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Applying Knowledge Retention to Preserve a Core Safeguards Technical Area

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Abstract:

The international safeguards community is facing the significant challenge of accelerating loss of practical safeguards expertise due to retirement of established and knowledgeable experts. This loss of critical expertise is particularly evident in safeguards areas that traditionally receive less attention during inspector or safeguards staff training. One such area is Containment/Surveillance (C/S). Existing training for C/S is usually relegated to a small part of broader-scope training, where far more attention is devoted to accountancy measures, nondestructive assay, and other aspects of safeguards.

Sandia National Laboratories (SNL) has been key to designing, developing, and implementing C/S technologies and approaches since the 1970s. C/S is a key competency of SNL and of critical importance to all past and evolving international nuclear safeguards approaches. To counter the persisting issue of knowledge loss, SNL is currently engaging in a C/S knowledge retention program to provide opportunities for young professionals to work directly with mid-career safeguards practitioners as well as senior safeguards practitioners on safeguards C/S related topics. This initiative aims at capturing institutional knowledge on C/S and support knowledge retention and transmission bringing safeguards practitioners in close and constant collaboration.

This program has several pillars for knowledge transfer which include C/S history, C/S technologies (past, present, and future), vulnerability reviews/assessment, best practices for C/S technologies and approaches and finally, current and future technologies and issues.

This paper will describe efforts to allow for knowledge retention and transmission of one of SNL core safeguards technical areas. It will also highlight how new key contributors can be tied into the subject matter, not only from within the traditional safeguards field but from other technical areas like chemistry. The paper will further show how to broaden the C/S safeguards horizon by bringing in novel ideas from different industries and unlikely partners to redefine the future technological directions of C/S. SAND2019-0265 A.

Keywords: International Safeguards; Containment/Surveillance; Knowledge Retention

1. Introduction

Due to retirement of established and knowledgeable experts, the international safeguards community is facing the significant challenge of accelerating loss of practical safeguards expertise. This is part of a broader trend in the nuclear industry where staff that started work in the late 1970s and 1980s, when nuclear fleets were expanding in a number of countries world-wide, are starting to retire, leaving a gap as fewer newcomers enter the nuclear industry. A similar situation is visible in the area of international safeguards: long-standing experts that have guided safeguards implementation through the Comprehensive Safeguards Agreement (INFCIRC/153) and the Model Additional Protocol (INFCIRC/540) have to hand over the reins, but often without an appropriate transition plan or sufficient time to pass along a lifetime of expertise.

While the problem of knowledge retention is universal through the international safeguards and non-proliferation community, it is even more profound in smaller, technical areas that receive less attention during safeguards inspector and staff training which focus on accountancy measures and which are burdened with an ever-widening scope of activities related to the verification of the absence of undeclared activities under the Additional Protocol and State-Level safeguards. One such technical area is Containment and Surveillance (C/S).

C/S activities are indispensable for the safeguarding of declared nuclear facilities to establish Continuity of Knowledge (CoK) about the absence of diversion efforts in-between inspector visits. Instrumentation installed by the IAEA needs to be rugged, highly reliable, and the data generated tamper-indicating. Designing, operating, and maintaining such instruments (e.g., surveillance cameras and seals) requires not only specialized technical expertise, but also knowledge in other areas such as data encryption and authentication, secure storage, and tamper-indicating enclosures. The combination of skills needed is quite unique for international safeguards and as such the relevant technical staff has to be prepared and trained in-house over time.

Unexpected departure of knowledgeable staff and retirement without sufficient time to train replacement can lead to the loss of expertise that is difficult to replace. As such, knowledge retention efforts become an essential plan of human capital development in this area. This issue is by no means restricted to safeguards agencies such as IAEA or EURATOM alone, but also affects the numerous research and development laboratories that for decades have supported the development of C/S instrumentation, performed vulnerability assessments, and who have supplied expertise to the international safeguards community.

The following paper will outline the knowledge retention management effort at Sandia National Laboratories (SNL) and describe several pillars for knowledge transfer which include C/S history, C/S technologies (past, present, and future), vulnerability reviews/assessment, best practices for C/S technologies and approaches, and finally, current and future C/S technologies and issues. It will also highlight how new key contributors can be tied into the subject matter, not only from within the traditional safeguards field but from other technical areas like chemistry. The paper will further show how to broaden the C/S safeguards horizon by bringing in novel ideas from different industries and unlikely partners to redefine the future technological directions of C/S.

