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INTERNATIONAL NUCLEAR SAFEGUARDS AND SANDIA NATIONAL LABORATORIES (SNL)

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ABSTRACT

Sandia National Laboratories (SNL) has a long history of contributions to international nuclear safeguards. From the beginning of the U.S. support program to the International Atomic Energy Agency (IAEA) in the late 1970's, Sandia has used its advanced systems engineering capabilities to provide subject matter expertise and develop technology to strengthen the safeguards regime. In this paper, we discuss the capabilities and technologies Sandia has developed over the last four decades to contribute to the field of international nuclear safeguards. In our view, safeguards is fundamentally an information system, potentially at risk of being deceived if a State were to attempt to divert material or hide clandestine activity. It is the critical need for dependable and secure information that is the unifying theme for Sandia's contributions to international safeguards. Sandia's strengths include information management, equipment security, containment and surveillance (C/S) measures, unattended and remote monitoring, and safeguards for geological repositories. As one of the largest multi-program laboratories in the U.S., Sandia draws upon substantial core research and development capabilities across a wide range of fundamental science and engineering disciplines.

Sandia's safeguards work is supported principally by the National Nuclear Security Administration's (NNSA) Next Generation Safeguards Initiative (NGSI). Sandia often collaborates with other U.S. national laboratories in developing safeguards solutions. International partners include Argentina, Brazil, Japan, South Korea, France, Germany, the United Arab Emirates, and the European Atomic Energy Community (Euratom). Sandia also supports the safeguards mission of the IAEA through the U.S. Program of Technical Assistance to IAEA Safeguards (POTAS). This work advances state-of-the art safeguards technology and helps ensure the cradle-to-grave surety of safeguards information.

INTRODUCTION

Since the late 1970's, Sandia has supported the advancement of international nuclear safeguards through research and development (R&D) initiatives and subject matter expertise. Currently, Sandia's safeguards work is carried out in the International Safeguards and Engagements Department within the Center for Global Security and Cooperation (CGSC). The mission of Sandia's Safeguards Department is to provide technical solutions to the international safeguards regime and support the development of safeguards and export control competencies in partner countries. Through our U.S. government sponsors, we research technologies, build capabilities, and provide analyses to support the international nuclear nonproliferation monitoring regime's mission of ensuring that nuclear activities are used for peaceful purposes.

PROGRAMS AND CURRENT SAFEGUARDS WORK

Sandia's safeguards program is a mixture of collaborative international projects and R&D. These efforts include joint research studies pertinent to safeguards concepts, approaches, methodologies, and technologies as well as training and technical cooperation to support our foreign counterparts and the broader international nuclear safeguards regime. Sandia also supports and facilitates professional development opportunities to cultivate the next generation of U.S. safeguards subject matter experts (SME's).

With respect to Sandia's international cooperation, Sandia supports the NNSA International Nuclear Safeguards Engagement Program (INSEP) in its mission to collaborate with foreign partners to strengthen safeguards at all stages of nuclear development. INSEP maintains a diverse portfolio involving cooperation with international partners with credible plans for nuclear power to develop their nuclear infrastructures with an emphasis on safeguards and nonproliferation. INSEP also works to increase the effectiveness and efficiency of safeguards in partner countries, and to demonstrate and evaluate in facilities of foreign partners the real-world performance of novel safeguards technologies developed at U.S. National Labs. Sandia provides technical, analytical and program management support to INSEP to help fulfill its mission of strengthening and sustaining the international safeguards system.

