

# Compliance Chronicles

Research from the Canadian Centre for Treaty Compliance

Number 4 > January 2007

## Integrated nuclear safeguards: development, implementation, future challenges

Jack Boureston and Yana Feldman



Canadian Centre for  
Treaty Compliance

Integrated safeguards is a program initiated by the International Atomic Energy Agency (IAEA) to rationalize the various layers of nuclear safeguards that have been increasingly accepted by states in fulfilment of their nuclear nonproliferation commitments. The program seeks greater efficiency and effectiveness in the application of nuclear safeguards while ensuring verifiability. This study investigates the background to and origins of the integrated safeguards concept and its application to date. Four cases, those of Australia, Canada, Japan and Norway, are highlighted. The study concludes by examining proposals for enhancing integrated safeguards.

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# **Integrated nuclear safeguards: development, implementation, future challenges**

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Published in Ottawa, Canada by the Canadian Centre for Treaty Compliance

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# Foreword

Integrated nuclear safeguards are still in their infancy, as this study by Jack Boureston and Yana Feldman indicates. Yet so little is known of their operation outside the International Atomic Energy Agency and the states in which they are applied that it seemed useful to commission an external assessment of their impact to date. This study seeks to fulfil that goal. Finding data and unclassified information at this early stage in the program proved more difficult than expected. By far the best-documented case is that of Australia, the first country to undergo the rigorous process of qualifying for and then implementing integrated safeguards. What can be safely said at this stage is that the implementation of integrated safeguards is proceeding apparently smoothly, albeit slowly, that it is beginning to reap financial and technical benefits and that to date there is

no evidence that verifiability has suffered. It will fall to future researchers to determine whether the integrated safeguards program is viable in the long term.

The Canadian Centre for Treaty Compliance is grateful to the Markland Group for funding both the research and resulting publication under the Markland Program on Armaments Treaty Compliance. Thanks also to Richard Jones for expert copy-editing and layout, completed with his usual skill and perseverance.

## **Trevor Findlay**

Series editor

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January 2007

# Acronyms

<b>AIP</b> Annual Implementation Plan	<b>MBA</b> Material Balance Area
<b>AP</b> Additional Protocol	<b>MOX</b> Mixed oxide
<b>ASNO</b> Australian Safeguards and Non-Proliferation Office	<b>MW</b> Megawatt
<b>BWR</b> Boiling water reactor	<b>MWt</b> Megawatt thermal
<b>CANDU</b> Canada Deuterium Uranium (reactor)	<b>NMA</b> Nuclear material accountancy
<b>C/S</b> Containment and surveillance	<b>NPT</b> Nuclear Non-Proliferation Treaty
<b>CNSC</b> Canadian Nuclear Safety Commission	<b>NSG</b> Nuclear Suppliers Group
<b>CSA</b> Comprehensive Safeguards Agreement	<b>OMV</b> Ongoing Monitoring and Verification
<b>DIV</b> Design information verification	<b>PDI</b> Person-days of inspection
<b>DNLEU</b> Depleted, natural and low enriched uranium	<b>PIV</b> Physical inventory verification
<b>ESARDA</b> European Safeguards Research and Development Association	<b>PWR</b> Pressurized water reactor
<b>EU</b> European Union	<b>RII</b> Random interim inspection
<b>G-8</b> Group of Eight	<b>SAGSI</b> Standing Advisory Group on Safeguards Implementation
<b>HEU</b> High enriched uranium	<b>SER</b> State evaluation report
<b>IAEA</b> International Atomic Energy Agency	<b>SNRIs</b> Short-notice random inspections
<b>INFCIRC</b> Information Circular	<b>SQ</b> Significant quantity
<b>IRC</b> Information Review Committee	<b>SSAC</b> State System of Accounting and Control
<b>LEU</b> Low enriched uranium	<b>SSS</b> Strengthened Safeguards System
<b>LOF</b> Location outside facility	<b>UDU</b> Unirradiated direct use (material)
<b>LWR</b> Light water reactor	<b>UN</b> United Nations
	<b>UNSC</b> United Nations Security Council

# Introduction

Since 1968, as prescribed in the Nuclear Non-Proliferation Treaty (NPT), the International Atomic Energy Agency (IAEA) has been operating and managing the international nuclear safeguards system. In the early 1990s, it sustained a terrible shock. The exposure of a secret nuclear weapons program in Iraq revealed the limitations and weaknesses of a verification arrangement that focused only on declared nuclear activities and material. The realization that a state could meet its IAEA verification obligations and simultaneously possess a parallel nuclear weapons program without Agency knowledge prompted the international community to demand new measures to strengthen nuclear safeguards.

The resulting changes included an expansion of the IAEA's safeguards mission: the organization would now verify not only non-diversion of declared nuclear material—that is, the *correctness* of nuclear material inventories reported to the IAEA by the state—but also the absence of undeclared nuclear material, facilities or activities in a non-nuclear weapon state, or the *completeness* of a state's declaration.

The new measures developed by the Agency were codified in May 1997 when its Board of Governors approved a model Additional Protocol (AP), INFCIRC/540 (Corrected).<sup>1</sup> The AP accorded the IAEA additional legal authority and afforded it new tools to make safeguards stronger and more comprehensive and complete. Yet, the IAEA was tasked with doing more without a budgetary

increase. Integrated safeguards (IS) were born out of this effort.

IS constitute 'the optimal combination of all safeguards available to the Agency under comprehensive agreements and APs which achieves the maximum effectiveness and efficiency within the available resources in fulfilling the Agency's right and obligation in paragraph 2 of INFCIRC/153 (Corrected)'.<sup>2</sup> IS provide the IAEA with the necessary instruments to draw safeguards conclusions in the most effective and efficient manner possible.<sup>3</sup> Efficiency, it appears, is the key concept behind IS, since safeguards are costly for both the IAEA and member states to implement. The Agency is constantly under pressure to find ways of relieving some of the verification burden on states, thereby saving both the Agency and member states money. Inherent in the IS concept is a trade-off: as the state takes on arduous and intrusive strengthened safeguards measures, and the Agency verifies the completeness and correctness of its declarations, the intensity of inspections decreases in that state.

This paper will examine the historical development of the IS approach, its elements and its guiding principles. It will review the implementation of IS in selected states—since 2001, IS have been applied in 11 countries—and assess the achievements of and the challenges to the system. Finally, the study will appraise various barriers to improving IS and making them a more valuable part of the IAEA's safeguards system.

