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USSP-IAEA Workshop on Advanced Sensors for Safeguards

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Abstract

The IAEA Medium Term Strategy (2006-2011) defines a number of specific goals in respect to the IAEA's ability to provide assurances to the international community regarding the peaceful use of nuclear energy through States' adherences to their respective non-proliferation treaty commitments. The IAEA has long used and still needs the best possible sensors to detect and measure nuclear material. The Department of Safeguards, recognizing the importance of safeguards-oriented R&D, especially targeting improved detection capabilities for undeclared facilities, materials and activities, initiated a number of activities in early 2005. The initiatives included letters to Member State Support Programs (MSSPs), personal contacts with known technology holders, topical meetings, consultant reviews of safeguards technology, and special workshops to identify new and novel technologies and methodologies.

In support of this objective, the United States Support Program to IAEA Safeguards hosted a workshop on "Advanced Sensors for Safeguards" in Santa Fe, New Mexico, from April 23-27, 2007. The Organizational Analysis Corporation, a U.S.-based management consulting firm, organized and facilitated the workshop. The workshop's goal was to help the IAEA identify and plan for new sensors for safeguards implementation. The workshop, which was attended by representatives of seven member states and international organizations, included presentations by technology holders and developers on new technologies thought to have relevance to international safeguards, but not yet in use by the IAEA. The presentations were followed by facilitated breakout sessions where the participants

considered two scenarios typical of what IAEA inspectors might face in the field. One scenario focused on an enrichment plant; the other scenario focused on a research reactor. The participants brainstormed using the technologies presented by the participants and other technologies known to them to propose techniques and methods that could be used by the IAEA to strengthen safeguards. Creative thinking was encouraged during discussion of the proposals. On the final day of the workshop, the OAC facilitators summarized the participant's ideas in a combined briefing.

This paper will report on the results of the April 2007 USSP-IAEA Workshop on Advanced Sensors for Safeguards and give an overview of the proposed technologies of greatest promise.

Workshop Objectives

The workshop was held April 23-27, 2007, in Santa Fe, NM. It was attended by representatives of the U.S. Support Program to IAEA Safeguards (USSP), including the Subgroup on Safeguards Technical Support and the International Safeguards Project Office (ISPO), the International Atomic Energy Agency (IAEA), other IAEA Member State Support Programs (MSSPs), U.S. national laboratories, companies and academia. Seven countries were represented. The workshop organizers encouraged the attendance of people who had no previous connection with the IAEA Department of Safeguards. This was to ensure the presentation and discussion of new ideas. The meeting was sponsored by the USSP and organized by the International Safeguards Project Office in cooperation with Organizational Analysis Corporation (OAC). OAC provided facilitation for the workshop working groups.

The workshop was intended to build on the October 2005 USSP-IAEA Workshop on Safeguards Tools for the Future.[1] This preceding Workshop addressed mainly data processing, data communications, and data security and information technology- (IT-) related infrastructure. The possibility of addressing sensors was considered in the planning phase in 2005, but it was decided to focus on the IT part.

During the sensors workshop, the IAEA wanted to uncover and discuss the capabilities required by the IAEA now and in

[1] Department of Safeguards Workshop on Safeguards Tools of the Future, December 2005, ISPO Report #524.

the future, advantages and disadvantages of prospective technology solutions, and to prioritize the technology recommendations while considering the constraints under which the IAEA operates.

The IAEA also wanted to address the objectives identified in its Medium Term Strategy Goals for 2006-2011.

Workshop Agenda

The workshop was conducted over a period of four-and-a-half days. The first day started with a keynote speech by Leonard Weiss of Stanford University's Center for International Security and Cooperation. Dr. Weiss was the architect of the U.S. Nonproliferation Act of 1978, and he shared his perspective on issues facing IAEA Safeguards now.

Dr. Weiss' speech was followed by several presentations by IAEA staff on the mission and challenges of the IAEA Department of Safeguards. These presentations were important for those attendees who had not previously worked with the IAEA.

One-and-a-half days were set aside for invited technical presentations. These are discussed in the following section of this paper.

The foregoing was preparation for two scenarios or brainstorming sessions. The meeting participants were divided into three working groups, each with its own facilitator, to consider two scenarios for which the IAEA is challenged to identify safeguards approaches. The first scenario involved clandestine enrichment activities at a declared location. The second scenario addressed clandestine production of plutonium at a declared nuclear research site that includes a research reactor. Each scenario was considered by the working groups in a half day session. The working groups were asked to be creative in their thinking to identify solutions to the IAEA's needs.

The meeting closed with the OAC facilitators each presenting their working groups' findings and recommendations. The results of these working groups are discussed later in this paper.

