Progress in safeguards: 1983 Implementation

by Peter Tempus

In June 1984 the Director General was in the position to advise the Agency's Board of Governors that *in 1983, as in previous years, the Secretariat, in carrying out the safeguards obligations of the Agency, did not detect any anomaly which would indicate the diversion of a significant quantity of safeguarded nuclear material – or the misuse of facilities or equipment subject to safeguards under certain agreements – for the manufacture of any nuclear weapon, or for any other military purpose, or for the manufacture of any other nuclear explosive device, or for purposes unknown. With the exception of two cases where the Agency was unable to draw conclusions for part of the year* (addressed below), *it is considered reasonable to conclude that the nuclear material under Agency safeguards in 1983 remained in peaceful nuclear activities or was otherwise adequately accounted for.*

Statements like the above, with minor variations in words, have been made annually since 1977 and reported in the Agency's *Annual Report* which is submitted by the Board of Governors to the Agency's General Conference and subsequently to the United Nations General Assembly. Perhaps less well known, however, is the manner in which the Director General arrives at statements of this nature. This article illustrates with a few facts and figures the efforts made and the methods employed by the Secretariat to assemble and evaluate information required to support such statements.

Status of safeguards agreements

At the end of 1983, 121 States, including three of the five nuclear-weapon (NW) States, were party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), or the NPT and the Treaty for the Prohibition of Nuclear Weapons in Latin America (the Tlatelolco Treaty). All five NW States have undertaken to respect the status of de-nuclearization in Latin America in respect of warlike purposes. At the end of 1983, safeguards agreements concluded pursuant to NPT and/or the Tlatelolco Treaty in accordance with document INFCIRC/153 (Corrected), hereafter called [153]-agreements, were in force with 77 non-nuclear-weapon (NNW) States.

Of the 118 NNW States party to NPT, 41 had not yet complied with their obligation under NPT regarding the conclusion of the relevant safeguards agreement with the Agency; however, none of these States have significant nuclear activities, except one which became party to NPT in 1982 and which is negotiating a [153]-agreement to replace the existing agreement in accordance with document INFCIRC/66/Rev.2, hereafter called [66]-agreements. A further 11 NNW States that do not have a safeguards agreement in force pursuant to either the NPT or the Tlatelolco Treaty have concluded with the Agency one or more [66]-agreements.

A [153]-agreement provides for the safeguards coverage of all nuclear material in a State or under its control (full-scope safeguards) and [66]-agreements provide for safeguards coverage of specific nuclear activities in a State. In five of the 11 NNW States mentioned above, all substantial nuclear activities of which the Agency is aware are subject to safeguards. In the remaining six NNW States, as in NW States, unsafeguarded nuclear facilities of significance for safeguards are either in operation or under construction.

Since 37 NNW States party to NPT with [153]-agreements in force currently have only negligible nuclear activities, it remained for the Agency to apply in 1983 safeguards in 39 NNW States under [153]-agreements pursuant to NPT or to NPT and the Tlatelolco Treaty; in one NNW State under a similar agreement pursuant to the Tlatelolco Treaty alone; and in all of the 11 NNW States mentioned above under [66]-agreements, except one where nuclear activities are as yet not of safeguards significance. (The Agency, in addition, also applied safeguards to nuclear facilities in Taiwan, China.) Furthermore, it applied safeguards in three NW States pursuant to either voluntary-offer or [66]-agreements, bringing the total number of States in which safeguards were implemented to 54.

Inspection effort

Table 1 provides some data illustrating the Agency's inspection effort spent in 1981, 1982 and 1983. Important inspection activities include independent measurements of nuclear material in the facility and the use of containment and surveillance (C/S) measures to monitor nuclear material between inspections. The time spent within the facility for inspection activities is measured in "man-days", where one man-day is up to eight hours spent on one calendar day by one inspector to carry out inspection activities.

Mr Tempus is the Deputy Director General heading the Agency's Department of Safeguards.

Table 1: Selected IAEA inspection activities in 1981, 1982 and 1983

Number of:	1981	1982	1983
Inspections carried out	1 400	1 700	1 840
Inspection man-days spent	5 061	6 307	6 727
Nuclear installations inspected	475	450	520
Accounting reports received in accordance with [153]-requirements	7 795	8 744	8 844
Seals applied and subsequently verified	4 000	6 000	6 600
Samples analysed by destructive assay in the Agency's Safeguards Analytical Laboratory	890	870	1 150
New data entries into the Agency's computer	345 000	655 000	800 000

As can be seen in Table 1, the number of man-days of inspection, the application of C/S measures and the scope of data processing increased considerably, while the number of inspector man-years available increased from 125.6 in 1981 to only 137.2 in 1983. Clearly, utilization of available inspector manpower has improved substantially.