# Background to integrated safeguards

Iraq was the impetus for, and the first example of, the application of strengthened verification measures under an eventual enhanced authority that the IAEA was to receive.<sup>4</sup> In April 1991, the United Nations Security Council (UNSC) passed Resolution 687, which gave the IAEA responsibility for uncovering and dismantling Iraq's clandestine nuclear program and developing and implementing a system of Ongoing Monitoring and Verification (OMV).

In a radical departure from past practice the Security Council granted the IAEA broad authority to conduct 'anytime, anywhere' inspections in Iraq. UN member states shared intelligence information and advanced verification techniques with the IAEA.

The need to verify Iraq's program created new opportunities to improve safeguards methods in general. In a 1991 speech, then IAEA Director General Hans Blix said that the Agency was best equipped to expose clandestine nuclear activities if three conditions were met:<sup>5</sup>

- > the Agency must be granted access to information obtained, inter alia, through national technical means, regarding sites that may require inspection;
- > the Agency must be able to exercise its unequivocal right to access any sites, even at short notice; and
- > the UNSC must be willing to back up the Agency's activities.

Between 1991 and 1993 the IAEA Secretariat, the Agency's administrative and verification arm, devised a plan to strengthen the classical safeguards system to improve the Agency's ability to draw conclusions about the correctness and completeness of each state's declaration.<sup>6</sup> That plan was called 'Program 93+2'.

## Program 93+2

The Secretariat launched Program 93+2 in 1993 to evaluate proposals made by the IAEA Director General's Standing Advisory Group on Safeguards Implementation (SAGSI), as to their technical, legal and financial implications, and to create a new Strengthened Safeguards System (SSS) by 1995. Program 93+2 comprised seven separate initiatives to strengthen safeguards:<sup>7</sup>

- > examination of the present safeguards implementation parameters;
- > assessment of increased cooperation with a country's State System of Accounting and Control (SSAC);
- > appraisal of the costs and effectiveness of environmental monitoring of safeguards;
- > evaluation of alternative approaches to conducting safeguards;
- > analysis of availability of all information relevant to states' nuclear activities;
- > training and information security; and
- > integration of all of the above into concrete proposals for a strengthened and streamlined safeguards system.

Some of the steps would make better use of existing resources, while others would take more advantage of existing inspectors' observational skills.

When presented to the Board of Governors in June 1995, Program 93+2 measures were divided into two distinct parts (see Table 1). Part 1 measures were deemed to be within the scope of authority granted to the Secretariat by Comprehensive Safeguards Agreements (CSAs), and thus could be implemented immediately. Part 2 measures—later subsumed into the Additional Protocol that would be appended to CSAs—were deemed to require additional legal sanction. In June 1995,

**Table 1**  
Safeguards strengthening measures<sup>b</sup>

<p><b>Part 1 measures</b></p> <ol style="list-style-type: none"> <li>1. Provision of information on new facilities or on modifications to existing facilities, and the right to continue verifying the facility's life cycle, including decommissioning.</li> <li>2. Enhanced evaluation of information derived from a state's declaration, including reliance on open and other sources.</li> <li>3. Voluntary reporting of inventories, imports and exports of nuclear material, and exports of specified equipment and non-nuclear material.</li> <li>4. Increased use of unannounced inspections.</li> <li>5. Collection of environmental samples at facilities and locations that the Agency has access to during inspections.</li> <li>6. Use of unattended and remote monitoring of movements of declared nuclear material in facilities, and transmission of authenticated and encrypted data to the Agency.</li> <li>7. Closer cooperation with state (and regional) systems to account for and establish control of nuclear material.</li> <li>8. Enhanced training in safeguards implementation for state personnel, IAEA inspectors and safeguards staff.</li> </ol> <p><b>Part 2 measures</b></p> <ol style="list-style-type: none"> <li>1. Provision of information on, and access for Agency inspectors to, all parts of a state's nuclear fuel cycle, including any location where nuclear material intended for non-nuclear use is present, as well as provision of information on a state's research and development activities related to its nuclear fuel cycle.</li> <li>2. Collection of environmental samples at locations beyond those provided under CSAs.</li> <li>3. Provision of information on, and access for inspectors to, all buildings on a nuclear site.</li> <li>4. Relaxed visa requirements for inspectors (valid for at least one year).</li> <li>5. Mandatory provision of information on the manufacture and export of sensitive nuclear-related technologies.</li> <li>6. Wide-area environmental sampling. The IAEA has the right to use internationally established satellite and other telecommunication systems.</li> </ol>
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the Board approved the Secretariat's plan to implement Part 1 at an early date, including measures requiring enhanced information, greater physical access, and optimization of the present system generally.

- > virtually unlimited state-wide access for verification purposes;
- > outside information, including IAEA member states' intelligence information;
- > environmental monitoring techniques; and
- > expanded IAEA member state nuclear program declarations.

### **Additional Protocol**

In late 1995, the Board of Governors established the Committee on Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System (Committee 24), to develop a new legal authority for implementing Part 2 verification measures. In April 1997, Committee 24 completed its work and the following month, the Board approved INFCIRC/540 (Corrected). The model AP affords the legal basis for the Secretariat to use many of the same enhanced verification measures successfully applied in Iraq, including:

An AP is not mandatory. If a state wants to implement its provisions, it is required to negotiate a new agreement with the IAEA (based on the model protocol), which is subject to normal signature and ratification processes. Once adopted, the state's AP is appended to its existing nuclear safeguards agreement with the Agency. States are unable to commence negotiations on an AP until they have concluded a CSA with the IAEA. As of 23 November 2006, 110 of the 140 IAEA member states had signed an AP, 78 of which were in force.<sup>9</sup>

# Emergence of the IS concept

The origins of the IS concept lie in the implementation of safeguards strengthening measures under Program 93+2. As the measures began to be developed and applied, member states and the Agency started to realize that there would be an exponential increase in costs.

For the Agency, these would result from the need for new safeguards implementation schedules, the development of new verification equipment, more intrusive inspections, the generation of more information for assessments, the creation of new tools for managing additional information and new measurements to evaluate declarations.

States too incurred more costs due to their expanded declarations and the provision of greater access to facilities (complementary access) by IAEA inspectors. Expanded declarations meant more investigations of member states' facilities and activities. Supplying historical background on national nuclear programs must also have resulted in greater expense. For some, implementation of the AP involved drafting new legislation to cover requirements to report on nuclear material and nuclear-related equipment and technologies. Furthermore, with expanded declarations came questions from the Agency about inconsistencies that necessitated clarification by the state. All of this demanded extra time and financial resources from the Agency and the state.

