LA-UR- 00-3028

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Submitted to: 41st Annual Meeting of the Institute of Nuclear Materials Management, New Orleans, July 16-20, 2000

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Future Safeguards Effectiveness: Concepts and Issues

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Abstract

With new safeguards measures (under old and new authority) now available to the International Atomic Energy Agency (IAEA), there will be fundamental changes in the manner IAEA safeguards are implemented, raising questions about their effectiveness in meeting expanded Agency safeguards objectives. In order to characterize the capability of various safeguards approaches in meeting their objectives, it will be necessary to fully understand what is involved in the new safeguards equation.

Both old and new measures will be required to construct a comprehensive picture of a State's nuclear activities and capabilities, and they both have strengths and weaknesses. There are (for political and cost reasons) likely to be tradeoffs between the two types of measures. Significant differences among measures with respect to the probability of their detecting an anomaly, along with other characteristics, need be considered in this context.

Given the important role of both types of measures in future approaches, their inherent differences with regard to their capabilities and limitations, and their potential impact on the credibility of safeguards, it will be essential to consider these measures systematically, independently, and in combination in any effectiveness evaluation. This paper will consider concepts and issues in addressing this need.

Introduction

With the availability of new strengthened safeguards measures and the adoption of the Model Additional Protocol (INFCIRC/540), there is a need to strengthen IAEA safeguards with respect to detection of undeclared nuclear materials and activities when a State adopts the Additional Protocol. This strengthening will attempt to achieve two fundamental IAEA safeguards objectives:

1. to assure that no declared nuclear material has been diverted or facility misused
2. to provide credible assurance that no undeclared nuclear material or activities exist within a State.

The challenge of integrating these dual safeguards goals has led to the consideration of "integrated safeguards." Integrated safeguards refers to the integration, or harmonization, of measures available under INFCIRC/153 and those available under the additional authority of INFCIRC/540 into a coherent set of measures. The objective of this integration is to improve the effectiveness of safeguards, to increase their efficiency, and to reduce costs where possible.

Both new measures and the integration process itself will introduce fundamental changes in the manner IAEA safeguards are implemented and require careful consideration to ensure these changes fulfill the objectives of integrated safeguards. In order to find a means to evaluate whether integrated safeguards do indeed meet their objectives, it will be necessary to fully understand what is involved in the new safeguards equation.

"Qualitative" and "Quantitative" Measures

Traditional safeguards have been limited to declared facilities and are largely based on "quantitative"[i] measures, although there are significant implicit and explicit "qualitative" aspects of traditional safeguards. Integrated safeguards will include measures to address undeclared as well as declared materials and activities and will by necessity have a new, expanded qualitative aspect.

Traditional and integrated safeguards rely on both qualitative and quantitative measures but in significantly different ways. Under any future integration, it is likely that detecting diversion from declared facilities will continue to rely heavily on quantitative measures, which have been carefully augmented in important ways by qualitative measures. For example, in many circumstances it is the use of qualitative measures such as seals and/or surveillance that provide confidence in the results of quantitative measures such as an item count. These qualitative measures in a sense enable quantitative measures to be used in an efficient and effective manner by narrowing the possibilities for concealment and limiting the general ambiguities associated with the loss of continuity of knowledge. Without these qualitative elements, there would be significantly reduced confidence in quantitative verification results.

In searching for undeclared activities, the prominence of these roles is to a large extent reversed with qualitative measures moving to the fore. The detection of undeclared activities depends on the successful application of qualitative measures in two capacities. First, qualitative measures will likely be used to focus the implementation of quantitative measures (e.g., information analysis queued complementary access with environmental sampling). This role is similar to traditional safeguards in that attempts are made to reduce broad safeguards objectives into specific, testable hypothesis upon which strong conclusions can be drawn. However, in the context of efforts to detect undeclared State-wide activities, this function is much more limited in capability.[ii]

Second, and perhaps more importantly, credible assurance or lack thereof will be derived from a comprehensive State Evaluation. The conclusion of no undeclared activities is inferred from the absence of any evidence to the contrary, not via direct confirmation. In this case, it is the results from qualitative analyses, supported by quantitative measures (e.g., environmental sampling) that provide the basis for judging whether or not undeclared facilities or activities are present in a State.

Both quantitative and qualitative measures are useful and indeed required to present a comprehensive picture of a State's nuclear activities and capabilities, and they both have strengths and weaknesses. Ultimately, qualitative measures can offer a broad insight into a State's programs.

These measures can be useful for confidence building, and possibly to assist monitoring and verification. They cannot be used alone in determining and making cases of noncompliance. Quantitative measures can in principle be used for monitoring and verification as well as confidence building, and can be used to make cases of non-compliance. However, alone they may be too narrow and unable to open a "window" on a State's nuclear activities unless they involve a clear indication of a material breach of an agreement. See Fig. 1.