The inspection effort varies from State to State, depending on the extent of nuclear activities conducted by the State: it is relatively small in States where, say, only a small research reactor is located, and it will be extensive in States which operate a complete nuclear fuel cycle. Thus, the inspection effort depends in part on the size of the national inventory of safeguarded nuclear material: it is small in the case of an inventory of less than one significant quantity (SQ) and progressively larger for greater inventories as measured in SQs.

The SQ is different for different types of nuclear material and is related to the approximate minimum quantity from which a nuclear explosive could be made. Typical values for an SQ range from 8 kilograms of plutonium to 20 tonnes of thorium. In 1983 there were some 20 800 SQs subject to Agency safeguards (Table 2). Figure 1 illustrates the distribution of NNW States in relation to their safeguarded facilities and the size of their safeguarded inventory of nuclear material.

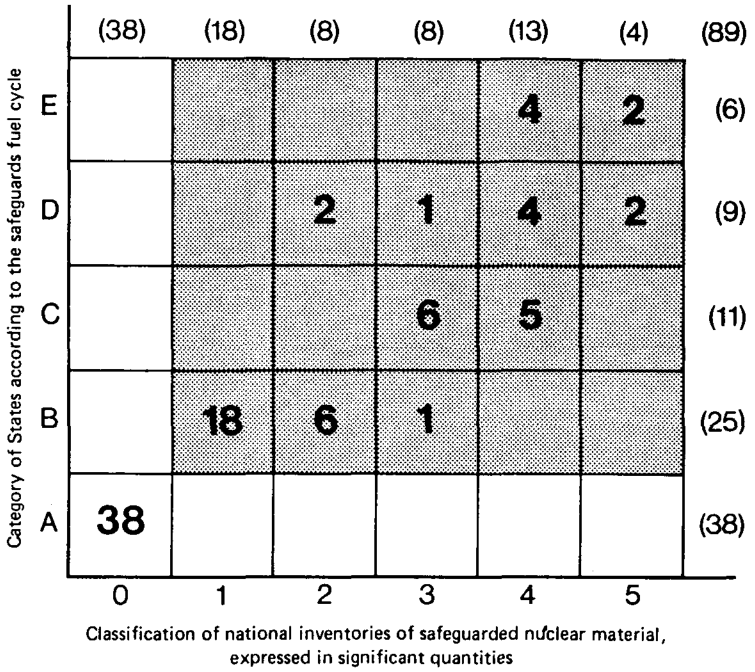
The inspection effort also depends on the nature of nuclear installations under safeguards: In reactors and storage facilities where the form and content of nuclear material is relatively stable and is contained in identifiable items such as welded fuel assemblies, a smaller effort is required than in the so-called bulk handling facilities (BHFs) where much of the nuclear material is normally moved and processed in the form of liquids,

Table 2: Approximate quantities of nuclear material subject to safeguards* in 1981, 1982 and 1983

Types of nuclear material	1981	1982	1983	1983
	Tonnes			Number of significant quantities
Plutonium contained in irradiated fuel	71	83	93	11 600
Separated plutonium	5	6	7	850
Highly (≥ 20% U-235) enriched uranium	10	10	11	260
Low (< 20% U-235) enriched uranium	15 459	16 782	18 590	5 820
Source material (natural or depleted uranium, thorium)**	22 183	25 000	28 000	2 270

* not counting nuclear material covered by voluntary-offer agreements with NW States.

** not counting yellow-cake for which only imports and exports are reported to the Agency.



The numbers in parentheses ( ) are the sums of the columns and rows.

A = Negligible nuclear activities
B = R & D facilities or storage areas
C = B plus power reactors
D = C plus conversion and/or fuel fabrication plants
E = D plus reprocessing and/or enrichment plants

0 = None or insignificant
1 = Less than 1
2 = 1 to less than 10
3 = 10 to less than 100
4 = 100 to less than 1000
5 = 1000 or more

States where safeguards were applied in 1983 are within the shaded area. In the 38 States outside the shaded area safeguards were not applied because their nuclear activities are as yet of negligible significance.

Figure 1: Number of non-nuclear-weapon States according to fuel cycle category and size of national inventory of nuclear material in 1983.

gases, or powders, or in large numbers of apparently identical items such as pellets.