The Agency's budgetary situation may have also helped make the case for IS. First, member states essentially imposed zero real growth on its budget from 1985 to 2003. Second, at the insistence of the developing countries, spending on safeguards could not be increased at the expense of expenditure on technical assistance programs.<sup>10</sup> The IAEA was thus expected to expand its verification mission without additional funds. This could explain the Agency's emphasis on the potential cost savings from IS.

Additional funding for implementing the AP in the meantime had to come from extra budgetary contributions from certain member states, notably the United States. No new Agency funding was available to cover the extra implementation costs borne by states, a matter of some concern to at least some of them.<sup>11</sup>

In addition to cost considerations, it became clear to the Agency and its member states that the new strengthened safeguards system resulted in both inconsistencies and redundancies. According to some former IAEA officials, the first expanded state declarations received by the Agency evidenced both a lack of consistency and clarity that made it difficult to process the new information in a timely manner. Member states noted that classical and strengthened safeguards had overlapping requirements. They suggested, therefore, that the IAEA find ways to integrate the two systems, thereby making them more efficient.

During the 1990s, the Secretariat considered various approaches to IS, examining how it might design optimal inspection arrangements that permitted a reduction in the inspection workload while enhancing or maintaining effectiveness.<sup>12</sup> The key concept was the integration of existing and enhanced verification measures to create the 'optimal inspection arrangement' and 'optimum combination of all safeguards measures', rather than layering them on top of each other.

For many member states, particularly those with larger nuclear programs, efficiency had to be a primary element of any safeguards redesign. It appears that some were willing to negotiate greater verification authority for the Agency in exchange for a more cost-efficient system. SAGSI acknowledged this bargain in April 1993: 'The principle of a trade-off between the introduction of a new capability to detect undeclared activities and a reduction in certain routine inspection activities is valid'.<sup>13</sup>

While praising the potential cost savings from integration of old and new measures, some states cautioned that in being more efficient, IS should not surrender any of the effectiveness of the old system. To achieve this, the IAEA's conclusions should be more independent, more technically sound and more logically based on the Secretariat's activities.<sup>14</sup>

## Adoption of IS

At its June 1997 meeting, SAGSI focused on two key terms: 'integrated systems' and 'burden reduction':<sup>15</sup>

- > 'The effectiveness and efficiency benefits of a new integrated [safeguards] system should be exploited to the full'; and
- > 'As the Protocol measures take effect, the focus should shift to the State as a whole, recognizing the overall characteristics of national fuel cycles, infrastructures and international interdependencies of States and fuel cycles'.

SAGSI's efforts resulted in a series of studies on IS, culminating in the Secretariat's formal reports to the Board on 'The Development of Integrated Safeguards'<sup>16</sup> and 'The Conceptual Framework for Integrated Safeguards'.<sup>17</sup> Under IS, measures required by the AP would no longer simply be 'layered' on top of existing measures but integrated synergistically.

After considering various approaches to the application of IS, the Agency ultimately settled on four basic principles:<sup>18</sup>

- > coverage of all plausible acquisition paths by which a state may seek to acquire weapons-usable nuclear material;
- > non-discrimination: 'the same technical objectives should be pursued in all States with comparable safeguards obligations, although the measures actually used in individual States may differ';<sup>19</sup>
- > continual reliance on nuclear material accountability; and
- > information review and evaluation, which is fundamental.

## The state-level approach

Integrated safeguards rely on a state-level approach to verification. By contrast, classical safeguards are based on a facility-level approach, which focuses on applying safeguards to individual nuclear facilities and nuclear material rather than verifying compliance by looking at the state as a whole. Classical safeguards are also applied quantitatively and uniformly to all states. Criteria for such safeguards are the same for each type of facility, regardless of the country in which it is located or any other related factors. This approach was originally implemented as a means of standardizing safeguards performance and avoiding discrimination.<sup>20</sup> However, it is inflexible and mechanistic. The number of facilities and the quantity of material determine the verification effort. Therefore, a state that has a larger nuclear power program is subject to a greater inspection burden. Such an approach does not allow for an increase in safeguards intensity in states where there is a higher risk of proliferation.

Strengthened safeguards marked the inauguration of the 'state-level approach'. This approach is more holistic than the facility-level approach, considers the state as a whole, and assesses wider characteristics of a state's nuclear activities, such as:

- > the structure of the nuclear fuel cycle;
- > the nature of fuel cycle-related research and development;
- > the manufacture and export of sensitive nuclear-related equipment and material; and
- > the effectiveness of the nuclear material SSAC.<sup>21</sup>

The state-level approach takes into account a wider range of criteria, and relies on model IS approaches and complementary access.<sup>22</sup> The concept is grounded in paragraph 81 of INFCIRC/153, which declares that some state-specific considerations should influence the implementation of the facility-level approach:<sup>23</sup>

The criteria to be used for determining the actual number, intensity, duration, timing and mode of routine inspections of any facility shall include: . . . The effectiveness of the State's accounting and control system . . . Characteristics of the State's nuclear fuel cycle . . . Inter-

national interdependence, in particular, the extent to which nuclear material is received from or sent to other States for use or processing.

The state-level approach is based on the following four overarching goals:<sup>24</sup>

- to be able to detect undeclared nuclear material or activities in the state as a whole;
- to be able to identify undeclared production or processing of nuclear material at declared facilities;
- to be able to recognize diversion of declared nuclear material; and
- to be able to resolve anomalies, questions and inconsistencies.

All states with CSAs are now evaluated according to the same four aims (whether or not an AP is in force).<sup>25</sup> The Agency emphasizes that while the state-level approach is state-specific, as long as the safeguards criteria goals are the same for all states and are objective and well documented, the process is not discriminatory but differentiable. Similar states are treated alike in being expected to meet the same aims of safeguards criteria.

The state-level approach allows for flexibility in safeguards implementation. ‘For States under integrated safeguards, there is even greater room for flexibility because of the Agency’s additional rights to information and access provided under an AP and due to the added assurances regarding the absence of undeclared nuclear material and activities.’<sup>26</sup>

## Timely detection

The goal of IS remains the same as that of traditional safeguards: ‘the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection’.<sup>27</sup> The only difference under IS is that various elements are made more efficient (fewer inspections

when possible) because of past performance and positive conclusions by the Agency and to avoid redundancy.

