Beyond Advanced Safeguards: What's Next?

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Abstract

The advent of the so-called "global nuclear renaissance", or in the case of the U.S. initiative, the Global Nuclear Energy Partnership (GNEP), coupled with the rapid development of advanced safeguards technologies, brings into question what direction future safeguards developments will pursue. Fundamentally, the question must take into account an anticipated safeguards environment. The central features of such a future environment, extending as far out as 20 years or more, will include the predicted increase in civilian nuclear power development worldwide; the resultant surge in the analytical and verification tasks the International Atomic Energy Agency (IAEA) and Member States may have to undertake; and the nature of future fuel cycle facilities.

The U.S. GNEP program, and the worldwide nuclear renaissance as a whole, pose certain safeguards challenges which are being addressed at advanced facilities throughout the world. These challenges, among others, are stimulating the safeguards community to look beyond nearer-term concerns to safeguards for the coming decades, 2020 and beyond.

In the case of GNEP, the intention is to incorporate highly sophisticated, designed-in safeguards to assure effectiveness and efficiency at GNEP facilities. This paper considers the problems of moving beyond the advanced safeguards currently in place at many facilities, to the next-generation technologies that will be critical not only for GNEP's success, but for a safe and secure expansion of nuclear energy worldwide, and for the achievement of international safeguards objectives. This movement toward a next-generation safeguards system is driven both by the demands on IAEA resources and by the need for increased efficiency in safeguards measurement operations of nuclear facilities today, particularly those in Japan, where the IAEA focuses its largest inspection effort. To address these issues, the United States and Japan plan to continue our long history of collaboration on activities that may include elements such as:

- Increased use of simulation and modeling, including predictive methodologies, to implement "safeguards by design" and to assess safeguards approaches

- Use of nontraditional data sources, e.g., advanced sensors and facility process control information as safeguards "observables"

- Increased automation in data collection, review and analysis to support AP requirements, moving towards safeguards evaluation in near-real time on a State-wide basis

- Safeguards approaches for next-generation reactor technology, including Fast Reactors and other reactor types that defy traditional methods

- New safeguards methodologies for process monitoring in increasingly large bulk handling facilities

- Renewed emphasis on cost efficiencies and effective deployment of human resources.

It is clear that Japan's pre-eminent standing in nuclear technology, coupled with the scale and complexity of its currently implemented safeguards, its strong desire for greater efficiency in safeguards implementation, and the long history of U.S.-Japan cooperation, provide an ideal environment for the development of those methods and tools that will answer the "What's Next?" question posed by this paper.

Introduction

Japan is home to the most extensive and technically advanced safeguards implementation in the world. State-of-the-art safeguards being applied around the globe have generally been developed and tested in Japanese facilities, in support of IAEA measurement needs. Examples include unattended data collection, remote monitoring, and advanced data reduction techniques. These tools have not only aided the IAEA in reducing the analytical burden of an expanding safeguards mission, but have helped reduce the dangers of nuclear proliferation worldwide. Yet these tools can be improved, and new technologies can be developed that will help ensure robust and sustainable safeguards in countries like Japan, where the scale of nuclear activity is large and expanding. In this paper, we will highlight topics that will drive the next generation of safeguards development and implementation.

There is no doubt about the enduring importance of nuclear material accountancy. For accountancy to be meaningful, however, there must be accurate material measurements and robust measurement technologies. Nevertheless, safeguards in the 21st century will demand more than measurements alone. As we move toward the future, other elements will assume much greater significance, including state-level assessments and all-source information analysis. Is it realistic to expect that measurement equipment and methods can be integrated with other sources of information? How mature are current safeguards measurement technologies? What significant developments in technology can be projected? What is required from information technologies for safeguards? These are but some of the many questions we must ask when looking into the future of safeguards.

The global nuclear renaissance will increase demands on state systems of accounting and control (SSACs) and on the international inspectorate. Historically, there has been a drive for inspection efficiency through technical means. During the early period of safeguards, the IAEA was restricted to attended-mode safeguards measurements. The 1980's saw the development of unattended instrumentation, and more recently, sensors are increasingly being monitored by remote means. We are also now seeing an increasing emphasis on the use of automation in data review. While this trend is in its early stages, there are clear signs that automation will play an increasingly important role, not only in reviewing the expected masses of data, but in drawing safeguards conclusions.