Technology Development

Current safeguards-related work at Sandia consists of technology development projects, international training and cooperation, and joint research. Over the years, Sandia has developed a number of safeguards technologies and has played a key role in their development. Examples include the Electronic Optical Sealing System (EOSS), for which Sandia conducted a vulnerability assessment in the late 1990s. Sandia also developed the Remotely Monitored Sealing Array (RMSA), an active loop seal for IAEA safeguards application. Another example of a technology development project is the Enhanced Data Authentication System (EDAS), underway since 2008 via support from INSEP. This effort recently completed a field trial at an operational nuclear facility subject to safeguards. As a means to branch information from an existing measurement system to a secondary observer, EDAS creates a separate signal branch to the secondary observer from a point close to the measurement sensor. This provides a trusted copy of the intercepted digital information to an inspectorate, while assuring the operator that no sensitive information is transmitted. Sandia designed, developed, and manufactured prototype EDAS software and hardware for INSEP under Action Sheets (AS) 32 (2008) and 41 (2011) that meets both operator and inspector requirements. Commercial off-the-shelf (COTS) and custom hardware were incorporated, as well as open source and custom software. The successful completion of the field trial demonstrated that EDAS benefits both the facility operator and safeguards inspectorate by providing a means to securely monitor existing operator instrumentation without undue burden on the facility operator. Moreover, the design, development and testing of EDAS addresses the IAEA Long Term R&D plan item 7.1, "Develop minimally intrusive techniques that are both secure and authenticated to enable the use of operator's systems, instruments and process monitoring for cost effective safeguards implementation."[1] If EDAS is commercially manufactured and approved for IAEA use, it could have a significant impact on C/S measures and on secure, remote monitoring capabilities.

Training

Sandia's international training and cooperation involves partners in Europe, East Asia and South America. As an example, thanks to the laboratories' strong safeguards expertise in containment and surveillance (C/S), Sandia was recently invited to teach a short course on electronic seals in Japan at the Japan Atomic Energy Agency (JAEA). The two-day hands-on training session focused on EOSS and RMSA. The high-level objectives were to teach students to identify the main components of each sealing system and to understand how to apply and use these seals in the field. The training helped students describe specific features of EOSS and RMSA, identify appropriate safeguards containment applications of the seals, understand the basic authentication and encryption concepts, including cryptographic keys, apply and verify the seals for typical containment situations, and recite the procedural steps for operator installation.[2] Following the hands-on training, JAEA expressed appreciation for Sandia's help in strengthening Japanese knowledge and understanding of electronic seals and requested additional future training in the upcoming year, specifically on the Next Generation Surveillance System (NGSS) DCM-C5 camera. Contingent upon INSEP resources, Sandia plans to provide this training in 2017.

Professional Development

Since 2009, Sandia has proactively strengthened its international nuclear safeguards human capital and technical capabilities by supporting and facilitating professional development opportunities. By hiring staff with multidisciplinary backgrounds such as nuclear, electrical and mechanical engineering, geology, geography, and political science, Sandia has built a multidisciplinary workforce that contributes to NNSA's Next Generation Safeguards Initiative (NGSI). In addition to growing the number of international nuclear safeguards SME's, Sandia has provided University undergraduate- and graduate-level courses on nonproliferation science, policy and safeguards. Sandia also hires summer undergraduate and graduate interns that support regular staff with safeguards R&D projects. Sandia's nuclear safeguards human capital has also been strengthened through participation in training courses such as Idaho National Laboratory's (INL) *Pre-Inspector Training Course* and the *Fundamentals of Nondestructive Assay (NDA)* course at Los Alamos National Laboratory (LANL). These professional development and training opportunities have strengthened knowledge and understanding of equipment and fundamental concepts of nuclear nonproliferation, safeguards, and export controls at Sandia.

SANDIA'S SAFEGUARDS EXPERTISE

The international nuclear safeguards expertise at Sandia leverages the laboratories' core science, engineering, and analytical capabilities. Examples include equipment and information security, remote and unattended monitoring, vulnerability assessments (VA), C/S, geological repository safeguards, data analytics, on-site inspection and managed access. These capabilities provide support to critical aspects of international nuclear safeguards. For example, Sandia has long been a primary contributor to the development and enhancement of safeguards equipment with built-in authentication, encryption, and tamper indicating functions. This expertise supports the advancement of the state-of-the-art in equipment and information security, capabilities that are critically important to the effectiveness and efficiency of remote and unattended monitoring for international nuclear safeguards. Sandia also has several decades of experience with VA's to conduct rigorous independent testing of safeguards equipment in support of the certification process of technologies and systems for routine use by the IAEA. Finally, in addition to Sandia's C/S expertise, the laboratories leverage years of experience with geological repositories

to conduct research and analysis on the application of safeguards to these prospective facilities. In fact, Sandia is continuously asked by the U.S. government, foreign counterparts, and the IAEA to provide expertise and guidance on the development of safeguards methodologies and approaches to geological repositories. In sum, Sandia provides a wide variety of safeguards expertise and capabilities that help bolster the international nuclear safeguards regime.