For example, irradiated fuel inventories are inspected X number of times a year because the Agency has determined that Y months (time between inspections) is the minimum necessary to divert the fuel for reprocessing at an undeclared facility. ‘Timely detection’ corresponds to ‘conversion time’, or the time needed to convert various nuclear materials into components of a nuclear weapon.<sup>28</sup> If the Agency is able to conclude that no undeclared facilities exist and/or that no undeclared activities are taking place in a state, it can reduce the level of activities intended to verify the non-diversion of material from declared facilities within that state.

As another example, the diversion of uranium hexafluoride (UF<sub>6</sub>)—a gas that is fed into centrifuges used to enrich uranium—and the operation of an undeclared uranium enrichment plant are part of the same pathway for illicitly acquiring high enriched uranium (HEU). If the IAEA can determine that there is no clandestine enrichment plant in a state, it can adjust inspections and other methods of verification of the state’s UF<sub>6</sub> inventories for use in its declared civil nuclear activities. Under the AP, ‘the Agency’s ability to provide assurance of the absence of such undeclared activities reduces the possibility that such activities may exist undetected and therefore creates the potential for changes in implementation parameters and reductions in verification effort for declared nuclear material’.<sup>29</sup>

As the Agency gains confidence that it is able to verify the absence of undeclared nuclear material or activities in a particular state, it can also redefine safeguards implementation parameters for less sensitive nuclear material, such as depleted, natural and low enriched uranium (DNLEU) and irradiated fuel. This allows for a reduction in the safeguards verification effort, including inspections, with respect to that material. It also permits a reallocation of resources to inspection of facilities of higher proliferation risk. IS and the state-level approach thus make possible the realization of significant savings and improvements in safeguards effectiveness.

## Model IS approaches for nuclear facility types

As part of the state-level approach, models have been developed for applying safeguards to light water reactors (LWRs) (whether or not they use mixed oxide (MOX) fuel), research reactors, on-load refuelled reactors, spent fuel storage facilities, and natural and low enriched uranium conver-

sion and fuel fabrication facilities (see Table 2).<sup>30</sup> For each state, the model facility approach is adapted to certain features and characteristics of that state, and to the specifics of each nuclear facility in that state. Each model facility approach includes alternative safeguards paths of comparable effectiveness. The following elements guided the development of model facility approaches:<sup>31</sup>

**Table 2**  
Verification characteristics of specific facilities<sup>32</sup>

Facility type	Verification characteristics
Light water reactors with and without MOX fuel	<ul style="list-style-type: none"> <li>➤ An annual physical inventory verification (PIV) process</li> <li>➤ A small number of random interim inspections and randomized selection of facilities for inspection</li> <li>➤ RIIs performed unannounced whenever possible, in an effective and efficient fashion</li> <li>➤ Where unannounced inspections cannot take place, alternatives will be employed, such as announced interim inspections supported by surveillance</li> <li>➤ At LWRs with MOX fuel, fresh MOX fuel assemblies are to be kept under containment and surveillance (C/S) from receipt at the reactor until loading into the core to ensure maximum efficiency in meeting the three-month timeliness goal</li> <li>➤ The timeliness goal for fresh MOX fuel can be satisfied either through announced quarterly interim inspections or quarterly evaluation of remotely transmitted C/S data</li> <li>➤ Surveillance to be used during refuelling and the reactor vessel to be sealed before and after refuelling</li> </ul>
Research reactors	<ul style="list-style-type: none"> <li>➤ An annual PIV, except for research reactors with small amounts—less than one significant quantity (SQ)—of nuclear material (in the latter case, the reactors will be randomly selected for a PIV)</li> <li>➤ A small number of unannounced inspections</li> <li>➤ One additional unannounced inspection per year at each high power research reactor—greater than 25 megawatts (MW)—capable of producing one SQ or more of plutonium per year</li> <li>➤ For facilities with more than one SQ of unirradiated HEU: one-month timeliness goal, reached either through scheduled monthly inspections, or use of C/S measures with remote data transmission for the fresh fuel, together with three to four unannounced inspections per year</li> </ul>
On-load refuelled reactors	<ul style="list-style-type: none"> <li>➤ An annual PIV</li> <li>➤ Continued use of unattended flow monitors for verifying fuel discharges from the core and C/S measures for spent fuel bays</li> <li>➤ A small number of RIIs</li> <li>➤ For transfers of fuel: broader involvement of the SSAC/facility operator; and the use of a ‘mailbox’ system for providing information on transfers and unannounced inspections</li> </ul>
Spent fuel storage facilities	<ul style="list-style-type: none"> <li>➤ An annual PIV</li> <li>➤ A small number of RIIs (these do not need to be unannounced)</li> <li>➤ The use of unattended monitors for verification of spent fuel receipts to achieve additional savings in the inspection effort</li> </ul>
Natural and low enriched uranium conversion and fuel fabrication facilities	<ul style="list-style-type: none"> <li>➤ An annual PIV with reduced activities</li> <li>➤ The use of a small number (one to three per year, depending on facility-specific conditions) of short-notice random inspections (SNRIs)</li> <li>➤ SNRIs are coupled with a ‘mailbox’ system to provide information on the facility’s planned operations and updated accountancy data</li> </ul>

- Nuclear material accountancy is of fundamental importance, and remains the current means of evaluating the nuclear material balance annually, using random selection of facilities as appropriate.
- The timeliness goal for irradiated fuel is extended from three months to one year, eliminating the need for scheduled quarterly inspections.
- For fresh MOX fuel assemblies the timeliness goal is extended from one month to three months, eradicating the need for scheduled monthly inspections.
- The use of cost-effective, random interim inspections (RIIs), which are performed unannounced where possible in order to be less predictable for the state.
- The verification requirements for less proliferation sensitive types of nuclear material are reduced.
- Verification procedures for specific types of nuclear material are modified to allow the Agency to re-establish inventories of such materials within the traditional timeliness periods if indications of possible diversion or undeclared nuclear material or activities emerge.
- Procedures involving increased cooperation with the SSAC are included for utilization under specific conditions.

# Implementation of IS

Before IS can be implemented in a particular state, several conditions must be met. First, a state must sign and ratify an AP to its existing CSA. Second, it must demonstrate compliance with all of its safeguards obligations, including the new measures required by its AP, in a timely fashion. Third, a comprehensive evaluation by the IAEA must show that under the CSA no diversion of declared nuclear material has taken place, and that under the AP there is no indication of undeclared nuclear material or activities. Once these stipulations are satisfied, the IAEA works with the state to design and implement an IS approach. The state must continue to fulfil these verification objectives to maintain its qualification for integrated safeguards.