2. Sandia National Laboratories and C/S

Traditional safeguarding of declared facilities includes a combination of inspections, analysis, and C/S measures. C/S methods ensure CoK about nuclear materials and stay at a facility between inspections. In the early days of the first rollout of C/S measures, the IAEA had some internal capabilities for technology development and built film camera systems as well as software-based systems using microprocessor technology in the 1970s. But quickly the design and development shifted from internal resources to outside parties, primarily to the laboratory community of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) Member States and the private sector.

SNL has been key to designing, developing, and implementing C/S technologies and approaches since the 1970s. During the early to mid 1980s, SNL was tasked to develop unattended monitoring systems, including surveillance and seals. In the early 1980s SNL developed the Cobra passive fiber optic loop seal [1]. The Cobra seal eventually became a standard tool for IAEA safeguards and EURATOM, and is – in an updated form – still a standard today.

In the mid 1980s, SNL developed a prototype surveillance system called the Modular Integrated Video System (MIVS) under DOE's program for international safeguards. Interestingly, even these early technologies included a tamper-indicating enclosure and tamper indication of the video and power line from the main unit to the camera unit, even though such measures were restricted in efficiency due to the analog nature of the data media. Requirements evolved from interactions between SNL and the IAEA's organization for system development and in the late 1980s MIVS was released for commercialization, involving the private sector for the first time [1].

Another effort beginning in the mid 1980s was for an active fiber optic loop seal for potential use by the IAEA. It was based on an earlier SNL developed RF seal that had been designed for domestic safeguards at the Hanford site, but would require the addition of a tamper-indicating enclosure and other tamper-indicating features. It was called the Authenticated Item Monitoring System (AIMS). Included in AIMS, and all subsequent digital systems was the concept of data authentication. International safeguards rely on accurate assessments of nuclear material and activities. Data authentication ensures that safeguards authorities can trust the information they receive [1]. The associated data security R&D formed the basis for the cryptographic data authentication approaches still used today.

SNL's safeguards work in the 1990s was influenced by the policy development manifested in the 'Programme 93+2', the results of the NPT review conference in 1995, and the Model Additional Protocol in 1997 which changed the legal framework for international safeguards oversight and expanded activities beyond declared nuclear facilities and traditional safeguards. From the late 1990s to present, SNL has developed systems and technologies for both traditional safeguards and safeguards enhanced through the Additional Protocol and has provided analyses, vulnerability assessments, training and demonstrations throughout the safeguards community.

In the mid-2000s, SNL developed a new generation of RF-based active sealing technology supported by a standardized communications protocol: The Remotely Monitored Sealing Array (RMSA). Installed as a series of active loop seals at dry storage site of spent fuel, a large number of RMSA seals can constantly report data back to a data collection translator via authenticated and encrypted wireless transmission. The translator can alternatively store data locally for retrieval by an IAEA inspector or – when allowed – transmit it automatically to the remote monitoring data center at IAEA headquarters in Vienna, Austria [2].

Another instance of the development of creative solutions for C/S is SNL's collaboration with Savannah River National Laboratory (SRNL) on a tamper-indicating, ceramic seal. This seal consists of a ceramic body with fluorescent tamper-indicating coating, electronic monitoring of unauthorized opening or penetration, a self-securing wire, and in-situ verification with a handheld reader [2]. SNL continues its tradition of developing safeguards surveillance technologies with its recent Standoff Video project which offers options for the surveillance of objects in highly radioactive and difficult-to-access hazardous environments [2, 3].

SNL's rich history and deep expertise in the authentication of data and protecting instrumentation from tampering has made the laboratories a frequent provider of vulnerability assessments of solutions developed by other parties. Several decades of experience in independent and rigorous testing to take on the adversary's role and try to defeat a system have made SNL a key partner in the certification process of solutions for routine safeguards use [2].

3. Relevance of C/S in Future IAEA Safeguards

With the shift from quantitative safeguards under the Comprehensive Safeguards agreement towards a more qualitative assessment of a State as a whole under State-Level safeguards, the question arises about the relevance of technical measures and C/S. If a state can be evaluated based on all available information from various sources, is CoK still a critical element or could such resources be of better use elsewhere in the analysis process?