It therefore seems clear that in order to strengthen safeguards, both qualitative and quantitative measures must be used. The question then becomes how best to utilize these measures in combination to meet safeguards objectives. Any credible answer must make some attempt at characterizing the effectiveness of the resultant system. Such a framework will be required if any claims of strengthening safeguards are to be justified.

A Measure of Effectiveness

Effectiveness must be measured by the extent to which safeguards objectives are met. Given the disparity between the objectives of verifying the correctness and completeness of a State's declarations and how they are pursued, one may wish to consider separate metrics for effectiveness in each case. However, for integrated safeguards to achieve what is expected of them, there is a need to identify areas for efficiency. Effectiveness and cost tradeoffs must be explored as an optimal combination of measures that meet safeguards objectives is sought. This necessitates a common denominator and framework for comparison.

The concept of timely detection in the context of acquisition path analysis provides a logical basis for which to compare safeguards approaches.[iii] Acquisition paths encompass the series of steps necessary to produce separated plutonium or highly enriched uranium, whether they involve declared or undeclared facilities or materials. Safeguards measures can be characterized in terms of their ability to detect each proliferation activity on a given path, cognizant of opportunities for concealment. As the verification of non-diversion and the credible assurance of no undeclared activities both ultimately rely on the ability of the IAEA to detect indicators of these actions with sufficient time to respond, such an approach appears reasonable.

By considering the probability of detection over time for each step in the acquisition of weapon-usable material, we can in theory describe the overall effectiveness of the system. This is achieved by aggregating the individual results to generate performance data for an entire path, which in turn enables an effectiveness comparison between various proposals for integrating new and old safeguards measures.

The adoption of an analysis framework provides a concrete means for identifying and discussing generic issues relevant to the effectiveness of future safeguards. But how should such a framework be used? What elements of safeguards approaches (and the acquisition paths they are designed to detect) significantly impact expected performance? Using the above description of how future safeguards are to be implemented, what differences are likely to exist between the effectiveness of old and new measures? What are the implications for overall system performance?

Traditional Safeguards (INFCIRC/153)	**Quantitative Measures** *(NDA, DA, etc.)* — **"Hybrid" Measures** *(C/S, EM, etc.)* — **Qualitative Measures** *(information analysis, export reports, etc.)*	**Additional Protocol (INFCIRC/540)**
Declared (Facility Specific)	← ***focus*** →	**Undeclared** (State Wide)
Verify States' Declarations	← ***safeguards objective*** →	**Assure no undeclared materials or activities**
Accountability Measurement and Continuity of Knowledge	← ***technical approach*** →	**Presence/ Absence of Indicators**
High Confidence (Verification)	← ***confidence provided*** →	**Low Confidence** (Inference)
Direct evidence (Low Ambiguity)	← ***actionability*** →	**High Ambiguity**

Fig. 1.

Issues

Given the important role of both quantitative and qualitative measures in future safeguards and their potential impact on the credibility of safeguards, it is essential to understand their differences both in terms of inherent capability and how they are applied. This will be necessary to determine the wisdom of any proposed tradeoffs between measures. In this context, the following areas raise key issues for understanding these measures, their interactions, and their utility.

Detection Capability and Coverage

The effectiveness analysis should reflect both detection capability and coverage; it requires for each relevant proliferation action a response with an estimate of detection capability as time passes. This must be done with the best information available, taking into account the proposed safeguards measures, the context and manner it is being applied, possible concealment attempts, and other factors.[iv]

Traditional measures are likely to have higher detection capability but cannot provide the breadth of acquisition path coverage required under integrated safeguards. They are effective in large part because they can provide definitive answers to narrow safeguards questions. They are not well suited to many aspects of the broad charter being established for future safeguards. New measures will be critical for filling holes in coverage.

However, increased reliability on qualitative measures adds ambiguity when interpreting results. At a minimum, this ambiguity results in delayed detection. This may mean that timely detection capability is ultimately reduced. This problem is further compounded by follow-up activities that may not be well characterized and may, ultimately, also possess imperfect detection capability. If the only available follow-up activities possess low detection capability, the collective effectiveness of the safeguards approach will suffer.

It should be noted that limits on capability are often related to safeguards objectives rather than the technical capability of a particular measure. For example, the same measure can have dramatically different safeguards effectiveness depending on how it is applied and for what purpose. Nondestructive assay (NDA) to detect presence of plutonium can very effectively indicate declared plutonium is now missing. NDA to detect presence of plutonium in a single environmental sample is largely ineffective at providing evidence of undeclared plutonium in a State. If more samples are taken, one could argue that the approach is more capable of meeting the safeguards objective. But it is still limited.

