IAEA Safeguard Technology Challenges — Continuous Unattended Remote Monitoring

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ABSTRACT

The implementation of new, innovative technologies is one of the many challenges facing the IAEA (International Atomic Energy Agency). The IAEA safeguards technology challenge is highlighted with a hypothetical and simplified generic case for a State with an advanced nuclear industry under the NPT (Treaty on the Non-Proliferation of Nuclear Weapons), with a CSA (Comprehensive Safeguards Agreement) and AP (Additional Protocol) in force, for which the IAEA applies a State-level integrated safeguards approach. In conjunction with routine onsite inspections, a range of potential onsite continuous unattended remote monitoring applications could be used, including electronic seals, digital cameras, radiation detectors, and reactor power monitors from which data could be transmitted electronically to IAEA HQ, a regional office, or an onsite office for the purpose of strengthening effectiveness and improving efficiency of safeguards.

INTRODUCTION

The list of International Atomic Energy Agency (IAEA) challenges related to safeguarding nuclear power is basically the same from year to year. The array of challenges is daunting, including employing new, innovative technologies; State cooperation for IAEA verification activities and communicating data; and obtaining sufficient human resources, adequate funding, and legal authority. Both obtaining and implementing effective and efficient safeguard tools continue to be important challenges as technologies evolve and new verification needs arise. This year — today — is no different than 10 years ago. Excellent papers related to addressing these challenges have been and are being published; for example, there are papers from IAEA symposia in 2006, 2010, and 2014; European Safeguards Research and Development Association (ESARDA) conferences; and INMM meetings, including the 2015 INMM 56th annual meeting. "We need to make better use of modern technology" was stated at the INMM 55th annual meeting in the plenary address: "Further Optimization of IAEA Safeguards Is Essential" [1].

This panel paper focuses on the challenge of employing new, innovative technologies for continuous unattended remote monitoring. This includes electronic seals, cameras, radiation detectors, and reactor power monitors. Applications range from quantitative techniques for verifying material balances to qualitative techniques for detecting signature change detection. These technologies can be applied to achieve the IAEA safeguards technical objectives for detecting diversion and for detecting undeclared nuclear materials and activities, while strengthening safeguards effectiveness and improving their efficiency for operators and the IAEA inspectorate. A case study is presented here to demonstrate the range of applications for continuous unattended remote monitoring technologies that could be applied in a State that has a complex nuclear industry and that is willing to cooperate.

DISCUSSION

Under a Comprehensive Safeguards Agreement (CSA) (INFCIRC/153) and Additional Protocol (AP) (INFCIRC/540), the IAEA seeks to (a) draw the broad conclusion that all nuclear material has remained in peaceful activities and (b) ascertain that there are no indications of undeclared nuclear material or activities in a State. To meet safeguard objectives, acquisition paths that could involve (a) the diversion of declared nuclear material, (b) the unreported production or processing of nuclear material at declared facilities, (c) undeclared nuclear material and equipment, (d) unreported imports of nuclear material, or (e) any combination of these must be identified.

The CSA and AP provide the legal basis for continuous unattended remote monitoring. Articles 6 and 74(a) of the CSA provide for the IAEA to “take full account of technological developments in the field of safeguards” and to “use other objective methods which have been demonstrated to be technically feasible.” Article 14.a of the AP provides for the IAEA to “make use of internationally established systems of direct communications” for various purposes, including “attended and unattended transmission of information generated by Agency containment and/or surveillance or measurement devices.”

The IAEA already has taken steps and established the value of unattended remote monitoring technology. The IAEA Annual Report for 2013 shows that the IAEA employed the following:

- 155 unattended monitoring systems that were in operation worldwide;
- 612 systems with 1,322 cameras at 251 facilities in 34 States;
- 200 cameras used jointly with regional and State authorities;
- 206 electronic seals transmitting remote data to IAEA Headquarters (HQ) (more than 25,000 seals were verified by the IAEA for maintaining continuity of knowledge); and
- 279 safeguards systems at 123 facilities in 23 States remotely connected to IAEA HQ, using 168 surveillance systems and 111 radiation monitors.

