ABSTRACT
Sandia National Laboratories (SNL) and the Russian Federal Nuclear Center-All Russian Research Institute for Experimental Physics (VNIIEF) (also known as Arzamas-16) are collaborating on ways to assure the highest standards on safety, security, and international accountability of fissile material. This includes systems used to reduce the need for human access to fissile material, reduce radiation exposure, and provide prompt safety-related information, and provide continuous international accountability information while reducing the need for intrusive, on-site visits. This paper will report on the ongoing SNL/VNIIEF efforts to develop technologies and monitoring systems to meet these goals. Specific topics covered will include: the Smart Bolt tag/seal development, development and testing of electronic sensor platforms (U.S. T-1 ESP and VNIIEF Radio Tag) for monitoring and transportation applications, the "Magazine-to-Magazine" remote monitoring system field test, and the "Facility-to-Facility" storage monitoring system field trial.

BACKGROUND
Sandia National Laboratories has been working with VNIIEF since 1993 on the development of storage monitoring technologies for the scenario shown in Figure 1. This long relationship has led to a variety of technologies and systems developed for both short and long-term storage of fissile

Figure 1: Storage Activity Monitoring
Figure 2: Single-Use Smart Bolt (left), Multi-Use Smart Bolt (right).

material [1-4]. Currently, work is being done on developing new hardware (tag/seals, ESP’s) and field trials are being tested to demonstrate monitoring scenarios. The field trials started with the “container-to-container” experiment, which lead to the “magazine-to-magazine” experiment, which was just completed in June of 1999. The facility-to-facility experiment is in its installation phase.

HARDWARE
Seal/Tag
Single-Use Smart Bolt The seal/tag technology being developed is primarily for sealing and tagging storage containers containing fissile material. There are two “Smart Bolts” being developed, the single-use (Figure 2) and the multi-use (Figure 2). The single-use bolt is intended for long-term storage where access is limited, and the multi-use bolt is intended for short-term storage scenarios where access is easy and necessary.

The single-use bolt has many features, which makes it attractive for long-term storage applications. It does not require power during the storage cycle but it has built-in memory (128 bytes) capable of storing information about the container, its contents, and passwords. Since there is no need for power or maintenance, the bolt essentially has an unlimited life. The bolt is used to attach the lid of the container to the can. Once the bolt is tightened the container is sealed. If an attempt is made to remove the bolt, the chip inside of the bolt is destroyed rendering the bolt useless and indicating that the bolt has been tampered with. Other characteristics of the bolt are its 10 mm thread diameter, stainless steel constructions which makes it corrosive-resistant, and its operating temperature range of -40 °C to 125 °C. The initial research on the single-use bolt was completed in 1996.

The reader-verifier adapter is a peripheral used to connect the bolt to a laptop computer. With this peripheral, the bolt can be initialized and verified. The reader-verifier can be used to interrogate the bolt to read the stored information. This information is controlled using two levels of password protection.

Multi-Use Smart Bolt The multi-use bolt is intended for short-term storage applications where access is easy and necessary. The multi-use bolt has many features, which makes it attractive for
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
short-term storage applications. This bolt is reusable and requires power during the storage cycle, which comes from two 1.5 volt batteries. The multi-use bolt has built-in memory (128 bytes) capable of storing information about the container, the container contents, passwords, and a count of times the bolt has been removed. Since there is a need for power, the bolt has a life of typically three to five years dependent on the type of batteries used and the number of interrogations of the bolt. The bolt is used to attach the lid of the container to the can. Once the bolt is tightened the container is sealed. If an attempt is made to remove the bolt, an access is written to the memory in the bolt. Multiple accesses can be registered. Other characteristics of the bolt are that it has a 10 mm thread diameter, stainless steel constructions which makes it corrosive-resistant, and can operate in temperatures ranging from –20 °C to 80 °C. Initial research on the multi-use bolt was completed in 1997. Multi-use smart bolt system which includes the reader-verifier and software, is currently being beta tested and enhancements to the software are being made.

The reader-verifier is an electro-optical peripheral used to connect the bolt to a laptop computer. With this peripheral, the bolt can be initialized and verified. The reader-verifier can be used to interrogate the bolt to read the stored information, which is protected, using two levels of password.