The IAEA plans the implementation of IS in each state according to the type and number of facilities there and its model facility guidelines. Originally developed in 2001, the two main elements of the latter are:

- > the safeguards measures to be applied at each facility and location outside facility (LOF) in the state; and
- > a complementary access plan that sets out the general level and focus of complementary access to be carried out in the state as a whole.

Designs for each state take into consideration state-specific features and characteristics. In addition, they adapt model integrated safeguards approaches to specific facilities and include a plan for implementing complementary access at nuclear sites and other locations.<sup>33</sup>

The Agency develops an Annual Implementation Plan (AIP) for each state on the basis of the state-level approach. AIPs include a larger set of measures and requirements than those under traditional safeguards, such as:

- > details of inspection activities;
- > complementary access plans;
- > design information verification (DIV) activities; and
- > lists of questions, inconsistencies or anomalies for follow-up and resolution.

The first AIP was developed in September 2005.<sup>34</sup> It consisted of safeguards activities grouped into three categories: nuclear material accountancy (NMA) verification and DIV; complementary access; and headquarters activities (such as scrutiny of AP declarations, open-source information analysis, satellite imagery assessment, and state evaluation report (SER) production review and appraisal).

The AIP is the foundation for gauging the effectiveness of safeguards; however, it is not a simple check-box comparison of goals and results. The AIP is evaluated at the beginning of each inspection year against the state's unique state-level approach, with the aim of judging whether the proposed measures will be able to satisfy the objectives. At the end of the inspection year, the results of safeguards activities carried out under each of the three categories of the AIP listed above are evaluated, using the state-level approach, against the generic state-level safeguards goals, and the AIP itself. Activities planned and activities conducted are also compared vis-à-vis their effectiveness. For example, if it was envisaged that complementary access would be required a certain number of times, and the actual number is higher or lower, there would be an examination of how each safeguards question expected to involve complementary access was actually resolved.<sup>35</sup>

At the IAEA's Department of Safeguards, a senior group called the Information Review Committee (IRC) periodically appraises each state's SERs. These reports document the results of the evalu-

ation of each state as a whole and contain background information on and analysis of its nuclear program. Each finding in the report is assessed as to whether or not it may weaken the basis on which safeguards conclusions are reached. The IRC reviews all information and offers recommendations for follow-up action. This kind of assessment allows the Agency to draw safeguards conclusions for the state as a whole. Additionally, a technical review committee in the Department of Safeguards examines each new state-level approach to ensure that it is consistent with the conceptual framework for IS and comparable to those applied to other states. Senior managers in the Department of Safeguards periodically review each state-level approach to ensure that it remains relevant to and consistent with the state's nuclear program.<sup>36</sup>

Each year the Agency evaluates each state's declaration, drawing conclusions regarding its correctness and completeness. This provides continuous assurance of the absence of undeclared nuclear material and activities and thus certifies the state's continued eligibility for integrated safeguards.

As of November 2006, integrated safeguards are being applied in 11 states: Australia, Bulgaria, Canada, Hungary, Indonesia, Japan, Norway, Peru, Poland, Slovenia and Uzbekistan.

**Table 3**

IAEA member states subject to integrated safeguards, November 2006

State	Qualifying year
Australia	2001
Norway	2002
Indonesia	2003
Japan	2004
Uzbekistan	2004
Hungary	2004
Bulgaria	2005
Slovenia	2005
Peru	2005
Canada	2005
Poland	2005

The following section discusses the successes and challenges associated with implementation of integrated safeguards in Australia, Japan and Canada, the only states that so far have made public their views on their experiences. The IAEA does not publish detailed information on its member states' safeguards experiences: such data are traditionally classified as 'safeguards confidential'.

## Australia

On 23 September 1997, Australia became the first state to sign an AP, and in December 1997, it became the first to ratify one. In January 2001, following three full cycles of evaluation under strengthened safeguards measures, the IAEA approved the implementation of IS in Australia.<sup>37</sup>

Even before it ratified and implemented its AP, Australia had spent several years reconstructing the history of its nuclear program and clarifying various issues for the IAEA in preparation for the Additional Protocol. This helped to shorten the time needed to resolve questions and inconsistencies identified by the IAEA in its information review of Australia in preparing for IS. In 1997, Australia amended its Nuclear Non-Proliferation (Safeguards) Act 1987 to allow the country's nuclear authority, the Australian Safeguards and Non-Proliferation Office (ASNO), to implement measures in anticipation of new obligations that would be placed on it under an AP. These measures included the provision of information on all nuclear-related materials and technologies, and the granting of complementary access to nuclear-related facilities not owned by the government.<sup>38</sup> ASNO also stepped up and broadened its effort to supply the IAEA with required information.

Once IS were applied to its nuclear facilities, Australia experienced a decrease in inspection intensity. Australia has five Material Balance Areas (MBAs), including the 10 megawatt thermal (MWt) research reactor at Lucas Heights near Sydney. Under classical safeguards, an annual physical inventory verification (PIV) was conducted for each MBA, as well as three quarterly interim inspections. At Lucas Heights that amounted to

four inspections a year (PIVs for different MBAs at Lucas Heights were performed concurrently). Under integrated safeguards, the timeliness period for irradiated fuel was expanded from three to 12 months, thus eliminating the need for quarterly interim inspections.<sup>39</sup> Under the new safeguards regime in Australia, the IAEA cut back its inspections to one PIV and an average of one unannounced inspection per year. Australia expects annual overall inspection effort savings to be around 45 per cent.<sup>40</sup>

Another result of the implementation of IS in Australia has been a change in the balance of ASNO and IAEA inspections.<sup>41</sup> According to an August 2005 report by ASNO, while in the second half of the 1990s inspection days rose for both the IAEA and ASNO, after 2002 Agency inspections began to decrease, while ASNO's increased.

Lastly, as a result of the implementation of IS, the IAEA has reoriented its activities in Australia from regular inspections to complementary access.

This reflects the shift in emphasis from verifying material inventories (verifying declared material), to verifying the absence of undeclared nuclear material or resolving questions or inconsistencies. One can assume that because of savings from IS in Australia, the IAEA has been able to focus its efforts and resources on other states.

