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Efficiency of IAEA Safeguards Implementation and Innovation

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Introduction

The International Atomic Energy Agency (IAEA) safeguards system, under which the IAEA Secretariat performs its verification functions (including on-site inspections), ensures that the nuclear material and activities falling under the scope of agreements between the IAEA and states (183 states in total, as of 2019) are not being used to build nuclear weapons or any other nuclear explosive devices. In the framework of the international nuclear non-proliferation regime, the IAEA performs the extremely important role of strengthening confidence between states in the peaceful use of nuclear energy, while serving as an early warning mechanism of possible violations, thereby enabling the international community to take timely steps in response. As described in the IAEA document GOV/2014/41, IAEA safeguards activities are conducted to detect (a) diversion of declared nuclear material from declared peaceful use facilities, (b) misuse of said declared facilities for nuclear weapons or for purposes unknown, and (c) undeclared nuclear material or activities anywhere on the territory of a state or under its control.

The amount of work required to meet these objectives is constantly increasing due to increasing amounts of nuclear material and the growing number of facilities under IAEA safeguards. Also increasing is the volume of information that should be processed to detect undeclared nuclear material and activities (if any) in states with comprehensive safeguards agreements (CSAs). Especially during times when the IAEA Regular Budget remains flat, the IAEA must improve the efficiency of safeguards implementation in order to maintain safeguards effectiveness.

Under Term No. 12.23 of the *IAEA Safeguards Glossary, 2001 Edition,* IAEA "safeguards effectiveness" is defined as "the extent to which the IAEA's implementation of safeguards is able to achieve the safeguards objectives."[1] The glossary does not, however, contain a corresponding definition for IAEA "safeguards efficiency," even though the terms "effectiveness" and "efficiency" are often used in tandem. Both are important: if safeguards are not effective, costs are irrelevant; if the agency does not receive the full funding needed, safeguards effectiveness will be impaired. The IAEA Secretariat has often been challenged to mitigate the impacts of a static budget by optimizing its use of available resources to achieve the maximum possible safeguards effectiveness and efficiency.

[1] *IAEA Safeguards Glossary, 2001 Edition* (International Nuclear Verification Series No. 3), Paragraph 12.23, "Safeguards effectiveness evaluation," https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf.

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The first edition of the *IAEA Safeguards Glossary,* issued in 1980, defined the efficiency of safeguards operations as a measure of productivity of IAEA safeguards, that is, how well the available resources (manpower, equipment, and money) are used in the implementation of safeguards. Recently, M. Aparo, the Deputy Director General and Head of the Department of Safeguards, addressed the Joint Annual Meeting of the Institute of Nuclear Materials Management (INMM) and the European Safeguards Research and Development Association (ESARDA) on the state-level approach (SLA) improvement project, indicating that this project also intended to achieve maximum efficiency under existing resource constraints.

While *safeguards effectiveness* is essential, *safeguards efficiency* is especially important in states bearing the burden of intrusive safeguards procedures and for states providing the IAEA with the necessary resources through mandatory budget assessments. Also, states providing voluntary extra-budgetary contributions are interested to know how the funds they supply affect safeguards effectiveness and/or efficiency. The IAEA Board of Governors oversight of safeguards implementation would benefit by including safeguards efficiency as a separate element in its reviews. Encouraging greater emphasis on efficiency should stimulate further innovation and possibly reduce assessments on states or, at a minimum, maintain the status quo.

This paper gives examples of efficiencies in safeguards implementation that have already been realized at declared facilities and in essential safeguards support tasks at IAEA headquarters and regional safeguards offices. Savings achieved through these means lower the budget requirements for effective safeguards and the direct burdens that facility operators must bear.[2]

These efficiencies came without clear mandates; there is no evidence that such results were ever systematically documented, analyzed, or reported. But they could be.

This paper then considers ways safeguards efficiency might be measured, in the hope of raising its visibility and encouraging further innovation. Specific instances such as those shown in Section 2 are examined, as well as comparative efficiencies.

