Argentina, Australia, Austria, Belgium, Bulgaria, Canada, CSSR, Euratom, Finland, Federal Republic of Germany, France, German Democratic Republic, Hungary, Italy, Japan, Sweden, UK, USA, and USSR.

Support programme review meetings:	*Date/place*
USSR Support Programme	March (Austria)
Canadian Support Programme	May (Austria)
US Support Programme	May (USA)
Italian Support Programme	May (Italy)
Japanese Support Programme	June (Austria)
Federal Republic of Germany Support Programme	June (Austria)
Swedish Support Programme	August (Austria)
French Support Programme	September (Austria)
Euratom Support Programme	October (Euratom, JRC, Ispra, Italy)
Canadian Support Programme	October (Canada)
Federal Republic of Germany Support Programme	November (Fed. Rep. of Germany)
Italian Support Programme	November (Austria)
US Support Programme	November (Austria)
UK Support Programme	November (UK)

type equipment is frequently used by Agency inspectors. The equipment available to them for this purpose is mainly designed to measure the gamma rays and neutrons emitted by various nuclear materials.

Gamma spectrometry. The main kinds of instruments for measurement of gamma radiation are scintillation counters (usually activated sodium iodide (NaI) crystals) and semiconductor detectors (usually high-purity germanium (Ge) crystals). The NaI detectors have a low energy resolution, but they can be made with much higher detection efficiencies than germanium detectors. The germanium detectors have a much better resolution, resulting in a capability to resolve complex gamma spectra and to provide much more information about the materials being examined.

Both low- and high-resolution gamma-spectrometric measurements are performed for safeguards purposes. In the area of low-resolution spectrometry, a hand-held gamma-assay monitor (HM-4) is widely used by Agency inspectors. This is a simple battery-operated, energy selective gamma monitor. This has been developed by a Member State Support Programme and partially replaces the older stabilized assay monitor (SAM-2). It is a pistol-grip instrument with a built-in NaI detector and a digital display, which is now in routine use and is intended primarily for measurements on unirradiated uranium.

Multichannel analysers (MCAs) are mainly used in the area of high-resolution spectrometry, in conjunction with germanium detectors. The superior resolution of these detectors can be used to isolate and measure gamma-ray peaks in a complex spectrum which cannot be resolved by scintillation spectrometry, for instance in the non-destructive determination of plutonium isotopic composition. This system has been used for a number of applications, including measurements on plutonium materials and the determination of the enrichment of uranium hexafluoride in cylinders. Silena Cicero MCAs with germanium detectors are typical instruments routinely used by Agency inspectors. Recently developed under a support programme is the portable multichannel analyser (PMCA). It can be used for both low- and high-resolution gamma-ray measurements, and performs many of the functions of the SAM-2.

Neutron counting. In the area of neutron counting, the most widely used equipment is the high-level neutron coincidence counter (HLNCC), which distinguishes between neutrons produced by spontaneous fission of plutonium isotopes and those produced by (α, n) reactions. Depending upon the specific detector head design,

NDA equipment

Low-resolution gamma-ray measurement devices (HM-4, SAM-2, and Pitman 322C)	75
Portable MCAs used for both low- and high-resolution gamma-ray measurements	38
High-resolution gamma-ray spectrometers (Silena MCAs used with germanium detectors)	47
Neutron coincidence measurement units (HLNCs and other neutron detectors with coincidence electronics)	46
Cerenkov-glow image intensifiers (night vision devices)	25
Ultrasonic thickness gauges	20
Load-cell-based weighing systems	13
K-edge densitometers	2
Ion chamber/fission chamber spent fuel monitors (ION-1 units)	2

IAEA inventory as of end 1987

this system can be used for various types of nuclear material containing plutonium. Again, development of HLNCC was done with the assistance of a support programme. *(See accompanying table for the IAEA's inventory of NDA equipment.)*

Containment and surveillance. Optical surveillance systems are in widespread use for monitoring the movement of nuclear materials and for maintaining continuous observation of stored materials, such as the spent fuel areas of nuclear reactors.

The basic photo surveillance unit used by the Agency is the twin Minolta system. The cameras are used in the single frame mode and triggered at selected intervals by a quartz-controlled timer of IAEA design. More than 200 of these units are in service. However, this type of film camera is no longer available on the market, since the company has decided to stop its manufacture. Hence, early development of systems to replace the Minolta systems is necessary. Several support programmes are working vigorously on this problem and it is expected that within 2–3 years, closed-circuit television systems suitable for the Agency's purpose could be in use.

A sealing system comprises the containment enclosing the nuclear material to be safeguarded, the means of applying the seal (e.g. a metal wire), and the seal itself. The type-E metallic cap seal is in widespread use in connection with copper or steel wire which is either knotted or crimped inside the seal. These seals are all numbered and have unique identification marks placed inside the cap which are recorded before seals are issued for use. On return of a used seal to headquarters the identity is verified. There are several developmental activities to produce seals which can be verified *in-situ*, without the need for removal and return to headquarters. *(See accompanying table for IAEA's inventory of C/S equipment.)* During the year of 1986, 10 300 seals were verified at Agency headquarters using video disc equipment.

Over many years, R&D activities for Agency safeguards have been performed in very broad areas. Considerable progress has been made by the vigorous assistance of Member States. It is believed that R&D work has reached a mature stage, and indeed much equipment, many procedures, and other products are now widely used by the Agency.

