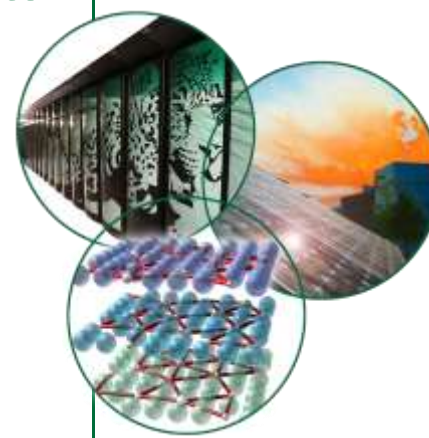
An Overview of Containment & Surveillance and Remote Unattended Monitoring Systems

Chris A. Pickett

Group Leader

Safeguards & Security Technology Group

Nuclear Security Isotope Technology Division



U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Agenda

- An Overview of Some Basic C/S Terminology & Concepts
- Sealing: What makes a Good Seal Good?
- Words of Wisdom on Seals
- C/S Technologies are typically implemented as unattended systems
- The future is building systems that maintain Continuity of Knowledge!

Some Basic Terminology

- **Adversary** - Any person or group of people that attempt to gain unauthorized access into a protected asset: for the purpose of theft, diversion, sabotage, vandalism, or espionage.
- **Attack -** Any attempt to defeat a safeguards/security device, layer, and/or system.
- **Defeat** - A successful attack of the safeguards/security device, layer, and/or system.
- **Insider** - A person that is officially affiliated with the organization that has access to safeguards and security information, operations, or materials and the motivation to act.
- **Lock -** A security device that can be opened and closed that does not provide any indication of entry. Its primary intent is to delay, complicate, and/or discourage unauthorized entry.
- **Seal or TID** - A device designed to leave non-erasable, unambiguous evidence of access or entry. A seal should have both **integrity and identity** as an integral part of its characteristics. **Integrity** is the seal's ability to indicate that an attack has occurred. **Identity** is the ability of the seal to be differentiated between otherwise identically appearing seals. Unlike locks, seals are not necessarily meant to resist access, just record that it happened.
- **Sigillography** - is the term used for the study of seals

More Terminology

- **Tag –** An unique assigned identifier or an intrinsic feature that is used for asset identification. Tags can be used to facilitate inventory taking, provide security, and protect against counterfeiting. Tags are typically attached to an asset and/or its containment.
- **TIE -** Tamper Indicating Enclosure designed to protect safeguarded items and equipment. A special kind of containment.
- **Use protocol** – Specifically designed procedures developed for a particular seal or safeguards/security system designed to ensure effective use of the seal.
- **Authentication** - is the act of establishing or confirming something (or someone) as authentic, that is, that information received is true. This might involve confirming the identity of a person, a sensor, device, or assuring that a computer program is a trusted one.
- **Encryption** - is the process of transforming information using an algorithm (called cipher) to make it unreadable to anyone except those possessing special knowledge, or a key.

More Terminology

- **Vulnerability Assessments (VA)** – Independent assessments designed to discover weaknesses and methods for defeating particular aspects or components of a safeguards/security system.
- **Red Teaming** – A (VA) team dedicated to break or find weaknesses, or defeat safeguards/security system.
- **Blue Teaming** - A team dedicated to thwarting attackers from defeating any of the components associated with a safeguards/security system.
- **Threat Assessment** – A thorough analysis designed to identify and "quantify" the types of credible threats that could be deployed against a safeguards/security system. Not the same as a risk assessment!
- **Passive seal** – Requires physical inspection to determine breach.
- **Active seal** – Provides continuous monitoring of seal for breach.
- **Anti-Evidence Seals** – Seals that are designed to remove or erase specific information or features upon opening.

Material Control typically refers to: Containment & Surveillance

- *Containment:* **Control, hold, surround, and limit**

"Protect"

- *Surveillance*: **Observation, close watch, or examination with scrutiny**

"Chain of Custody"

"Monitoring"

"Help provide Continuity of Knowledge"

Provide assurance that the recorded measurements are still valid!