### Challenges to implementing IS in Australia

Australian authorities identified several challenges early in the implementation process. For instance, because of the country's large land mass, some logistical difficulties occurred when arranging short-notice complementary access to a number of nuclear sites. In the case of unannounced inspections, because of the requirement that ASNO personnel be present during inspections, and concern regarding the availability of facility personnel, the Australian authorities insisted that unannounced inspections should aim to be unpredictable rather than surprising. ASNO and the IAEA have agreed to three hours' notice of required access for unannounced inspections, reflecting the travel time from ASNO's headquarters in Canberra to Lucas Heights, where most facilities are located. This also points to the Agency's determi-

nation that activities at these sites could not be concealed in under that time. The Australian authorities also suggested that the IAEA employ remote monitoring with more frequency, especially in circumstances where routine inspections have to increase due to unresolved questions or concerns.<sup>42</sup>

Another challenge centred on discrepancies regarding low-level nuclear material. Such material can be used in non-nuclear industrial processes, such as the production of paints, alloys or ceramics, and in the case of depleted uranium, in the manufacture of body armour. When the material is used in non-nuclear applications, as was the case in Australia, it does not need to be reported and thus was not included on the original inventory provided by Australia to the IAEA.<sup>43</sup> The Agency questioned an inconsistency discovered during a complementary access inspection and requested clarification of the declaration. There was no plan to put the material to nuclear use, but in the absence of a national radioactive waste facility, it had not been disposed of. Since there is no way for the IAEA to distinguish between this type of material and that which needs to be declared for nuclear purposes, Australia chose to declare all of it to the Agency and add it to its inventory. The matter was thus resolved to the satisfaction of both parties.

In conclusion, it appears that in Australia the four IS objectives have, to date, been achieved. The Agency and Australia have implemented integrated safeguards smoothly without interruption, and efficiency gains are evident through some savings—for Australia and the IAEA—based on a decrease in inspection activities. However, the cost savings were not as large as both parties may have anticipated. This may be because it is difficult to minimize inspections of a small program that already has minimum safeguards placed on it.

### Canada

Canada signed its AP on 24 September 1998 and brought it into force on 8 September 2000. In September 2005, following five years of implementing

strengthened safeguards measures, Canada became, after Japan, the second state with a large nuclear program to qualify for IS.<sup>44</sup>

Canada has one of the world's largest uranium mining, natural uranium conversion and nuclear power industries. Substantial growth is expected in the future. Consequently, Canadian and IAEA officials determined that continuing traditional safeguards approaches to safeguarding spent fuel transfers to dry storage facilities and at natural uranium conversion plants would place a tremendous burden on the country and the Agency. Canada therefore worked closely with the Agency to develop a cost-effective safeguards model that does not undermine effectiveness and is consistent with the state-level approach.<sup>45</sup> In preparing for IS implementation, Canadian Nuclear Safety Commission (CNSC) authorities met with national nuclear industry officials and the IAEA to ensure that a common understanding of regulatory requirements and industry challenges was forged.<sup>46</sup>

Since IS have only recently been applied in Canada, it is not yet possible to assess their effectiveness or to evaluate the full extent of any savings that may result.

## Japan

Japan signed an AP on 4 December 1998, and ratified it on 16 December 1999. In September 2004, a year ahead of Canada, it became the first state with a large nuclear fuel cycle to apply IS to its facilities.<sup>47</sup>

To prepare to meet its AP requirements, Japan revised relevant legislation to allow it to provide the additional information required by the Agency and to permit complementary access to its facilities. Japan also revised and strengthened its nuclear material SSAC. The Nuclear Material Control Center in Tokyo was designated the official entity for fulfilling national safeguards responsibilities.<sup>48</sup>

In 2001, Japan began working with the IAEA to develop the most appropriate pattern of inspections for its LWRs, of which it has 55 in operation. It had originally agreed on an option whereby RIIs would be performed on an unannounced basis with two hours' notice. However, Japan's

requirement that national inspectors be present during inspections makes it practically impossible to undertake them at remote facilities within two hours. Subsequently, the IAEA and Japanese authorities renegotiated the Agency's safeguards pattern in Japan to include short-notice random inspections (SNRIs) with 24 hours' notice, with surveillance cameras in 'overwrite mode'.<sup>49</sup>

Model IS approaches to other types of facilities were also negotiated and agreed throughout 2002 and 2003. For research reactors, SNRIs were considered feasible. Since SNRIs are already carried out at Japan's low enriched uranium (LEU) fabrication facilities under the existing INFCIRC/153 comprehensive safeguards regime (five to six inspections per year per facility), these are being continued, but at a reduced rate. Given that the detection probability is thereby also reduced, PIVs are being conducted annually at half of the facilities, selected at random. The adoption of IS has thus reduced the number of SNRIs from an average of 20 per year<sup>50</sup> to about eight per year, a 60 per cent decrease.<sup>51</sup>

In 2003, Agency-Japanese trials were held prior to implementation of IS to offer the IAEA and Japanese nuclear authority staff and facility operators some practical experience of integrated safeguards.<sup>52</sup> The Agency proposed a three-phased IS trial for LWRs that do not use MOX fuel. Phase 1 consisted of RIIs on preset dates at one pressurized water reactor (PWR) in Hokkaido (Tomari #2) and at one boiling water reactor (BWR) near Tokyo (Tokai-II). Phase 2 involved 24-hours' advance notice of RIIs at the same reactors. Phase 3 involved 24-hours' advance notice of RIIs at any LWR except the two previously inspected. Both parties deemed the trials successful.

The Japanese authorities anticipate that the average number of inspections at its power reactors will fall from four per year to approximately 2.4 per year, achieving savings of about 40 per cent.<sup>53</sup> However, such savings may not yet have been realized.

It appears that overall, the Agency has to date achieved its IS objectives in Japan. Integrated safeguards have been applied without interruptions to operations and without major difficulties. The reduction in costs without affecting verifiability

is, as with Australia, indicative of the potential efficiency gains. However, one must note that those gains have yet to materialize.

## **Norway**

Integrated safeguards have been in place in Norway since 2002. Norway's activities in this regard

include supporting the IAEA in performing unannounced inspections, granting complementary access, permitting environmental samples, and assisting with other verification measures. Norway's measurements of the successful implementation of IS are fewer inspections or inspection days per year. According to a safeguards official, however, these goals have yet to be met. As of late 2006, Norway has not accrued any cost savings.