Next-generation nuclear systems will pose next-generation safeguards challenges. There is general agreement on a number of issues that already confront us and need to be addressed, including:

- New material forms (actinide sequestration under GNEP and FaCT)
- New recycling flowsheets (UREX++ and NEXT)
- New processes (Pyro-processing, direct recycle)
- New reactor types (Pebble Bed, "grid appropriate reactors", AFRs)
- New fuel forms (metal, oxide, nitride, carbide)

If these issues are before us now, we can only imagine the challenges that are beyond the advanced safeguards currently under development. Safeguards tools and approaches for next-generation reactor technology, including Fast Reactors and other reactor types that defy traditional methods, will be necessary in the coming years. New methodologies will also be required for increasingly large bulk handling facilities. Along with the development of these systems a means of evaluating the effectiveness of new approaches will be vital to ensuring appropriate allocation of safeguards resources.

In the sections that follow, we will discuss key issues that may arise as the safeguards environment evolves over the coming decades, and we will suggest some potential approaches to addressing them.

Simulation and Modeling

Increased use of simulation and modeling as an aid to implementing "safeguards by design" and to assessing safeguards approaches holds significant promise for ensuring the effectiveness and efficiency of future systems. In process modeling, for example, parameters relevant to the safeguards environment could be manipulated to simulate reprocessing environments. Advanced process simulation and sensor response modeling could be used to detect weaknesses in safeguards systems. For example, with predictive modeling methodologies, individual diversion pathways need not be identified. Instead, the notion of accrued measurement error could be used to predict material unaccounted for (MUF) -- with some specified uncertainty -- and to assess the vulnerability of a safeguards system. The operator's declared MUF could be compared for fit with the prediction of the model. A poor fit might indicate a simple equipment error or something more serious.

Theoretically, predictive models could be implemented to examine not only facilities, but entire sites. Designing safeguards into facilities, now an accepted approach at the facility level, could be extended to the site level, and perhaps to the entire fuel cycle. Using this approach would result in a significant cost savings for safeguards implementation than would be the case after commitment to a particular course of fuel cycle development or actual construction. Japan is now developing a Site Level safeguards approach for part of JAEA's facilities, at JNC-1, and will soon begin work on the State Level Approach. Simulation and modeling tools may be a significant aid in addressing these developments.

The Advent of Nontraditional Data Sources

Use of nontraditional data sources, e.g., advanced sensors and facility process control information that can be subjected to trend analysis as safeguards "observables" holds much promise for addressing future challenges. It is important to note that gathering these data elements will only be possible if authenticated systems are designed in well beforehand. As process monitoring data authentication issues are resolved, however, it will be natural to extend safeguards data collection to sources that under classical safeguards would have been ignored or unavailable. Inclusion of these new data sources will provide a fuller picture of facility operations and fuel cycle activities. The picture produced by such additional measures will increase confidence in facility declarations. This improvement will come at a cost, however: a flood of data will ensue. We must prepare to manage this swelling volume of data.

Automation and the Coming Data Flood

Reading the tea leaves regarding the direction of international nuclear safeguards, it is apparent that future approaches, particularly at large complex facilities, will generate enormous quantities of data at extremely high rates perhaps up to a TeraByte per minute. Safeguards approaches already challenge network bandwidth limitations. Increased deployment of video surveillance, for example, has resulted in a data volume explosion. Questions naturally arise as to how this surge of data will be handled. Will network limitations be the limiting factor in safeguards data flow rates? How can we archive data rates of multiple TeraBytes per hour? If these data are to be stored how can they be retrieved for review purposes? Clearly, real-time data reduction and data filtering are critical. The data volumes of future safeguards systems will be too great for human-based data reduction to be practical or even possible.

Process monitoring on a large scale will result in a second tidal wave of data. A third wave of data volume increase will occur as future safeguards systems utilize a site-wide or country-wide analysis rather than a facility-based analysis. Increased automation in data collection, review and analysis will be needed to support Additional Protocol (AP) requirements, and safeguards evaluation will need to occur on a near-real time basis. As if this were not enough, yet a fourth wave will crash upon the safeguards system – and already is – as all-source information analysis becomes more central to Integrated Safeguards and to the State-Level Approach. Information will have to be provided in digital form, converted from third party reports, video images, and satellite monitoring.

We are at risk of not being able to effectively reduce the incoming data to a manageable level. Assuming that we can do so, without missing key data elements, how are we to analyze these data to draw valid safeguards conclusions? Data that is not fully reviewed is effectively lost, for safeguards purposes. In the early days of unattended monitoring, data was filtered and compressed to save space on local drives. Big drives and reliable storage have allowed the community to move away from filtering and compression while permitting enormous data volumes to be collected – especially for image data. The anticipated flood of data from expanded use of video, process monitoring and an expanding array of sensors will force another shift in data handling. Local filtration and selected remote transmission combined with automated data management can limit data flow over burdened networks to the essential data. Larger complete data sets can be transmitted during off-peak times when expert systems request ancillary data for further analysis.