While such a reallocation of resources might be tempting, the determination of compliance with safeguards agreements remains based on the verification of whether a diversion of nuclear material took place. Information analysis of a state as a whole is an extension of using all available data, but not a replacement for the usual verification methods applied at a facility. As such, C/S, along with the other disciplines such as material accountancy or sampling and analysis, will remain relevant [4].

This relevance underscores the dangers of the loss of critical expertise and the need for knowledge retention measures so much more immediate. C/S measures will need to continue to evolve to stay ahead of advancing methods to defeat older technologies, and a skilled workforce will be needed to develop new solutions, test new approaches, and train safeguards inspectors in their use [4].

4. Knowledge Retention at Sandia National Laboratories

SNL is currently engaging in a C/S knowledge retention program to provide opportunities for young professionals to work directly with mid-career safeguards practitioners as well as senior safeguards practitioners on safeguards C/S related topics. To support this program (and others), SNL has developed a Knowledge Transfer (KT) Process (Figure 1) for Subject Matter Experts (SME) in order to guide those who are involved in off-boarding activities (whether that be an internal move/transfer or other departure such as retirement) through a best-practice, step-by-step approach designed to support the successful transition of projects, work, and especially key knowledge [5].

The purpose of this process is also to stimulate conversations with regards to Knowledge Management and Knowledge Preservation by providing a basic structural framework to begin this work. Figure 1 depicts the flow of this process [5].

Figure 1: Knowledge Transfer Process for HR Business Partner (HRBP), Management and SMEs

Note: This process is designed to be used to meet urgent/emergent KT/Off-Boarding needs (Steps 1-9) as well as help support short and long-term Knowledge Management Process that enhance and build business/team/innovation capacities (Steps 4-12).

In the context of our C/S knowledge retention program we used the Steps 4-12 as describe below to guide our project goals and methodology:

Step 4 – Identify Key/Critical Roles: The purpose of this step is to identify the key/critical roles that are essential to fulfilling the C/S group's mission. It is best practice to ensure there is bench strength within the key/critical roles.

Step 5 – Identify Key SME's: Identification of the individuals who have the key/critical knowledge that is essential in fulfilling the group's mission.

Step 6 – Identify Key/Critical Tasks: This step is designed to gain an understanding of what tasks are critical to a role or job.

Step 7 – Identify Key/Critical Knowledge: Once tasks have been identified and knowledge to do those tasks as been identified, this knowledge needs to be preserved and in a timely manner. As a tool, a

Knowledge Capture Decision Matrix could be used to determine what information is important to capture and when it needs to be captured.

Step 8 – Set Knowledge Capture/Transfer Priorities: The purpose of this step is to rank the importance of knowledge as it relates to ensuring the capabilities of the group are preserved. This priority list should drive the order of knowledge capture efforts in the next step.

Step 9 – Create Knowledge Capture/Transfer Plan: The purpose of this step is to create an actionable plan for both capturing and transferring essential knowledge and what methods will be used to do this work.

Step 10 – Process Documentation: In many cases, processes are all in people's heads (tacit knowledge) and it needs to be made explicit. Therefore, it is important for SMEs to capture essential processes that support their work, their ideas, their thinking, etc.

Step 11 – Project Documentation: Project documentation is very important for the continuity of many of the group's programs, especially those programs that have many projects associated with them and that extend over a broad period of time. This work is also essential when someone is vacating a position and others will be taking over where they left off. The sharing of the project documents is essential to the off-boarding/on-boarding process.

Step 12 – Other Identified Knowledge Transfer Activities [5].

5. C/S Knowledge Retention Program

C/S is a key competency of SNL and of critical importance to all past and evolving international nuclear safeguards approaches, yet is greatly underrepresented in the existing training and as such particularly sensitive to knowledge loss. Existing training for C/S is usually relegated to a small part of broader-scope training, where far more attention is devoted to accountancy measures, nondestructive assay, and other aspects of safeguards.

The initiative of a C/S knowledge retention program at SNL aims at capturing institutional knowledge on C/S and support knowledge retention and transmission bringing young professionals and mid- to high-level career safeguards practitioners in close and constant collaboration, following the process outlined above.

This program was envisioned to comprehensibly cover the subject area. To set the stage, it is covering all concepts of (dual) C/S, explain the concept of CoK, and outline the major elements that comprise C/S and also the following: tags, seals, tamper-indicating enclosures, data authentication and encryption, video surveillance, video review, unattended systems, remote systems, secure communication, vulnerability assessments, etc.