Technologies Presented

The technologies that were presented at the workshop are too numerous to discuss in this paper, but they are discussed in detail in the workshop report[2] and are available for viewing on the ISPO website.[3] A complete listing of the presentations is provided in Table 1, and a few of the technologies thought to have promise are discussed below.

The IAEA has a need to detect subsurface structures and hidden entries into containers. Stephen Mersch of Point Source, Inc., presented Speckle Photography. Speckle Photography, which is known by a number of names, provides a means of detecting hidden underground structures or other non-visible items. The system uses subtle differences in surface response to light. It requires significant interpretive analysis that is not yet well established.

Power management is a constraint on the IAEA's use of unattended monitoring systems. Larry Gadeken of BetaBatt, Inc., presented Betavoltaic Energy Conversion and Storage. This technology uses very efficient betavoltaic semiconductor devices to capture energy from beta particles emitted by tritium. A silicon wafer is chemically processed to produce deep micron-sized pores on the wafer. The energy conversion layer is fabricated in the pore space by diffusing *p-n* junctions into the pore walls. The pores are subsequently infiltrated with a Tritiated polymer. Beta particles emitted by the Tritium strike the *p-n* junctions resulting in the production of electricity continuously for 12 or more years.

The IAEA has an identified need to verify spent fuel. Shireen Adenwalla of the University of Nebraska-Lincoln, presented Boron Carbide Based Neutron Detectors. Most materials have a tiny capture cross section for neutrons. Boron carbide is a semiconductor with a large capture cross section and promising material for neutron detection. The technology is still under development with commercialization expected in two to five years. Boron carbide crystals are expected to cost approximately ten U.S. dollars.

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[2] Department of Safeguards International Safeguards Workshop for Sensors for Advanced Safeguards, draft, ISPO Report #533.
[3] www.bnl.gov/ispo

Robert Krause, of Los Alamos National Laboratory, presented Nuclear Magnetic Resonance (NMR). NMR provides a quantitative measure of the number of nuclei of a given isotope in a given sample. LANL developed a means for measuring the NMR signature of materials in ultra-low magnetic fields and at ultra-low frequencies. Applications include UF_6 flow monitoring, measuring ^{235}U and ^{238}U in enrichment monitoring, and UF_6 cylinder measurements. The benefits of NMR are that it is non-intrusive and no source is required. This technology was considered by the workshop participants to be revolutionary and the top priority for further study.

Table 1: List of Workshop Presentations

KEYNOTE ADDRESS

"Nonproliferation and Safeguards: Then and Now" by Leonard Weiss

SAFEGUARDS PRESENTATIONS

1. Opening Remarks, by Nikolai Khlebnikov
2. The Mission of the IAEA's Department of Safeguards, by Wan Soo Park
3. IAEA Safeguards Equipment , by Manfred Zendel and Martin Moeslinger
4. Research and Development Activities at the IAEA, by Bernard Wishard/Julian Whichello
5. Sensor Information and IAEA Safeguards Conclusion, by M. Lieskovsky/Tim Ayers
6. The U.S. Support Program (USSP) to IAEA Safeguards, by Albert Queirolo

TECHNICAL PRESENTATIONS

1. New types of Unattended Systems for Enrichment Plant Safeguards, by Mark Pickrell, et. al.
2. Speckle Photography for Revealing Hidden Structures, by Steve Mersch
3. Boron Carbide Based Neutron Detectors, by Shireen Adenwalla, et. al.
4. A System for Simultaneous Beta and Gamma Spectroscopy and its Application to Nuclear Non-Proliferation, by D.M. Hamby, et. al.
5. Advancements in High Resolution Gamma-Ray Detector Deployment, by Sam Hitch
6. Superconducting Ultra-High Energy Resolution Gamma-Ray and Neutron Spectrometers, by Stephan Friedrich
7. Novel Concept for a Directional Fast Neutron Detector, by D. Stuenkel, et. al.
8. Application of Imagery for Nonproliferation and Safeguards, by Yu Hashimoto
9. Multi-Isotope Process Monitor for Reprocessing Plants, by J. Schwantes, et. al.
10. Monitoring Solutions for Nuclear Materials Safeguards, by S. McElhaney, et. al.
11. Tritiated 3D Diode Betavoltaic Microbattery, by Larry Gadeken
12. Front-End Electronics for Thermal Neutron Detectors, by Kiril Ianakiev et. al.
13. Improving the Accuracy of an Uranium Enrichment Monitor Based on a NaI(Tl) Spectrometer and Transmission Source, by Kiril Ianakiev, et. al.
14. A Solid-state Hand-held Neutron Radiation Sensor by Sina Balkir
15. Use of Acoustic Wave Analysis for Safeguards Applications, by Michael Goldfarb, et. al.
16. Design for Stand-off Radiation Detector System Using Compton Scattering, by D. Stuenkel, et. al.