# Assessment and future developments

Integrated safeguards appear to be on course to satisfy the objectives envisioned for them. More countries are expected to qualify in coming years, as the IAEA and the international nonproliferation regime strive to achieve universal application of the AP.

IS have been beneficial in three ways:

- they are helping to reduce the overall verification burden on the IAEA Secretariat and its member states;
- they are increasing the national verification capacity of participating countries; and
- they are strengthening the Agency's ability to carry out its verification mission.

The success of the IS approach, though, needs to be evaluated with respect to efficiency and effectiveness. While the two aims of IS can be assessed individually, they are closely connected.

## Efficiency

Since official IAEA documentation on IS does not appear to define efficiency, this study adopts the definition used by management consultants in the business world. Efficiency, for them, is the ratio of the value of the output to the cost of the input. Hence, efficiency does not simply equate with saving money. It means achieving the same or greater productivity at the least cost.

Applied to integrated safeguards, greater efficiency would involve an increase in 'verifiability' (or at least the same level of 'verifiability') at less expense. Unlike in the business realm, where the value of inputs and outputs is usually readily quantifiable, in the case of IS, while it is relatively easy to identify costs, quantifying verifiability is more difficult. Consequently, while one can cal-

culate cost savings due to a decrease in inspection effort, it is more difficult to judge whether 'verifiability' has suffered, stayed the same or been enhanced. Without an effective assessment of 'verifiability', one cannot easily draw conclusions about efficiency.

With these caveats in mind, it is possible to pinpoint actual and potential cost savings resulting from IS. Overall reductions in safeguards inspection costs for Canada, Japan and European Union (EU) member states reportedly range from 27 per cent for power reactors to 38 per cent for conversion and fuel fabrication plants that handle indirect-use nuclear material (DNLEU).<sup>54</sup>

In terms of person-days of inspections (PDIs), it is expected that once the system is fully implemented, 600 fewer PDIs will be required each year for light water and on-load Canada Deuterium Uranium (CANDU) reactors and DNLEU conversion and fuel fabrication facilities in Canada, Japan and the EU—the current annual total is 2,000.<sup>55</sup> In 2005, implementation of IS in all of the qualifying states resulted in a net saving for the IAEA of approximately 230 PDIs.<sup>56</sup>

While one can calculate PDI savings, it is not possible to identify cost savings resulting from IS by looking at the IAEA verification budget as a whole. Indeed, since IS implementation began in 2001, the verification budget has grown annually.

**Table 4**

The IAEA's verification budget

Year	Value
2001	US\$60,812,000
2003	US\$63,551,000
2005	US\$68,707,400
2006	US\$72,064,100

This may be due to a shift of the workload from states under IS to those whose declarations may contain discrepancies and need further investigation by the Agency's inspectorate.

The projected 2007 verification budget is US\$71,258,800, a 1.1 per cent decrease on 2006—the first reduction in seven years. However it is not clear whether it can be attributed to cost savings from IS specifically because, as noted earlier, the IAEA budget is 'safeguards confidential' and therefore not broken down by verification costs in each country.<sup>57</sup>

## Effectiveness

Although IS have only been implemented over the past five years, gradually and in a limited number of countries, some interim conclusions can be drawn about their effectiveness.

In states where they have been introduced, they are being applied continuously and are functioning smoothly. Furthermore, as there is no evidence of non-compliance by any of these states, one can conclude that the Agency has achieved its verification objectives for IS. The reason for this, though, may be continued implementation and verification of CSAs, not any new efforts emanating from the introduction of IS.

Another benefit, based on the experience of Australia and Japan at least, has been that implementing IS results in a more competent national authority, which contributes to an increasingly effective and efficient safeguards system.<sup>58</sup> Strengthened safeguards measures prompt national authorities to become more active and promote the development of a more coherent SSAC.

A more competent national authority will reduce the workload of the IAEA in terms of fulfilling its responsibilities under the NPT, allowing it to reallocate its resources to address higher proliferation risks, thereby making its verification mechanism more effective.

These achievements to date do not mean that IS will be effective in all cases, but they are an early indication of the likely future success of the integrated safeguards approach.

## Proposals for and continued challenges to improving IS

Any attempts to improve IS will focus on developing further implementation efficiencies while continuing to ensure non-diversion and non-proliferation. If IS were enhanced, perhaps more states would sign APs, implement them, and further strengthen the international community's nonproliferation drive.

The Integrated Safeguards Working Group of the European Safeguards Research and Development Association (ESARDA)<sup>59</sup> identified the following areas for additional improvement:<sup>60</sup>

- > PIV periods;
- > verification requirements for unirradiated direct use (UDU) material;
- > acquisition paths for weapons-usable nuclear material;
- > non-discrimination between states;
- > the relative recoverability of various nuclear materials; and
- > more meaningful use of complementary access.

Some of these are worth elaborating. The ESARDA group suggested that the Agency consider randomized sampling of similar facilities in a state and extrapolating those results to the entire population of similar facilities in that state using standard statistical methods. In the case of LWRs, it proposed that a PIV be performed only when the core of the reactor is open and all fuel assemblies are available for verification. Where spent fuel storage facilities are difficult to access, the group noted the possibility of employing advanced containment/surveillance (C/S) technologies and possibly random inspections to lower the frequency of PIVs.<sup>61</sup> SAGSI has made analogous recommendations, stating that the current 'fixed' number of facilities chosen for inspection under model facility approaches could be replaced with a range of values to allow for greater flexibility in the state-level approach.<sup>62</sup>

A reduction in annual PIVs and their replacement with randomized sampling of similar facilities does not appear to have much savings potential.

The majority of states under IS or on the path towards them (having signed an AP) do not have nuclear programs with multiple facilities of a certain type. Thus, a move from an annual PIV at each facility of a certain type, to a random selection of a PIV at one facility and the extrapolation of inspection results to the rest, would not significantly reduce costs for most IAEA member states. Moreover, replacement of an evaluation based on mandatory annual PIVs with randomization, will lead to a decrease in data. For states with large nuclear programs, the savings from randomization could be significant. However, any measure that produces savings that benefit only the few and risks lowering the effectiveness of the system overall, is unhelpful and likely to be politically unacceptable.