In addition to unfettered access to the accumulated expertise of mid- and high-level safeguards experts, young professionals are working hands-on with funded projects and actual devices, equipment and systems. The program also covers the legacy systems and the evolution of C/S over the years in reviewing safeguards knowledge left by recently retired safeguards experts. Understanding safeguards policy is critical for the appropriate placement of new research and development projects, as such, fundamental safeguards concepts (comprehensive safeguards agreement, model additional protocol, state-level concept, etc.) was covered, as well.

Consideration of candidates for the C/S knowledge retention program included SMEs with technical background, junior level experience at SNL, and high interest/enthusiasm for the field. SNL was initially unable to find a candidate with all three characteristics. However, a senior staff member had a new junior staffer (less than two years at SNL) on an NNSA project (NA-22 funded project "Tamper-Indicating Enclosures with Visually Obvious Tamper Response"). The young professional has a PhD in chemistry and works in the "Microsystem Packaging and Polymer Processing" department. While we did not initially consider a chemistry background for the candidate, he presented numerous ideas in the chemical field that could be relevant to C/S and tamper-indicating technologies. These ideas have the potential to significantly contribute the technical aspects of C/S. Furthermore, he demonstrated an enthusiasm for the field, and thus was ultimately selected for the position.

6. C/S knowledge Retention Program: Work in Progress

This project has identified and is currently training the selected junior staff member with several pillars for knowledge transfer. These include:

- C/S history (including NNSA & ESARDA C/S course for background as well as SNL historical documents)
- C/S technologies (past, present, and future)
- Vulnerability reviews/assessments
- Best practices for C/S technologies and approaches
- Current and future C/S technologies and issues.

Once the individuals who have the key/critical knowledge that is essential in fulfilling the C/S knowledge retention program's mission were identified, the team identified and reviewed relevant literature and organized exchange with senior- and mid-level experts for the pillars mentioned above.

As part of the program, the Sandia Technology Training and Demonstration Area for equipment demonstration and hand-on learning was used (Figures 2 and 3).

Figures 2 and 3: Equipment demonstration during the C/S Knowledge Retention Program

Furthermore, SNL selected relevant training/workshop/conferences for the junior staff to attend and contribute, including:

- INMM Just Trust Me Workshop (March 2019): This workshop provided a professional development opportunity to learn from policy and technology experts involved in safeguards, security, and arms control around the theme of how we establish and authenticate trust. Its format combined presentations, and scenario-based table top exercises that integrate key themes from the presentations (Figures 4 and 5).

- 41st ESARDA Annual Meeting (May 2019): The 2019 Symposium marks the 50th anniversary of ESARDA, which provides a unique opportunity for research organizations, safeguards authorities and nuclear plant operators to exchange information on new aspects of international safeguards and non-proliferation, as well as recent developments in nuclear safeguards and non-proliferation related research activities and their implications for the safeguards community.

- DOE/NNSA's introductory course on nuclear nonproliferation and safeguards (June 2019): The purpose of the course is to provide participants with a fundamental understanding of the nuclear fuel cycle, the nuclear nonproliferation regime, international safeguards agreements and verification mechanisms including: nondestructive assay techniques and equipment, destructive assay techniques, environmental sampling, and C/S.


Figures 4 and 5: INMM Just Trust Me Workshop

7. Knowledge Retention and Cross-disciplinary Synergies

Exposing young professionals from other scientific fields to expertise transmitted during knowledge retention exercises can have an exciting side effect: it can inject novel ideas from different industries and unlikely partners into the original field. As an example, the young professional attended the 2018 Packaging Exposition (Pack Expo) in Chicago, IL. It provided an opportunity to evaluate unique techniques for tamper indication and unique identifiers for safeguard application purposes, from a field that is usually not connected to international safeguards in any way.

During this expo, there was a particular process that was identified that showed potential for application in C/S. A facile UV-curable ink was demonstrated on a small piece of plastic. The piece of plastic was placed on a conveyer belt that then went under an ink applicator followed by an UV light that instantly cured that ink into a solid. If the plastic was removed before the UV light then the ink easily wipes off. Upon closer examination of the cured ink it was seen that the ink application process is performed in lines and that the curing process causes patches of ink to come together. A second sample was requested from the company representative to compare the reproducibility of the ink patches upon curing. The optical images of the two samples is provided below (Figure 6) along with three particular areas in each.