**Next Generation Smart Bolts**Currently, research is continuing in the seal/tag area. The Next Generation Smart Bolts are shown in Figure 3. This additional research is being done to make the bolts more reliable and compatible with a radio frequency (RF) cap. Using this cap, an inspector will be able to remotely access the information stored in the bolt, determine if the bolt has been tampered with, and/or determine the state of health of the bolt. Access to either bolt can be made from as far as 2500 meters using the RF cap.

![Next Generation Seal/Tag Hardware](image)

---

**Figure 3:** Next Generation Seal/Tag Hardware
There are some common enhancements being made to both the single-use and multi-use bolts. Information storage and access capabilities, both reading and writing, will be enhanced. Also, the design of the bolts has been changed for two reasons: 1) to reduce the likelihood that the bolts can be circumvented or spoofed and 2) to accommodate the RF cap that has been developed.

Electronic Sensor Platforms
Both the U.S. T-1 ESP (Electronic Sensor Platform) and the Russian radio tag ESP systems are comprised of the ESP (Figure 4) and its interrogator transceiver. The transceiver interrogates, or submits requests, for data to individual ESPS and receives the resulting data supplied by the ESPs through two-way RF communications. The ESP is described as an electronic sensor platform, because it supports a variety of internal and external sensors. The data from these sensors is then authenticated and sent to the interrogator transceiver. The T-1 ESP sensor mix is designed to provide the maximum flexibility while providing key attributes of the state of health of the ESP itself. The following sensors are supported: fiber optic seal, motion, temperature, battery voltage, high/low temperature alarm, and case tamper. Moreover, the circuitry can also accommodate an additional 2 analog ports and 3 digital input/output control ports. Detailed descriptions are available in separate publications [5-7]. The Russian radio tag ESP has similar capabilities as the T-1 and has range of 2500m. To date, well over 100 T-1s have been produced, and production continues at the DOE Allied Signal plant in Kansas City. VNIIIEF will have the first prototype of the radio tag completed by July 1999.

T-1 ESP Testing: To ensure that the T-1 ESP will be reliable in a variety of locations, environmental testing will be done. The test plan that will be followed is based on a life-cycle environment profile typical of transportation and handling environments. The environmental test of the T-1 is critical in determining its reliability. The sample size of 30 T-1 ESPs will be delivered to VNIIIEF, and will be subjected to the following environments:
- Powered Temperature/Humidity Cycles Phase I
- Powered Temperature Shock
- Powered Random Vibration Tests with Temperature Control
- Powered Shock Tests
- Powered Temperature/Humidity Cycle Tests, Phase II
The testing of this sample is to be completed in early 2000.

Figure 4: U.S. T-1 ESP (left), Russian Radio Tag (right)
FIELD TRIALS
Sandia and VNIIEF have established a series of remote monitoring field trials to provide a mechanism for joint research and development on storage monitoring systems. These efforts consist of the "Container-to-Container", "Magazine-to-Magazine", and "Facility-to-Facility" field trials and are summarized in Figure 5.

Container-to-Container  The Container-to-Container field trial enabled Sandia and VNIIEF to initiate work on a remote monitoring system and establish near real-time exchange of sensor information via the Internet. This field trial was completed September 30, 1998.

Magazine-to-Magazine  The Magazine-to-Magazine field trial and the implementations in both the US and Russian magazines used RF based sensors for individual item monitors, Echelon network-based sensors, video, advanced authentication implementations and information security [8]. The data from the Magazine-to-Magazine field trial is available on the Internet at: http://magtomag.ca.sandia.gov. This site provides live and historical data from both the Sandia and VNIIEF magazines. With the completion of the VNIIEF magazine, the Magazine-to-Magazine field trial entered its second phase: system evaluation. The major emphasis of the field trial in 1999 was to exercise the magazine system and determine its strengths and weaknesses [9]. The following are lessons learned from the field trial:

- **Configuration Control – Software Components**: Only necessary applications should be run on the main monitoring system computers. Additional programs can disturb the rest of the system.

- **Configuration Control – Software Installation**: The magazine was upgraded numerous times. This led to some problems with knowing exactly what drivers, files, etc. were loaded. For future systems, it is recommended that a clean software installation be performed for each computer.

![Figure 5: Field Trial Demonstrations](image)

**Figure 5: Field Trial Demonstrations**
• **Configuration Control – Sensor Programming.** Similar to the above problem, numerous people over time programmed sensors. During the evaluation, it was uncertain how certain sensors were configured with the rest of the system. A single, standard location for storing sensor configuration data on the system is needed.