17. Standoff Detection and Identification of Nuclear Materials by Passive FTIR Radiometry, by Eldon Puckrin, et. al.
18. Investigation of Ultra-Low Field Nuclear Magnetic Resonance for UF6 Flow Measurements, by Robert Kraus, Jr., et. al.
19. Modern Safeguard Systems, by Chris Pickett, et. al.
20. Development of SiC Schottky Diode Detectors as an Advanced Sensor for Safeguards by Measurement of Actinide Concentrations in Molten Salt Electrolyte, by Thomas Blue, et. al.

Summary of Brainstorming Sessions

The working groups considered two scenarios. The first scenario involved clandestine enrichment activities at a declared location. The second scenario addressed clandestine production of plutonium at a declared nuclear research site that includes a research reactor.

The working groups were composed of IAEA staff members, member state representatives, Member State Support Program representatives, national laboratory, company and university representatives, and government employees. The participants shared their particular expertise to address the problems presented by the scenarios.

Enrichment Activities

The participants identified a number of shortfalls in the IAEA's ability to detect undeclared enrichment activities. Existing tools are sometimes too bulky and heavy, making them impractical for inspectors to carry. In addition, continuing training is required for inspectors to be comfortable using the variety of equipment they are expected to use on inspections. The training reduces their availability to conduct inspections but is essential to their collecting credible data.

Current tools leave the IAEA unable to detect the overproduction of low enriched uranium or the existence of remote piping that may be feeding clandestine facilities. The IAEA is limited by the accuracy of its instruments. Improved accuracy would strengthen the IAEA's ability to verify conclusively the flow and inventory of nuclear material.

The working groups made the following observations and recommendations:

- Accurately measuring the material balance is important in order to address diversion
- NMR could be a revolutionary technology for safeguards.
- The IAEA should also consider gamma ray tomography, tunable diode lasers, sampling of vacuum system cold traps, active neutron interrogation, and portable swipe sampling.

Research Site with Reactor

Some of the challenges and shortfalls for this scenario were similar to those identified for enrichment activities. The IAEA's existing tools are sometimes too bulky and heavy, and continuing training is required for inspectors to be comfortable using the variety of equipment they are expected to use on inspections.

Currently available tools leave the IAEA unable to detect partial defects of core and spent fuel, and give the IAEA no means to detect irradiated targets. Moreover, the IAEA is aware that the on-site power monitors that track the reactor operation history could be defeated, making the IAEA unable to independently estimate the plutonium production.

The working groups made the following observations and recommendations:

- Clandestine production of plutonium is the major concern with research reactors.
- Existing technologies could help but are not acceptable to the member states due to intrusiveness or the nature of data transmission.
- Advanced sensors should be smaller and detect unexpected materials and changes in physical configurations.
- Portable mass spectrometry could be used for detection of plutonium production.
- A portable environmental sampling analysis and recording system would allow inspectors to follow-up on findings while still on site, rather than making a follow-up trip.
- A high-resolution gamma system could be used for on-site identification of actinides.
- A portable information system and communication device could provide reference materials for inspectors to

use and allow them to get back-up support from their IAEA colleagues during inspections. [This recommendation was also made during the October 2005 Workshop on Safeguards Tools for the Future.]

IAEA Follow-Up Action Plan

Following the workshop, OAC and the IAEA compiled a workshop report. The report summarizes the workshop content, including the technical presentations, and documents the recommendations that were made during the brainstorming and close out sessions.

The IAEA Department of Safeguards will conduct an in-house review of the results of the meeting. The workshop was well-timed in that the IAEA is updating the Agency's R&D Programme for 2008/2009 and the recommendations that are accepted by the IAEA can be included in the Programme, which will address new and novel technologies. Once the R&D Program is updated, the IAEA can submit requests to its MSSPs for assistance in addressing the recommendations.

Conclusion

The Workshop on Advanced Sensors for Safeguards was held in Santa Fe, NM, April 23-27, 2007. The participants recommended technologies that could be used by the IAEA to strengthen safeguards. The IAEA will review the technical ideas and, if found to be valid, the IAEA will include them in the R&D Program. Technology that is already available will be tested and/or further developed under appropriate MSSP collaborations. The final technology recommendations will be sent to all MSSPs for comment and consideration.

The IAEA is considering a future workshop that will focus on integration of the IT driven October 2005 workshop with this hardware-oriented workshop.