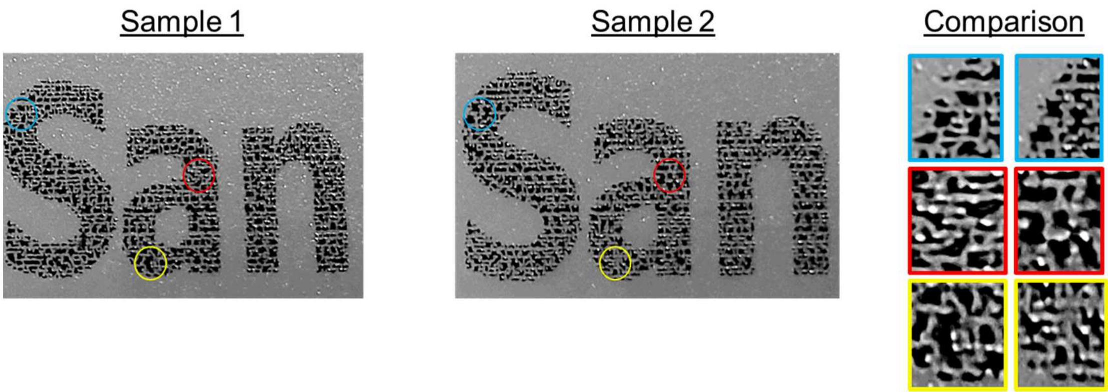

Figure 6: Two samples of UV-cured ink on a piece of plastic. Close-up comparisons of individual areas show drastically different patterns.

Due to the stochastic behavior of the curing process, every print and cure of ink is unique and could potentially be used as an efficiently-made identifier for safeguards applications. Furthermore, after discussions with printing subject matter experts, they suggested that the stochastic behavior and the minimum height of the ink would be very difficult to reproduce or counterfeit. Further investigation of this idea will follow.

8. Conclusion

Knowledge retention is a significant challenge in general and even more pronounced in smaller, niche applications of international safeguards, such as C/S. It can be addressed with foresight, planning, and the application of a standardized process to capture and preserve critical knowledge. Following the example of a young professional at SNL, benefits of such an effort become quickly visible.

With the understanding of the importance of the mentoring aspect, the young professional selected for the C/S knowledge retention program has in turn been encouraging his post-doctorate to join certain background sessions of the program to also get acquainted with not just the C/S application space itself, but also the very important role SNL has had in the past, present, and future in international safeguards. The post-doctorate is also significantly involved in the novel tamper-indicating enclosure project funded by NNSA. Together they bridge the gap between these applications spaces and the materials that are developed for them. Safeguards are constantly in need of updated or novel materials and mechanisms and utilizing materials scientists with application space knowledge retention is a promising avenue for the future of safeguards.

Finally, as a result of this program, a recent opportunity has presented itself for the involvement of the junior professional in areas related to vulnerability assessment. This topic is a key component of many areas of research, including those seen in C/S. If involvement is proven successful, additional experience will be obtained that will aid in the development of this retention program.

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10. References

[1] Tolk, K, Mangan, Glidewell, D, Matter, Whichello, J; *Safeguards Sensors and Systems: Past, Present, and Future*; Journal of Nuclear Material Management, vol. XXXV, no. 4, pp. 101 – 109, Summer 2007.

[2] Haddal, R, Blair, D., Finch, R; *International Nuclear Safeguards and Sandia National Laboratories*; Proceedings of the 57th Annual Meeting of the Institute for Nuclear Materials Management, Atlanta, Georgia, July 2016.

[3] Baldwin, G., Sweatt W., Thomas, M.; *Authentication Approaches for Standoff Video Surveillance*; Abstract for the IAEA Symposium on International Safeguards: Linking Strategy, Implementation and People, IAEA Headquarters, Vienna, Austria, October 2014.

[4] Carlson, J.; *Future Directions in IAEA Safeguards*; Harvard Kennedy School, Belfer Center for Sciences and International Affairs, November 2018.

[5] VanArsdale, A.; *Off-Boarding/Knowledge Transfer Toolkit*; Sandia National Laboratories; SAND2017-13443PE.