INTERNATIONAL COOPERATION AND SUPPORT FOR THE IAEA

International Cooperation

Since the mid-1980s, Sandia has been engaged with the international nuclear safeguards community through R&D and training. Today, Sandia collaborates with partners in East Asia, South America and Europe. For instance, Sandia is currently cooperating with partners at Argentina's Autoridad Regulatoria Nuclear (ARN) to examine the application of C/S technologies to spent fuel verification. Sandia will help organize and facilitate a workshop at ARN for up to 20 participants to clarify the specific safeguards verification challenges, such as transfer verification of spent fuel elements between spent fuel ponds and dry storage facilities. The outcome will be strengthened knowledge and understanding amongst ARN staff of equipment available for safeguarding spent fuel in reactor storage and in transit, and various technological approaches. As previously mentioned, Sandia also collaborates with Japan on safeguards training, primarily in the application of C/S technologies.

In addition to international cooperation with Argentina and Japan, Sandia was recently engaged in research with Germany's Forschungszentrum Jülich (FZJ) to examine lifecycle challenges of the EOSS seal. The one-year collaborative effort sought to identify and analyze technical challenges and needs with the use of EOSS in the German safeguards program. Once the challenges were identified, the project considered certain adaptations to hardware and software as well as revisions to procedures relevant to the decommissioning process in Germany. Continued collaborative research with FZJ is under consideration.

IAEA Support

Since the late 1990s, Sandia has provided technical support to the IAEA through the U.S. Support Program and the Program of Technical Assistance (POTAS). POTAS is a U.S. government interagency committee whose members come from the U.S Departments of Energy, State, and Defense, as well as the U.S. Nuclear Regulatory Commission (NRC). POTAS is managed by the International Safeguards Project Office (ISPO) at Brookhaven National Laboratory (BNL) and funded by the Department of State. When the IAEA identifies a specific need, it issues a request for proposals known as an "SP-1". ISPO relays the request to qualified technical organizations, including the U.S. National Laboratories and certain commercial providers. If appropriate, Sandia will assemble a team to develop and submit a proposal. If Sandia's proposal is accepted, a contract is established to plan and execute the project.[3]

A recent example is Sandia's support to the IAEA for the design and development of the Remotely Monitored Sealing Array (RMSA).[4] As an active loop seal for IAEA safeguards application, the RMSA both reduces the number of IAEA inspector-days in the field needed to seal and verify spent fuel in dry storage and increases confidence in seal-verification processes. Sandia employs a system of low-cost, remotely interrogated active seals that can be easily

applied in large sealing arrays. RMSA provides information on seal integrity via authenticated and encrypted wireless transmission to a central translator that stores and forwards collected data from all remote sensors. The RMSA is optimized for low power consumption with a battery life of up to 5 years. The plastic fiber-optic seal cable is easy to install and terminate and incorporates advanced tamper indication and communications capabilities. The RMSA offers certain advantages over other seals, including its low-cost and its capability to remotely and securely store and transmit data (tamper events, open/close events, seal status) via a radio frequency (RF) signal. The RMSA represents several years of research and development at Sandia and has undergone IAEA safeguards certification. It is now being commercially manufactured by Canberra Industries and will soon be deployed in the field by the IAEA.[5]

RESEARCH AND DEVELOPMENT (R&D)

Sandia is continuously involved in safeguards R&D with the support of both U.S. government sponsors and internal Laboratory Directed Research and Development (LDRD) funds. Recent efforts involve the exploration of new C/S technologies as well as advanced tools for information analysis. Examples include the development of a ceramic seal and research on a form of secure video surveillance in hazardous environments, as described below.