In respect to item (c) of the general safeguards objectives, it is worth noting that years of effort to develop a unified measure of safeguards effectiveness, beginning in 1979, were never successful. In the absence of an

[2] Safeguards must be implemented under the conditions defined in Paragraph 4 of all CSAs:
"The Agreement should provide that those safeguards shall be implemented in a manner designed:
(a) To avoid hampering the economic and technological development of the State or international co-operation in the field of peaceful nuclear activities, including international exchanges of nuclear material;
(b) To avoid undue interference in the State's peaceful nuclear activities, and in particular in the operation of facilities; and
(c) To be consistent with prudent management practices required for the economic and safe conduct of nuclear activities."

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The IAEA has comprehensive safeguards agreements with 178 states.

agreed methodology, granting a state the broader conclusion (BC) expresses the sense that safeguards as applied in the state have been effective. The process of deciding on the BC involves safeguards evaluation group assessments of states' nuclear activities and capabilities by highly trained safeguards inspectors and analysts. Although those involved say that further improvements are still needed, the process for such collective BC judgments is now accepted, deservedly so. Perhaps a similar process of evaluation could enable the IAEA to conclude that safeguards in a state were also efficient—or, better, both effective and efficient.

It is necessary to note that this undertaking is intended to identify topics where U.S. and Russian experts might examine possibilities for future safeguards improvements through the perspective of efficiency, to give efficiency greater prominence. These examples are not exhaustive, and the ones presented are brief, so as to keep this paper readable.

Specific Examples of Safeguards Implementation Savings

Significant savings in safeguards implementation have come about through various means, including the widespread use of computers, improvements in the functionality of the more than 100 types of verification equipment currently authorized for inspector use, and innovative inspector deployment strategies agreed by the national authorities, facility operators, and the IAEA. Greater transparency in safeguards would be achieved if the IAEA Secretariat and relevant member states would document specific instances of such savings, which could be summarized, for example, in the annual Safeguards Implementation Reports (SIRs).

Safeguards Enhancements at Declared Facilities

- Technology improvements, in the forms of new scientific methods, widespread adoption of computers, and significant improvements in the quality and durability of safeguards equipment, have produced substantial savings in safeguards implementation costs to the IAEA and to the states affected.
- Facility operator cooperation has produced significant savings in inspector requirements. For example, one operator organized operations in three facilities so as to allow timeliness inspections to be carried out with a single team rather than multiple teams.

Savings Achieved through Inspector/ Analyst Deployment

- Regional safeguards offices established in Toronto and Tokyo, with inspectors based there rather than at IAEA headquarters, have doubled the number of inspection days that inspectors can conduct, reduced travel costs, facilitated higher usage of

inspection equipment, reduced the number of equipment shipments, and increased reliability of IAEA safeguards equipment.

- The on-site analytical laboratory at Japan's Rokkasho Reprocessing Plant has allowed faster sample analyses and greatly reduced the number of radioactive samples requiring air transport, mitigating public criticism.

Efficiency Gains through Modernizing IAEA Headquarters Support Tasks

- Over the years, the IAEA has adopted professional standards for the specification, procurement, and management of safeguards equipment and technical services. Functionality, performance, and reliability have dramatically improved both effectiveness and efficiency of safeguards.
- Substantial savings have resulted from modernizing the equipment and procedures used for managing safeguards information, for analytical and environmental sample analyses, for procurement and analysis of satellite imagery, and for nuclear trade analyses.
- Future R&D offers the possibility of game-changing ideas that could benefit safeguards effectiveness and efficiency. Digital twin technology may be one such example.[3]

Efficiency Gains through Integrated Safeguards

- The implementation of integrated safeguards beginning in the early 2000s for states with the BC generally has resulted in the reduction of inspector days in the field, specifically for states with larger nuclear programs and multiple facilities under safeguards. These reductions are due to, for example, the extension of timeliness goals, less intense verification activities, and broader use of random interim inspections at facilities handling less proliferation-sensitive types of nuclear material. At light water reactors alone, several hundred days of inspection have been saved due to the elimination of routine quarterly inspections.