Table 3 lists the number of installations in NNW States which were under safeguards, or contained safeguarded nuclear material, in 1981, 1982 and 1983. The average number of man-days of inspection spent per category of installation ranged from 0.6 for category I (other locations) to 140 for category E (reprocessing plants). Although the BHFs (categories C through H) constituted in 1983 only about one-quarter of all nuclear installations inspected, they required about 56% of the more than 6700 inspection man-days spent altogether. Since the types of facilities that require more inspection effort are concentrated in a relatively small number of States, a relatively large proportion of the total inspection effort is concentrated in these States.

With so many variables determining the inspection effort per State and per nuclear installation, the inspection scheme has to be carefully planned, keeping in mind the technical objective of safeguards. This is stated in [153]-agreements as "... the timely detection of diversion of significant quantities of nuclear material ... and deterrence of such diversion by the risk of early

Table 3: Installations in NNW States under safeguards or containing safeguarded nuclear material by installation category at the end of 1981, 1982 and 1983

Type of installation	Number of installations		
	1981	1982	1983
Power reactors	130	143	147
Research reactors and critical assemblies	176	177	177
Conversion plants	4	6	7
Fuel fabrication plants	38	39	40
Reprocessing plants	6	6	6
Enrichment plants	4	4	4
Separate storage facilities	20	23	28
Other facilities	40	42	46
Other locations	422	404	425
Non-nuclear installations	0	0	1

detection." The basic parameters used in such planning – namely significant quantity, detection time, detection probability and false alarm probability, which constitute the detection goals – cannot be deduced from physical and technical axioms alone: reasonable values have to be selected on the basis of technical-political judgement.

Detection time, i.e. the maximum period that may elapse between diversion and its detection, should correspond roughly to conversion time, i.e. the time estimated for the conversion of different forms of nuclear material to the metallic component of a nuclear explosive device, assuming that all required conversion and manufacturing facilities are available and all non-nuclear components of the device have already been fabricated, assembled and tested. Conversion times are estimated to range from about one week for metallic plutonium to one year for natural uranium or thorium. A detection probability of 90 to 95% and a false alarm probability of below 5% are used for planning nuclear material accountancy measures.

The above detection goals are used as guidelines in establishing the inspection goals for a particular facility (or type of facility) – taking into account the actual conditions at the facility, requirements of the safeguards agreement, limitations on measurement accuracies, potential diversion paths and concealment methods, the technical capabilities of the Agency, and many other factors. These inspection goals are divided into quantity verification goals (which may differ between BHFs and facilities where nuclear material is contained in identifiable items) and into timeliness goals (which are derived by adapting detection time guidelines to specific conditions at facilities and reflecting available methods).

Attainment of inspection goals

The extent to which these inspection goals are attained may be used as one indicator of the effectiveness of the safeguards applied. Figure 2 shows percentages of inspection goal attainments over the years 1978 to 1983 for all nuclear installations that handled more than one SQ of nuclear material. As can be seen, the cases where the Agency has fully attained its inspection goals have increased almost monotonically from 17% in 1978 to 46% in 1983 for the facilities inspected, and from 48% to 64% with respect to highly enriched uranium and plutonium in these facilities. (The figures include cases of full attainment for all types of facilities except enrichment plants where the safeguards approach to cover some diversion paths is still under development.) In many other cases, goals were attained at least partly.

It should be emphasized that as long as the specific facilities for which the inspection goals will be attained are unpredictable in advance by a potential divertor, the fact that inspection goals are not being attained for all facilities does not prevent attainment of the deterrence effect included in the technical objective. Although the deterrence effect produced by Agency safeguards in the past has been considered by many to be reasonable, improvements are necessary to provide more demonstrable and acceptable results in the long run. In the case of two power plants where the Agency was not in a position to perform adequate verification for some time, technical measures judged by the Agency as necessary to enable it to perform effective verification were put into effect during the first half of 1983 with the agreement of the States concerned.

Ideally, the objectives of safeguards can only be accepted as having been fully met when all inspection goals are fully attained for all facilities and all locations. However, in practice, the objectives can often be met to a considerable extent when inspection goals are attained only partly. There is considerable value, for example, in detection capability actually achieved, even if not within a particular timeliness goal. Temporary failure to meet a particular timeliness goal within the year does not affect the validity of the year-end conclusion with respect to non-diversion. Also, failure to carry out certain measurements reduces attainment primarily with respect to the more complex and, therefore, less attractive diversion possibilities. After all, even a detection probability of much less than 90% may still be sufficiently high to deter a State from attempting diversion. The difference between full and partial attainment is the result mostly of technical limitations (such as failure of surveillance instruments), the lack of sufficient Agency manpower and the long time needed to reach agreement with States on the use of new safeguards equipment. The current sensitivity of inspection and evaluation activities is rather high, as is shown by the fact that in 1983 more than 420, mostly minor, discrepancies or anomalies were found. They were all – except one that is still being investigated – explained satisfactorily upon subsequent appraisal.