It is true, nevertheless, that R&D activities on international safeguards should be continued. Successive Safeguards Implementation Reports have identified the problems encountered throughout the implementation of Agency safeguards. Some problems are caused by the lack of adequate technology to measure specific types of nuclear material, other problems stemmed from the malfunction of equipment. It is urgently necessary to develop further reliable equipment to overcome these types of problems.

It is also important to prepare for the changes to be made in the nuclear industry. There is a trend in the direction of more automated plants, especially in fuel cycle facilities. In those facilities in which operations are highly automated, some verification activities of the Agency may be very difficult. Inspectors' accessibility may be strictly limited. Direct application of NDA or sample-taking by the Agency might not be possible. So, constant R&D is vital for the future success of Agency safeguards performance.

Perspectives on future trends

As described above, Member State support programmes have been beneficial for the Agency as well as for the Member States. It is foreseen, therefore, that their support programmes will be increased further. In September 1987, the representative of the German Democratic Republic expressed the country's willingness to establish a support programme in January 1988, and further additions may be expected.

On the other hand, the Agency's resources for the co-ordination of support programmes are not likely to be increased under the present zero-growth budget situation.

Containment/surveillance equipment

Photo surveillance units	287
Closed-circuit television units	36
Spent fuel bundle counters	16
Video surveillance units custom-made by the IAEA	2
Underwater TV camera	1

IAEA inventory as of end 1987

Future R&D needs. Presently the Agency has consolidated its R&D needs from all divisions in the department and informs the support programmes in the form of a "needs list". In addition to such overall requests, individual R&D requests are formulated on the occasion of support programme review meetings. Many R&D projects are needed in various areas and it is impossible to cover all areas in this short description. Inevitably, therefore, this section does not contain an exhaustive list of tasks.

● *Upgrading of reliability of C/S systems.* In some future applications of safeguards it is foreseen that there are certain situations in which, once material accountancy is established, re-measurement would be extremely difficult. In such cases the role of the C/S system would become vitally important, and it is very necessary to upgrade the reliability of C/S systems.

● *Safeguards measures in automated facilities.* As described above, this is a challenging task. A combination of NDA, DA, and C/S measures will be needed. Further R&D on authentication techniques should be initiated, since it is expected that in many situations the Agency must use the operator's data processing system and/or measurement system.

● *Measurement of plutonium in spent fuel.* There is still no reliable, non-intrusive technique to directly measure plutonium/uranium contents in spent fuel.

● *Improvement of the efficiency of Agency safeguards implementation.* Recognizing the zero-growth budget situation of the Agency, and also the foreseeable increase in the number of nuclear facilities under Agency safeguards, R&D work aimed at reducing manpower/financial resources needed for safeguards implementation would be most beneficial.

Some examples would be a system study to examine the possibility of using random selection of inspection activities. In the measurement of large numbers of nuclear material items, it is an established practice to use random sampling. It would be helpful to establish the theory of using random selection in reducing the number of inspection visits to facilities, or in the consideration of national fuel cycles.

Another area for efficiency improvement is assistance of inspectors in the verification of developed films. Many frames taken during surveillance periods must be reviewed by the inspectorate, which is a very time-consuming job. By using image processing technology, if we can reduce the reviewing time significantly, it would help to save manpower resources.

● *Co-ordination of support programmes.* There are several proposals to maintain the present scale of support programme activities. Listed below are possibilities still under discussion by the parties concerned; therefore, future decisions by the Agency/support programmes might be different from those suggested here.

● *Develop a categorization based on the level of resources required by the Agency and implement it.* Not all tasks (currently 270 in 12 support programmes) require the same Agency effort. While some tasks need involvement of Agency project officers (normally from support divisions) and operations divisions' personnel, with consequent large expenditure of the Agency effort, other tasks may require minimal effort from the Agency. It would be advisable to reduce the number of tasks which require heavy involvement of the Agency.

● *Inter-support programme co-operation.* In the course of co-ordinating support programmes a number of situations have arisen that can be efficiently addressed by direct co-operation between two or more support programmes. This has proven to be very effective in producing high quality work with minimum utilization of Agency manpower. Increased co-operation will be encouraged to further reduce the Agency input.

● *Encourage support programmes to carry a greater proportion of the workload.* Many development tasks could be carried further by support programmes by giving them responsibility for arranging for in-field testing, preparing the documentation, and in arranging for suppliers for production equipment.

● *Reduced administration load.* Some of the administration load could be borne by the support programmes. In particular, the provision of more cost-free experts, within certain overall guidelines, would greatly enhance the Agency's administrative efficiency. In addition, the number of support programme review meetings involving wide participation by the Secretariat should be reduced.

Conclusions

As past history shows, tremendous efforts that have been made by Member States and the Agency to improve and modernize safeguards technology have led to a quite remarkable achievement. However, technology progresses literally day by day, and the case of nuclear technology is no exception. To solve short-term problems (e.g. SIR problems) and also to prepare for future changes (e.g. automation, fast breeder reactor, large-scale reprocessing plant), further effort to improve R&D work must be made.

Therefore, the activities of Member States support programmes must be maintained and oriented to the right direction. At the same time, it is vitally important that the resources to be spent in co-ordination of R&D activities should be the minimum necessary. There are many ways to achieve such goals.