Measuring Safeguards Efficiency

The ratio of the IAEA total expenditure on the safeguards program in a given year to the number of states for which conclusions have been drawn could be published in the SIR. However, because the level of safeguards verification effort, and hence the resources required to draw safeguards conclusions for individual states, varies widely among states, this metric may be too crude to serve as a meaningful measure of safeguards efficiency. Instead, such calculations could be made by the IAEA Secretariat by using all available data. In principle, member states could make their own calculations using information made available to the public.

To illustrate this sort of calculation, Table 1 shows the relevant financial information and the safeguards conclusions drawn by the IAEA (as stated in the annual reports and the SIRs) for the 10-year period from 2010 to 2019. During that period, the state-level safeguards concept was in use.

[3] C. Ritter, et.al., "Digital Twin to Detect Nuclear Proliferation: A Case Study," Proceedings INMM-ESARDA Joint Annual Meeting, 2021.

TABLE 1. Source Data

Budget (million euros)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Expenditure (RB/EBF)	110.2/ 18.2	114.8/ 27.8	121.2/ 36.4	122.5/ 14.5	124.4/ 21.8	130.7/ 27.0	133.0/ 29.4	137.0/ 27.4	138.6/ 18.9	142.9/ 20.1
Next-to-previous ratio		1.0/ 1.0	1.0/ 1.3	1.0/ 0.4	1.0/ 1.5	1.0/ 1.2	1.0/ 1.1	1.0/ 0.9	1.0/ 0.7	1.0/ 1.1
Number of states for which safeguards were implemented and conclusions drawn	175	178	179	180	180	181	181	181	182	183

As the table shows, regular budget spending on the safeguards program was practically stable, reflecting zero-growth decisions by IAEA Member States. At the same time, extrabudgetary expenditures from voluntary contributions of some Member States show bigger variations in both increases and decreases—which may track with funding requested for specific items or changes in the willingness of governments to provide extrabudgetary contributions, for example. As is customary, extrabudgetary funding is used not for the purpose of financing verification activities but for infrastructure investments that improve safeguards effectiveness—for example, improved training of personnel or capital investments in high-cost safeguards equipment, such as a large-geometry secondary ion mass spectrometer for the IAEA's Safeguards Analytical Laboratories at Seibersdorf, Austria.

Given that the costs of verification are covered in the regular budget, it would be more appropriate to try to evaluate a safeguards implementation efficiency index using only regular budget figures as is shown in Table 2.

Table 2 indicates that the safeguards implementation efficiency index has been stable as well. Given the real amount of work performed by the IAEA Secretariat to obtain the results used in these efficiency calculations, and the non-uniform distribution of effort spent among the states, one might conclude that safeguards implementation efficiency actually improved during this 10-year interval. There were increases in both the amounts of nuclear material placed under IAEA safeguards and the number of facilities and locations outside facilities where nuclear material is stored or processed. Table 3 shows the amounts of nuclear material and the number of material balance areas, along with :FN "Dn sDg'w , for the same period.

TABLE 2. Efficiency Evaluation Based on Source Data

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Efficiency (million euros/state)	0.629	0.645	0.677	0.680	0.691	0.722	0.735	0.757	0.761	0.781
Next-to-previous ratio		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 3. Changes in the Quantity of Nuclear Material and Number of Facilities/Material Balance Areas Containing Locations Outside Facilities

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Facilities and Material balance areas (MBAs) containing locations outside facilities[4]	1170	1209	1314	1261	1267	1286	1290	1298	1314	1324
Nuclear material (significant quantities in thousands)	172.2	177.5	183.8	188.5	193.5	200.1	204.1	208.9	212.8	216.4
Expenditure (Regular Budget/ Extra Budgetary funding)	110.2/ 18.2	114.8/ 27.8	121.2/ 36.4	122.5/ 14.5	124.4/ 21.8	130.7/ 27.0	133.0/ 29.4	137.0/ 27.4	138.6/ 18.9	142.9/ 20.1