When, as is currently the case, the ideal of full attainment of all inspection goals for all facilities and all locations cannot be achieved – and some circles hold the view that this will never be possible, given the stringency of the criteria adopted – it is most important to allocate the resources available in such a manner as to optimize their utilization. The inspection effort needs to be concentrated on those stages of the fuel cycle that involve the production, processing, use or storage of nuclear material from which a nuclear explosive could readily be made, e.g. plutonium and highly enriched uranium in BHFs and in certain, mostly large, research reactors and critical assemblies. The Agency will continue to assign priority to the full attainment of inspection goals at these facilities, and to increase subsequently the number of cases with partial (and later full) attainment at the remaining types of facilities.

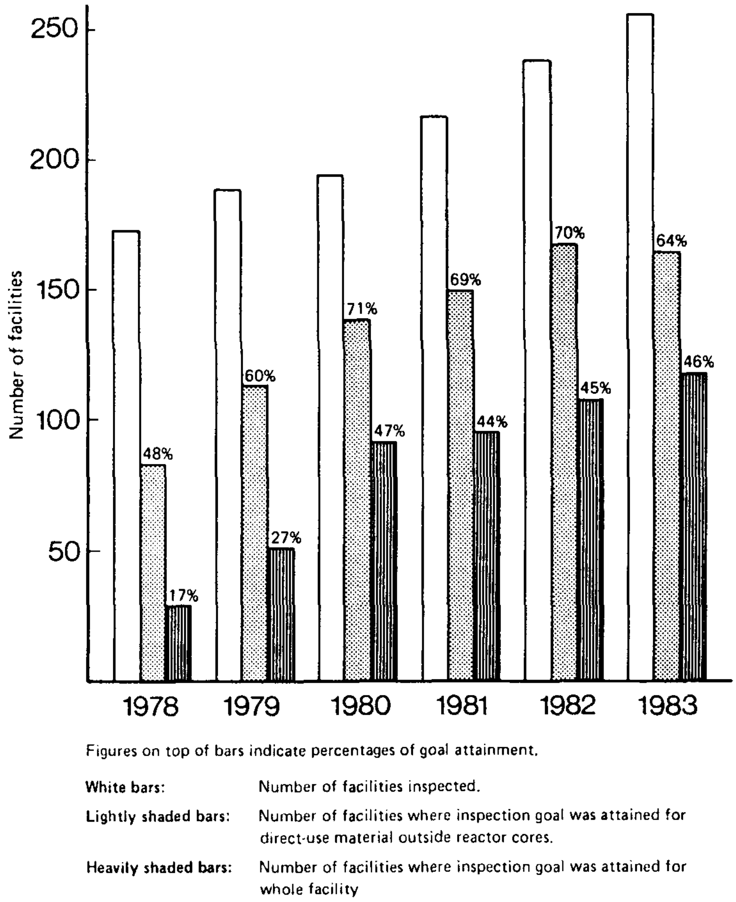


Figure 2. Development of inspection goal attainment at facilities inspected.

Problems and progress in current safeguards performance

One factor affecting efficiency in attaining the inspection goal is the timely availability of information that the State, e.g. through its System of Accounting for and Control of Nuclear Material (SSAC), is required to provide to the Agency. That information takes the form of various reports such as inventory change reports, physical inventory listings, and material balance reports, to be transmitted to the Agency at predetermined dates. The timeliness with which the Agency receives such accounting reports is one indicator of the proper functioning of an SSAC. There are some States that currently submit their reports after the agreed deadlines. Another difficulty encountered by the Agency that still persisted in 1983 (though less so than in 1982) is the frequent lack of data on the uncertainties of the operator's measurements, so that the Agency in these cases had to base its work on its own estimates. These difficulties affect efficiency and timeliness of final conclusions but do not prevent effective safeguards.

In addition, technical procedures proposed by the Agency for standardizing the reporting of international transfers of nuclear material have only been followed to a limited extent, making it difficult for the Agency to reconcile data from the shipping and the receiving States.