Strengthening the effectiveness of safeguards and improving their efficiency both for the IAEA inspectorate and for operators are essential as demands on IAEA safeguards grow and as the nuclear industry expands and becomes more complex. The ability to meet strategic safeguards objectives in effective and efficient ways depends on the IAEA’s capability for implementing new and novel technologies. The physical presence of inspectors onsite remains essential, but there are tradeoffs in effectiveness and efficiency associated with the use of continuous unattended remote monitoring technologies, routine inspections, complementary access, and unannounced or short-notice random inspections.

Continuous unattended remote monitoring systems have the potential to increase the effectiveness and efficiency of IAEA safeguards by reducing the number of times that inspectors need to travel to a facility and by permitting inspectors to focus on other verification measures. These advantages can reduce the frequency and intensity of onsite inspections while providing virtually continuous inspection coverage and improving detection timeliness. At sites where direct access to nuclear material is limited (such as independent spent fuel storage installations), verification efforts must be replaced by continuous unattended remote monitoring, or at least significantly reduced through the use of unattended remote monitoring.

The benefits of remote monitoring to the IAEA and operators include the reduced cost of onsite inspections, reduced intrusiveness at the facility, reduced radiation exposure to IAEA and operator staffs, greater confidence in State declarations, more timely detection, and more timely conclusions regarding safeguards. Reduced onsite presence is a favorite benefit for operators. Facility operators, in particular, always seek ways to reduce costs of and intrusiveness into operations.

Potential drawbacks include the reduced onsite presence for making visual observations, reduced human access, increased technology costs, and State resistance to electronic transmission of data across national boundaries. State cooperation is essential for transnational data transmittal and ensuring safeguards information cyber security. The joint use of equipment and information sharing may be possible and acceptable (in cases in which the information is of interest to the State, operator, and IAEA) while data authenticity and independence are maintained.

In States with advanced nuclear fuel cycle activities (e.g., States with gas centrifuge enrichment plants, plutonium production reactors, reprocessing plants, fuel fabrication facilities, spent fuel storage, nuclear technology R&D, and equipment manufacturing capabilities that support nuclear activities), the IAEA can only achieve its objectives by using an information-driven, integrated safeguards approach to maximize effectiveness and efficiency. A recognized example of where the IAEA applies this approach with extensive remote monitoring is in Japan's advanced nuclear industry.

The IAEA long-term R&D plan for 2012–2023 reports continued high-level urgent need for the following:

- Increased ability to detect undeclared nuclear material and activities;
- Elemental and isotopic signatures of nuclear fuel cycle activities and processes (e.g., enrichment), including detecting process emanations;
- Tools and techniques to enable potentially real time detection of HEU production in LEU enrichment facilities;
- Remote monitoring of operators' equipment and unattended IAEA equipment for maximum efficiency; and
- Minimally intrusive techniques that are secure and authenticated to enable use of operators' instruments and process monitoring for cost effective safeguards.

There also is continued medium-level urgent need for the following:

- Tools and techniques to enable real time flow measurement of nuclear material, including UF_6 at enrichment facilities; and
- Equipment to establish and maintain knowledge of spent fuel in storage and transport containers at all points in their life cycle.

CASE STUDY: A CHALLENGE FOR CONTINUOUS UNATTENDED REMOTE MONITORING

Described here is a hypothetical and simplified generic case for a State with an advanced nuclear industry under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), with a CSA and AP in force, for which the IAEA applies a State-level integrated safeguards approach. In conjunction with routine onsite inspections, a range of potential onsite continuous unattended remote monitoring applications could be used, including electronic seals, digital cameras, radiation detectors, and reactor power monitors from which data could be transmitted electronically to IAEA HQ, a regional office, or an onsite office. This case study provides examples of locations (10) and activities (18) that illustrate the potentially wide application for employing continuous unattended remote monitoring.