Another issue pertaining to any discussion about the efficiency of IAEA safeguards implementation is the IAEA's use of innovative technologies in such areas as collecting and processing information (especially from open sources); instruments and equipment for destructive and non-destructive measurements of nuclear material and environmental samples; remote containment and surveillance measures; and radiation- and movement-monitoring instruments. Open sources such as the IAEA official reports often lack the information needed for external analysis—although some bits of data can be found in presentations by IAEA Secretariat personnel at various conferences. To judge from the presentations delivered by secretariat staff for the member states at exhibitions of equipment used for safeguards purposes, these technical means and instruments are constantly improving. But because the efficiency of the implementation of IAEA safeguards remains almost unchanged (as estimated above), efforts to improve the instruments and equipment used for safeguards implementation do not seem to have a significant effect on efficiency.

[4] The actual number of LOFs is not given but, rather, the number of material balance areas containing LOFs. (An MBA can contain multiple (or several) of LOFs—called a catch-all MBA.) This is used not only for small quantities protocol states (where there is typically one MBA containing all the LOFs in the state) but also for states with significant nuclear activities.

At present, there are IAEA Member State support programs with 20 member states and the European Commission; all of them aim to strengthen the capabilities of IAEA verification activities. For example, 73 tasks were successfully completed in 2018. Such support is important because the IAEA Secretariat does not have its own R&D capabilities, and hence the IAEA relies extensively on the R&D capabilities of its member states. Almost all the instruments and equipment used by the IAEA for safeguards purposes were developed with active participation of national support programs, with the secretariat playing a coordinating and steering role. To that end, the agency regularly develops, and coordinates with member states, a two-year plan[5] and a strategic plan for safeguards-related R&D.[6]

Conclusion

Efficiency is important in IAEA safeguards implementation and should be examined in assessing the overall performance of the IAEA safeguards system.

There is no doubt that, as stated in the 2019 Safeguards Statement posted on the IAEA website (in the section on improving the effectiveness and efficiency of IAEA safeguards), the agency is undertaking a great effort to make safeguards implementation more effective and efficient.

It can be also concluded that even though the IAEA budget (including the safeguards implementation program) has not grown, because of the zero-growth budget policy—despite the increasing amount of nuclear material and the growing number of nuclear facilities placed under safeguards—the efficiency of the IAEA Secretariat's safeguards activities is at the very least not deteriorating.

However, an effort should be made to further analyze the costs and inspection effort required to carry out verification tasks and identify alternative solutions. Assuming that effectiveness is not impaired, the lowest-cost alternative would be the most efficient. Note that consideration must be given to the preferences expressed by states in conjunction with the requirements of INFCIRC/153, Paragraph 4.

Trend analyses of the safeguards implementation costs should be conducted regularly to detect system changes.

It might be also useful to make a comparative analysis of cost of safeguards implementation for the states having similar, or at least practically similar, factors, such as CSAs with an Additional Protocol in force and nuclear fuel cycle facilities (including only nuclear power reactors or research reactors), to determine whether differences in cost, if any, are justifiable.

Unitary measures of overall safeguards system efficiency may provide useful tools for monitoring the performance of the overall safeguards system. It could also be useful to carry out a joint study involving experts in this work to examine the feasibility of evaluating the overall safeguards system's efficiency—or, better, both effectiveness and efficiency.

[5] See, for example, IAEA, *Development and Implementation Support Programme for Nuclear Verification 2020–2021,* STR-393, January 2020, https://www.iaea.org/sites/default/files/20/01/d-and-s-programme-2020.pdf.

[6] See, for example, *Research and Development Plan: Enhancing Capabilities for Nuclear Verification,* STR-385, January 2018, https://www.bnl.gov/ISPO/docs/STR-385-IAEA-Department-of-Safeguards-RD-Plan.pdf.

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