There were in 1983 some additional problems that would be amenable to solution only in co-operation with Member States – for example, the timely conclusion of the technical and administrative procedures designed primarily to implement the safeguards procedures laid down in the safeguards agreement. Also, transport restrictions for plutonium samples create substantial difficulties in some cases, and the use of a special air-transport container designed to improve the shipment of safeguards samples containing plutonium that is now available has not yet been licenced by some Member States. However, shipments of samples to the Agency's Safeguards Analytical Laboratory (SAL) were on average faster than in previous years. In addition the application of a Cherenkov glow measuring device for verifying spent fuel has run into difficulties because of national regulations on facility lighting; however, modified devices capable of operating under ambient lighting conditions were tested in 1983 and found to give satisfactory results, though they are not yet approved for routine use in inspections.

On the other hand, there are problems the solution of which would fall solely within the Agency's own responsibilities: for example, although the failure rate of automatic surveillance equipment has dropped from 9% in 1981 to 3.6% in 1983, it is hoped that the introduction of advanced types of instruments that would better withstand the local conditions over the necessary periods of time without specialized attendance will improve equipment performance. Also, time for the destructive analysis at SAL of samples from safeguarded facilities are likely to be further reduced once the modest enlargement of SAL now being undertaken is completed. Increased use is also being made of the Agency's Network of Analytical Laboratories.

During 1983, a relatively large number of equipment items, most of which were specifically developed within the framework of formal national programmes in support of Agency safeguards, were tested and evaluated under operational conditions – in particular, a portable analysis unit for plutonium isotopic measurements, equipment for the simultaneous measurement of gamma radiation and neutrons from irradiated fuel assemblies, and special detector heads for high-level neutron coincidence counters for carrying out measurements of plutonium in specific chemical and physical forms. Nevertheless, the use of non-destructive analysis (NDA) in inspections needs, in general, to be extended and the utilization of available NDA instruments better documented and analysed.

Following the recommendation resulting from the Hexapartite Safeguards Project in early 1983, preparatory work was done on including the "limited-frequency unannounced-access" concept in the safeguards approach for specific enrichment plants.* Negotiations were initiated with certain States for this purpose.

Although the inspection effort increased, as shown in Table 1, by about a third from 1981 to 1983, the fact remains that it is still far from reaching the level of effort estimated in negotiations with States and agreed in the facility attachments as being required in conformity with the stipulation that the number, intensity, duration and timing of routine inspections be kept to a minimum consistent with the effective implementation of safeguards. The further narrowing and, ultimately, closing of that gap will depend, apart from an overall increase in manpower and resources, on a more efficient utilization of manpower already available. Some progress was made in that direction in 1983: new recruitment procedures are gradually eliminating the excessive replacement delays that have existed in the past; the increased use of inspection assistants has set experienced inspectors free for more complex work; and the reorganization of the Department of Safeguards carried out in 1983 is gradually producing a higher degree of co-ordination.

Marked improvements were made in the electronic processing of safeguards data in respect of timeliness, quality and user-orientation. By the end of 1983, the data base of the Agency's Safeguards Information System (ISIS) contained about 2.9 million records, i.e. accounting, design, inspection and other data. Software and quality control procedures for the computerized inspection report sub-system were developed, tested and used in 1983. In one of the Operations Divisions, a pilot project was initiated involving the use of two microcomputers, one in the field and one at Headquarters; telex-type messages are transmitted between these via a commercial network.

Agency safeguards in nuclear-weapon States

As previously noted, safeguards also were applied during 1983 in three NW States. The inspection effort in those States amounted to 410 man-days, or about 6% of the total inspection effort. The safeguards approaches used were, as a matter of principle, similar to those for corresponding facilities in NNW States. Five separate storage facilities, four power reactors, two fuel fabrication plants and one reprocessing plant were inspected under voluntary-offer or [66]-agreements in the three States. The facilities the Agency selected in 1983 for its safeguards inspections in NW States involved a quantity of nuclear material of 1996 SQs. A fourth NW State declared in 1982 that it also intends to conclude a voluntary-offer agreement with the Agency, and negotiations between the two parties to implement that offer were continuing. It is expected that the draft voluntary-offer agreement will soon be submitted to the Agency's Board of Governors for approval.

Conclusion

Agency safeguards is a young discipline and still rapidly developing. Major progress has occurred. The results so far have not been perfect but are recognized to have been effective. However, improvements are still necessary to achieve the safeguards objective in the long run.

* The Hexapartite Safeguards Project, as noted in IAEA's 1981 *Annual Report*, related to ultracentrifuge uranium-235 enrichment plants. IAEA was one of the parties to that project.