Ceramic Seal

Since 2011, Sandia has collaborated with Savannah River National Laboratory (SRNL) on an NNSA-sponsored project to develop a tamper-indicating ceramic seal. This seal, which recently completed the prototype development process, includes a frangible ceramic body, exterior fluorescent tamper-indicating coatings, electronic monitoring of unauthorized opening or penetration, a self-securing wire, and in-situ verification using a handheld reader.[6] This seal advances security and improves efficiency for small form-factor, single-use, passive-loop seals for maintaining continuity of knowledge or chain of custody. Potential applications include international nuclear safeguards, arms control, and high-value assets. Work is currently underway to develop a handheld reader with authentication and the ability to verify external fluorescent coatings. A separate tablet interface reader is able to connect to a network, allowing data management in a consolidated location. Field testing is scheduled for 2016. Once development and testing is complete, the seal could replace the IAEA's metal cup seal, for use by other safeguards inspectorates, or for use by entities in need of a sealing device for high-value assets.

Standoff Video

Since 2014, Sandia has been researching options for the surveillance of objects in difficult-to-access hazardous environments, such as a hot cell. Supported by NGSI's Safeguards Technology Development subprogram, this work explores optical architectures that introduce a standoff distance of several meters between the scene of interest and the surveillance camera. Several proposed approaches enable one to authenticate not only that the extended optical path is secure, but also that the scene is being viewed live. These approaches employ optical components with remotely operated spectral, temporal, directional, and intensity properties that are under the control of the inspector. If permitted by facility operators, illuminators, reflectors and polarizers placed in the scene offer further possibilities to authenticate the image. Any tampering that substitutes an alternative image source for the camera, although undetectable with conventional cryptographic authentication of digital camera data, is easily exposed.[7]

Authentication is conducted by using LED illumination of the scene, which varies in intensity, position, color and timing. 'Spots' are displayed in the image of the object that uniquely identifies the image, providing authentication. Should this research be funded for further R&D, such as prototype development and field trials, it could support the advancement of C/S approaches and improve the IAEA's ability to implement safeguards in difficult-to-access hazardous environments.

CONCLUSION

Sandia's support for and involvement in international nuclear safeguards dates back nearly four decades. By using the Laboratories' unique science, engineering and analytical capabilities, Sandia has advanced and strengthened international safeguards. Through international cooperation, R&D, training, and professional development, Sandia provides a unique tool set of both subject-matter expertise and technical solutions to the international safeguards regime. Specifically, Sandia's R&D efforts in areas such as containment and surveillance and information security, human capital development, and systems analysis provide a positive impact on the international nonproliferation regime's mission to ensure that nuclear activities are intended for peaceful purposes only.

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[1] IAEA Department of Safeguards, *Long-Term R&D Plan, 2012-2023*. Page 7, item 7.1. Vienna, Austria. January, 2013.

[2] Smartt, Heidi. *Electronic Optical Sealing System (EOSS) – Hands on Training*. Sandia National Laboratories. SAND2016-4491TR.

[3] Haddal, Risa. *International Nuclear Safeguards at SNL: History and Background*. Slides 8 and 9. Next Generation Safeguards Professional Network (NGSPN). March 10, 2014. SAND2013-8037C.

[4] SP-1. *Development of a Remotely Monitored Sealing Array*. International Atomic Energy Agency. 07/TSR-005. November 29, 2007.

[5] Canberra Industries. *Seals, RMSA Remotely Monitored Sealing Array*. http://www.canberra.com/products/safeguards_surveillance_seals/seals.asp

[6] Smartt, H. *Advanced Tamper-Indicating Loop Seal*. Sandia National Laboratories (SNL) Fact Sheet. SAND2015-88110.

[7] Baldwin, G. T. *Authentication Approaches for Standoff Video Surveillance*. Abstract for the IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People. IAEA Headquarters. Vienna, Austria. 20-24 October 2014. SAND2014-3196 A.