Time Period of Interest

The probability distribution for detection time is the foundation for effectiveness analysis. By nature, the cumulative detection probability for each event will increase with time. However, to be most meaningful, detection must occur before weapon-usable material is acquired, or shortly thereafter.[v] Detection after this time, no matter how certain detection may become at this point, is problematic. In any case, it is the probability of detecting an anomaly before actual material acquisition that should contribute to assessments of system performance.

Timely detection is also impacted by the ambiguity or limits to resolvability associated with the results from a measure. Ambiguous results may require multiple follow-up activities before eventually being reconciled, if this can be done. The time of detection should include the time spent pursuing such follow-up actions. The point in time at which an anomaly is viewed to be "real" probably best represents the detection time for the purposes of analysis.

Uncertainty in Estimated Detection Capability.

While the magnitude and shape of the detection probability distribution is important, so is the associated uncertainty. Performance uncertainty breeds risk. For some, a known but reduced performance is preferable to an expected higher but more uncertain performance. Although such risks may not be avoidable and ultimately may be viewed as acceptable, they should be characterized and reviewed carefully.

Confidence in an estimate of detection capability scales with the number of uncertain variables. The greater the number of unknowns, the greater the uncertainty in system performance. For safeguarding declared facilities and materials, it is possible, to a large extent, to select the desired performance. The location of the facility or material is known and the inspection frequency and detection goal can be selected. This cannot, in practice, be done when searching for unknown activities. Not knowing when and where to look introduces more uncertainty in the estimate of capability. These considerations combine to reduce confidence in any estimated detection capability for undeclared activities, especially those at undeclared sites.

More generally, new measures are not yet well characterized and are, therefore, plagued by conceptual and other uncertainties. Focused measures intended to "prove" the presence of undeclared activities will likely be queued by information analysis. The availability, completeness, and accuracy of information available to the Agency on which to base such actions is, at least in part, beyond the Agency's control.[vi] Instituting a rigorous protocol for information gathering and other "best practice" methods will be important, but it is likely that uncertainties will remain regarding what is known and what is knowable.

Resolvability

The above discussion identified the potentially negative impacts of not having suitable follow-up activities available. Ineffective and ambiguous follow-up alternatives lead ultimately to lower detection capability and increased uncertainty. In some cases, it may mean detection is not possible. This effect can be minimized by reducing the reliance on measures that lack definitive follow-up options. In the area of detecting undeclared activities, this is perhaps unavoidable but its impact should be recognized.

Detecting the use of undeclared facilities and materials is likely to be laden with weak indicators. A negative environmental sample could be viewed as a weak indicator to prove that plutonium is not being produced in the State. A materials accounting inconsistency represents a more direct indicator of diversion. This is not to say that a number of weak indicators cannot ultimately generate a level of confidence at least comparable to that of a single strong indicator. However, this should not be taken to be true in all cases a priori. Even if it is the case that a multitude of weak indicators provide sufficient confidence, this may still result in a negative impact on timely detection.

Conclusion

To achieve future safeguards goals will require a balance of quantitative and qualitative measures. It will be essential to consider both types of measures systematically in any effectiveness evaluation. This will entail addressing the complex problem of optimization. Tradeoffs will have to be rationalized carefully to strengthen safeguards and provide credible assurance of no undeclared activities. In principle, this could be done in many ways, from a subjective judgement on the basis of all relevant (quantitative/qualitative) information to the use of mathematical formulae for combining all this information in a meaningful sense. There is an urgent requirement to determine which approaches to take, with a view to issues such as their strengths, limits, issues, complexity, etc.

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[i] The terms quantitative and qualitative are in vogue in the emerging IS debate. Their current use in the debate is caricatured, however; traditional measures are seen as quantitative and 540 measures as qualitative. Although this problem is easily remedied, the terms are not ideal and it is difficult to place C/S and EM, for example, precisely. These measures may have certain characteristics that are quantitative and others that are qualitative, and may be referred to as "hybrid" measures. The use of all of these terms below is designed to give them greater clarity.

[ii] It is not feasible to survey or seal an entire country.

[iii] An attempt to apply acquisition path analysis to integrated safeguards is currently under development and initial application. See, for example, "Illustrative Application of the Integrated Safeguards Evaluation Methodology: ISP-1/Rev. 1 and Current Safeguards," Kory Budlong-Sylvester, et al., Los Alamos National Laboratory, LA-UR-00-1362, March, 2000.

[iv] A formal expert elicitation process appears to be the best means of proceeding with this task.

[v] This is consistent with traditional notions of detection roughly within conversion times.

[vi] Joseph F. Pilat and Kory W. Budlong-Sylvester, "Information Analysis and Integrated Safeguards," presented at the Institute of Nuclear Material Management 41st Annual Meeting, New Orleans, Louisiana, July 16-20, 2000.