Future safeguards systems need to designed to automate data reduction and require safeguards conclusions to be drawn in real time using machine-based rather than inspector-based methodologies. At a minimum, since image data is already too voluminous for thorough review, machine-based image-object analysis will clearly be needed to cope with these data, in addition to the automated surveillance reviews already underway. For example, a close analog to image-object analysis exists in the form of Google's development of image searching algorithms.

"Expert Systems" can be developed to reduce and analyze the tremendous volume of safeguards data. Is it possible to train a neural network to perform the required analysis reliably and convince the community that the network is adequately and properly trained? If not, is it then possible to develop effective heuristic algorithms that sidestep the neutral network approach? Put another way, could a rules-based approach be developed that would result in sufficient confidence that its safeguards conclusions are considered valid?

Bearing in mind that proliferation is a phenomenon that can expand over decades, conventional safeguards verification methods have inherent limitations in uncovering covert operations. While the Additional Protocol and Integrated Safeguards go a long way toward addressing this issue, detection can be improved through enhanced data collection and evaluation. This can be done by incorporating into the State Level Approach a model that collects data at a variety of levels, from key measurement points within a facility, to facility-wide monitoring, overall site assessment, complete fuel cycle analysis and finally to State conclusions.

Last but not least, the person who needs the most useful access to safeguards information is the inspector. No matter what advances are made with future computing methods, there never will be a substitute for the in-field expertise of the safeguards inspector. He or she must have access to relevant information quickly and efficiently without being unduly burdened with a flood of extraneous information. Therefore, a central aspect of managing the coming data flood is to do it in such a way that information is relevant and timely for inspectors.

A Growing Need for Cost Efficiency and Effective Resource Allocation

Achieving the optimum combination of all measures to meet safeguards goals is the unending search of the IAEA, of member States like Japan with large and complicated nuclear systems, and of the safeguards community as a whole. The search is for a system that not only achieves maximum effectiveness and efficiency but is robust, credible, and inherently self-improving. The problem can be addressed in several ways:

> First, to make effective use of limited resources, we must turn to new data sources even as we increase the amount of safeguards data; we must improve analysis techniques; and achieve confidence that operations are consistent with declarations.
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> Second, we must engage in rigorous cost/benefit analyses when imposing new requirements on safeguards systems.
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> Third, we need to determine the "worth" of intangible safeguards data, such as images, operations transparency, and additional confidence measures.
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> Fourth, we should consider closer collaboration between support programs, greater synergy between scientific and technical fields, and the possibility of private sponsorship to address the issue of limited funding for safeguards development and implementation.
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> Fifth, we must manage human resources more flexibly and creatively. Given staff turnover and vanishing expertise worldwide, young specialists with the right sets of skills need to be attracted to the field. The IAEA itself has been populated by professionals who were founding members of the safeguards community. The immense contribution of these men and women needs to be captured and preserved, not only through technology and knowledge management, but through direct teaching, mentoring, and side-by-side field experience. A significant increase in the number of safeguards internships and fellowships will be a key element in addressing future human resource needs. Such an increase should occur throughout the safeguards community, both domestically and internationally, and should be supported by appropriate funding commitments.

Conclusion

Is it reasonable to expect that a robust safeguards system capable of addressing the challenges discussed here can be developed? Can such a system handle an expanding civilian nuclear fuel cycle, new reactor types, and new facilities worldwide and yet be internationally credible? Will it be possible to reach the broader safeguards conclusion given such a radically changed safeguards environment? Ideally, improvements in the integration of future safeguards systems across the fuel cycle and at State levels will increase the probability of detection more effectively and efficiently that the classical safeguards systems have been able to do. Yet the enormous size, extent and complexity of this environment will present a major challenge to individual States as well as to the IAEA.

As has been historically the case, we can say that Japan is, and will be, at the forefront of exploring and testing the capability of state-of-the-art safeguards systems. Certainly, given its nuclear expertise, its large number of facilities and the extent of its nuclear industry, Japan will be a world leader in developing methods for processing the enormous volumes of safeguards data generated by new data sources. The United States has also historically been a strong supporter of safeguards research and development. Both countries believe that such development should lead to the most efficient possible methods that maintain the credibility of the safeguards system. The United States and Japan, in close cooperation with the IAEA, will of course carry on their unique partnership in the safeguards arena, and we believe that the outcome of this collaboration will be positive, as past history indicates. It is anticipated that effectiveness and efficiency will be the hallmarks of this outcome.

We have examined several parts of the answer to the “What’s Next?” question asked in the title of this paper. We can see trends and predict possible scenarios. But whether the tools, methods and processes we develop will be equal to the task depends ultimately on the combined efforts of each of us in the safeguards community.