1. Operating gas centrifuge (GC) uranium enrichment facility
   (1) Monitor declared GCs in declared operating enrichment plant for undeclared nuclear activities (5% LEU → >20% HEU).
   (2) Monitor declared inactive GCs in storage.
2. Shut-down GC uranium enrichment facility
   (3) Monitor declared GCs in declared shut-down enrichment plant for undeclared nuclear activities (NU → LEU).
   (4) Monitor for related nuclear activities.
3. R&D location
   (5) Monitor for nuclear R&D and testing activities (e.g., enrichment, radioisotope production, research reactor, fuel fabrication, reprocessing, and presence of fissile material).
4. Equipment manufacturing location
   (6) Monitor nuclear-related materials and equipment manufacturing (e.g., GCs, bellows, rotors, maraging steel, carbon fiber, zirconium).
5. Operating heavy water (HW) reactor
   (7) Monitor HW reactor operation, reactor R&D, and radioisotope production.
   (8) Monitor HW reactor spent fuel.
6. Operating HW production plant
   (9) Monitor HW production and storage.
7. Operating fuel fabrication/conversion facility
   (10) Monitor down blending.
   (11) Monitor fuel fabrication (UF_6 → fuel plates and assemblies).
   (12) Monitor declared 20% EU UF_6 stockpile.
   (13) Monitor declared 5% EU UO_2 stockpile.
8. Operating LEU research reactor with hot cells
   (14) Monitor reactor operation and reactor R&D.
   (15) Monitor hot cells for isotope separation.
9. Operating LEU nuclear power plant
   (16) Monitor reactor operation.
   (17) Monitor fresh and spent fuel storage.
10. Uranium mining, milling, and conversion plant
   (18) Monitor conversion (U_3O_8 → UF_6).

Use of continuous unattended remote monitoring is particularly applicable to complex, large-scale nuclear programs for monitoring material handling, operation, and design as declared in a Design Information Questionnaire (DIQ). The use of new and novel technologies for radiation monitoring (i.e., gamma and neutron) is a necessity, not only for quantitatively confirming material balance closure with a physical inventory verification, but also for qualitatively detecting nuclear signatures and monitoring variations from threshold levels (e.g., for HEU versus LEU or for plutonium presence). In some situations, it may be necessary to replace electronic monitoring with visual observation under managed access. An integrated safeguards approach with continuous unattended remote monitoring can be a large undertaking, with an estimated IAEA cost being on the order of $20 million annually, even with the resultant inspection resource efficiency and optimized effectiveness.

Several United States Department of Energy (DOE) national laboratories have been involved in developing advanced safeguards technologies, including remote sensing and monitoring sensitive nuclear materials in facilities. Argonne National Laboratory, under the auspices of the DOE Office of Packaging and Transportation, Environmental Management, has developed three innovative systems for remote and wireless monitoring and tracking of packages containing sensitive nuclear and radioactive materials: the ARG-US (meaning "watchful guardian") Radio Frequency Identification (RFID) for materials monitoring (patented and licensed), ARG-US CommBox (patent pending) for transport tracking, and ARG-US Remote Area Modular Monitoring (RAMM, patent pending) for monitoring critical nuclear facilities, including spent fuel dry casks in long-term storage [2]. Potential application of the ARG-US technology to enhance transport security can be found in reference [3], which described the development of an International Best Practice Guide (BPG) entitled "Electronic Tracking for the Transport of Nuclear and Other radioactive Materials, Revision 1.0." for the World Institute for Nuclear Security (WINS) and the World Nuclear Transport Institute (WNTI). The WINS/WNTI's BPG also featured a Case Study: "The ARG-US Radio Frequency Identification (RFID) System; A Case Study from the US."

SUMMARY OF CONCLUSIONS

New and novel remote monitoring technologies are needed to strengthen the effectiveness of safeguards and improve their efficiency. Their use is legally grounded in agreements. Their success relies on the cooperation of States in facilitating their implementation. As the nuclear industry continues to evolve and as costs continue to escalate, further optimization involving integration and cooperation is essential. New and novel technologies can benefit the operators, as well as the IAEA. Fortunately, "a major strength of the safeguards system is its capacity to adapt and evolve" [4].

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REFERENCES

1. Varjorante, T., "Further Optimization of IAEA Safeguards Is Essential," INMM 55th Annual Meeting, Plenary Address, July 21, 2014.
2. Tsai, HC, Liu, Y.Y. and Shuler, J.M., "Remote Area Modular Monitoring (RAMM) of Dry Cask Storage Systems," INMM 56th Annual Meeting, Renaissance Esmeralda, Indian Wells, California USA, July 12–16, 2015.
3. Liu, Y.Y. et al., "Electronic Tracking for the Transport of Nuclear and Other Radioactive Materials," INMM 53rd Annual Meeting, Orlando, FL, July 15–19, 2012.
4. Scheinman, A.M., "International Safeguards: Challenges and Opportunities," Proceedings of an International Safeguards Symposium: Addressing Verification Challenges, Vienna, Austria, October 16–20, 2006.