Regarding the verification requirements for UDU material, the Integrated Safeguards Working Group suggested that the isotopic composition and physical form of plutonium be taken into account in devising a safeguards approach for UDU. It argued that ‘the intensity of verification could be adapted to the “strategic value” of the material’.<sup>63</sup> Reassessing the verification requirements for materials makes sense and could be a logical extension of the state-level approach. The presence of UDU in itself does not inherently constitute an ability to weaponize it, however; several other steps must be taken. Therefore, a qualitative assessment of whether other indicators exist could reduce verification requirements for UDU, bringing about further efficiency gains.

The ESARDA group also cautioned the IAEA against becoming ‘overly systematic’ in the performance of complementary access, and urged it to draw on qualitative factors more than quantitative ones. Qualitative elements suggested for IS include increased transparency and direct access by the Agency to the relevant operational data sets and other, non-quantitative, data that confirm the operational status of the facility.<sup>64</sup>

So what is left? Again, the key point is to identify efficiency gains. Improved efficiency does

not always mean cost savings, but it could result in the streamlining of some activities, possibly administrative, possibly operational, allowing the IAEA and member states to do their jobs better. This in turn would permit the Agency to focus its efforts on countries that may have further need of verification.

The Agency continues to seek improvements in existing IS approaches as well as develop new model IS approaches. In its ‘Research and Development Programme for Nuclear Verification 2006–2007’, the Department of Safeguards identified objectives for continuing development of IS. These include projects to:

- > create and test IS approaches for special facility types, such as enrichment plants and MOX fuel fabrication facilities;
- > develop further specialized IS components, such as randomly scheduled inspections, unannounced inspections, and random selection of facilities for inspection;
- > generate guidelines for the resolution of anomalies in the implementation of IS; and
- > establish suitable approaches for monitoring and evaluating the effectiveness of safeguards implementation in states with IS.

Specific initiatives include the following: the review of safeguards at gas centrifuge enrichment plants; verification of transfers of spent fuel to dry storage; research reactor fuel stabilization; SNRI regimes for uranium conversion and DNLEU fuel fabrication plants; and safeguards for geological repositories and new commercial enrichment plants.<sup>65</sup>

Some of these are longer range (to be finalized by the end of 2007), but some are due to be completed by the end of 2006. While all will help to improve the efficiency of IS, the last one may be most significant, as it will allow the IAEA to understand the impact of IS on the overall effectiveness of safeguards in the states where IS have been applied.

# Conclusion

IS are not a revolutionary new system of safeguards. They are instead a product of the successful implementation of existing safeguards. IS are the optimal combination of classical and strengthened safeguards, meant to make the implementation of safeguards more efficient, thus fulfilling the IAEA's commitment to continue to strengthen and enhance its verification mission. Although IS do not primarily focus on making safeguards more effective, they do provide assurances that classical and strengthened safeguards have been successfully implemented and integrated in a participating state, and that the IAEA has been able to successfully reach conclusions about the correctness and completeness of that state's declaration. That IS require an annual re-certification is an added assurance of nonproliferation by the state.

Do IS produce cost savings? In states with large fuel cycles and multiple facilities of the same type, IS measures, including modifying inspection intervals and/or inspection criteria, may produce cost savings. These may be seen as a reward for the arduous process of qualifying for IS and for agreeing to the increased intrusiveness required by the AP. However, in the majority of states, which have small- or medium-scale fuel cycles (or no fuel cycles at all), inspection intervals are likely already at their most efficient (possibly at their minimum level possible) even before the implementation of IS and therefore cannot be further rationalized. Savings are more likely to

come from new verification methods and technologies constantly under development by the IAEA and its member states.

Could IS still be an incentive for additional states to sign and implement an AP? Probably not on the grounds of cost savings, given that most states will not benefit from these and that the extra verification measures required by an AP will come at some cost. Yet a decision by the IAEA to apply IS in a particular state is an important signal that all necessary safeguards have been implemented by the state and that the IAEA has been able to draw affirmative conclusions about both the correctness and completeness of the state's declarations. A state that wishes to demonstrate its good intentions to the international community may thus be willing to make the extra effort needed to sign an AP and implement all related measures in the expectation that it will also qualify for IS as a further 'seal of approval'.

The future of integrated safeguards is probably secure, but they may never be dramatic in their impact. They should continue to produce an overall decrease in inspection levels and cost savings for both the IAEA and most of the states involved. For states with relatively small nuclear programs, where financial savings will not be as significant as for those with large ones, the AP and IS have political and symbolic value, providing an opportunity to further showcase their non-proliferation credentials.

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- 52 Naito and Saeki.
- 53 Naito.
- 54 Cooley, 'Integrated nuclear safeguards: genesis and evolution', p. 38.
- 55 Naito and Saeki.
- 56 IAEA, 'Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System Including Implementation of Additional Protocols'.
- 57 The Agency's safeguards budget is broken down by the following categories: 'Verification in states with comprehensive safeguards agreement'; 'Verification in states with comprehensive safeguards agreement and an additional protocol in force'; 'Verification in states with INFCIRC/66-type agreement'; and 'Verification in states with voluntary offer agreements'. The category of 'Verification in states with comprehensive safeguards agreement and an additional protocol in force' is the largest by far: approximately US\$41 million in 2006 compared with between US\$1.1 and US\$1.6 million for the other categories. This is the grouping that most likely includes states under integrated safeguards. However, it is impossible to tell what proportion of that budget is IS-specific.
- 58 Leslie.
- 59 The ESARDA group was established in 2000 to evaluate AP and IS implementation consequences.
- 60 IAEA Board of Governors, 'Reviews of the safeguards programme and criteria: Report by the Director General', GOV/2004/86, 2 November 2004; Carlson, Leslie, Riggs and Berriman.
- 61 Christophe Xerri and Herman Nackaerts, 'Integrated safeguards: a case to go beyond the limits: consequences of boundary limits set to the reduction of "classical safeguards measures" on efficiency and resources allocation in integrated Safeguards', paper presented at ESARDA's 25<sup>th</sup> Symposium on Safeguards and Nuclear Material Management, 13–15 May 2003, Stockholm, Sweden.
- 62 Discussions with IAEA officials in Vienna, March 2006.
- 63 Xerri and Nackaerts, p. 3.
- 64 Xerri and Nackaerts, p. 4.
- 65 IAEA, 'Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System Including Implementation of Additional Protocols', GC(50)/2, 7 August 2006, [http://www.iaea.org/About/Policy/GC/GC50/GC50\\_Documents/English/gc50-2\\_en.pdf](http://www.iaea.org/About/Policy/GC/GC50/GC50_Documents/English/gc50-2_en.pdf).