• **Configuration Control – Facility Anomalies.** It is necessary to closely examine where a sensor is going to be deployed and determine what facility factors may generate false data.

• **Configuration Control – Detailed Checklist.** Small details can detract from the robustness of the system if overlooked. A detailed checklist that covers all the possible settings and details is needed for a system to be robust.

• **Configuration Control – Phraseology.** Some of the terms used in the monitoring system were confusing. The wording of the specific messages viewed by users should be reviewed by the entire team and validated before the software is released. Once the phrases and messages are agreed to, they need to be documented, along with any necessary context.

• All the sensors should report at least once per day.

• **Windows NT Problems.** Despite Microsoft’s attempt to make Windows NT a robust operating system, it will still generate anomalies. An occasional “Out of Memory” or other error messages still occur at random times. Until the community decides to move to an alternate operating system, it will be necessary to insert “Dead Man” timers into the NT machines. These devices look for a “heart beep” of the NT operating system. If for some reason the operating system hangs up, the device will reset the computer.

**Facility-to-Facility**  
The next major step in Sandia's and VNIIEF's Storage Monitoring Collaboration is the Facility-to-Facility field trial. Just as the Magazine-to-Magazine field trial allowed the collaboration to face "system" issues, the Facility-to-Facility field trial will provide an opportunity to address true "operation" issues. Working in a real storage facility with real material and real operations will provide many challenges to a material monitoring system.

The monitoring system in the US storage facility for the Facility-to-Facility field trial began operations in July 1999 and is located at the Savannah River Site (SRS) in Aiken, South Carolina. Sandia and SRS are installing a comprehensive material monitoring system in the SRS facility used to store HEU as shown in Figure 6. The monitoring system is being configured to allow a segregated portion of the facility to be utilized as the US facility in the Facility-to-Facility field trial.

The material monitoring system for the US facility consists of the following components:

• Twenty-five T-1 Electronic Sensor Platforms equipped with a temperature sensor, motion detector, and fiber optic seal. These units are used to monitor the status of nested storage containers with data transmitted using RF communications.

• Two Passive infrared (PIR) volumetric motion detectors.

• One Neumann DCM-14 camera to provide authenticated video snapshots. (The camera is triggered by one of the PIR detectors.)
- Two NT vision cameras to provide change detection video surveillance.
- One balanced magnetic switch door sensor.

The layout of these sensors is described in Figure 6. The data from these sensors is collected by a central computer and stored in a database. This information is then sent across a fiber optic network to a web server for dissemination to authorized users.

VNIIEF is completing the design of the monitoring system for the Russian facility for the Facility-to-Facility field trial. A vault located within a controlled technical area at VNIIEF has been chosen as the initial Russian facility and necessary utility modifications and approvals are being pursued at this time. In addition, the VNIIEF team is making modifications to available monitoring system hardware and software, based on the experience gained in the Magazine-to-Magazine Field Trial, to facilitate acceptance and approvals at Russian nuclear material storage facilities. It is anticipated that the monitoring system in the Russian facility for the Facility-to-Facility Field Trial will begin operations in early 2000. Long range plans call for the Russian monitoring system to be moved to a nuclear material storage facility at the Mayak Production Association.

Once the monitoring systems in the US and Russian Facilities are in routine use, the Facility-to-Facility Field trial will enter its second phase: system operation and evaluation. The major emphasis of the field trial in the second half of FY00 will be to exercise the facility monitoring
systems and determine their strengths and weaknesses. A major component of the facility monitoring system evaluation will be the input from the facility operators and custodians. In addition to the system evaluation, the collaboration participants will begin discussing approaches for transferring the monitoring technology base and lessons-learned in the Storage Monitoring Collaboration to the appropriate parties in the US and Russian Nonproliferation and Arms Control communities.

CONCLUSIONS

The SNL/VNIIEF storage monitoring collaborations have been proceeding smoothly over the years and are continuing. The total storage monitoring scenario is being addressed in both the technology area and in field trials. Research and development is being done to enhance the hardware and implementation of that hardware. Soon SNL and VNIIEF will have new Smart Bolts used to seal containers, RF caps to monitor those bolts, ESPs to monitor the facilities, and field trials to determine the effectiveness, reliability, and the operational impact of the material monitoring systems.

References


Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department on Energy under Contract DE-AC04-94AL85000.