Together work to Detect Theft or Diversion

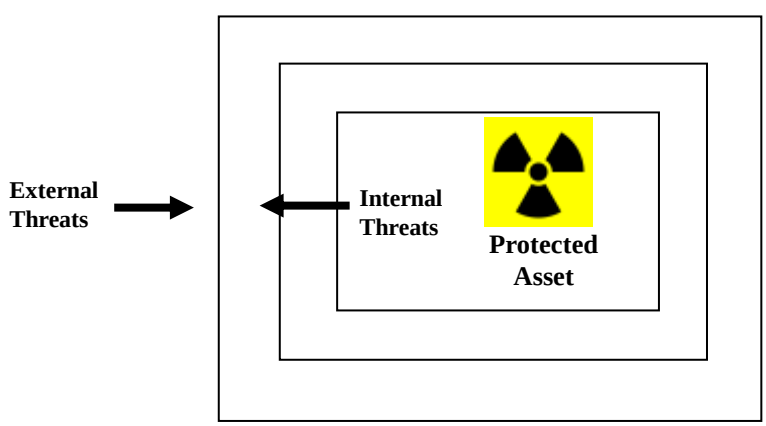
Containment & Surveillance

- **Containment and Surveillance (C/S) technologies** are part of integrated system approaches designed to provide "**continuity of knowledge**" of declared nuclear assets and activities.
- C/S technologies have increased importance for arms control efforts since many measurement-based techniques may be considered too intrusive.

The function of any safeguards Containment and Surveillance (C/S) system is to collect information that can be used to verify activities at a nuclear facility.

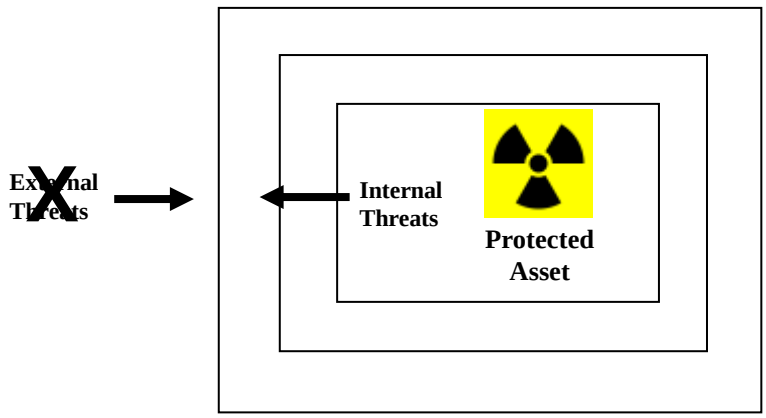
- **Containment systems** represent systems and technologies that are designed to provide secure methods that control, surround, protect, and some cases delay access to nuclear assets. The primary purpose of containment is to facilitate the accountancy and security of nuclear assets.

Basic (Domestic) Safeguard System Design



Layers of Protection designed to protect against both types of threats (established by facility owner)

Basic (Non-domestic) Safeguard System Design



Layers of Protection designed to detect insider activities (established by IAEA)

Containment Systems: Many sizes and Shapes

DOE Standard 3013 Welded containers
–5" diameter 10" long
–For long term Pu storage

Russian SNM storage container

Waste Transport Containers

Dry Cask Storage

Containment

Containment Systems

- Containment Verification can be difficult
  - Visual inspections represent best efforts, but all areas may not be visible
  - Eddy Current & Ultrasonic Techniques very good but slow. Welded regions are good place to authenticate.
  - Surface scans can be problematic due to operational wear and tear that most containers see in the field.
  - We must rely heavily on our sealing techniques and protocols!
  - ***Need more tools for containment verification!***

" If we cannot protect it, we cannot use it"

Past: Seals or Tamper Indicating Devices

- The earliest known seals date back to Babylonian times around 4000 BC. They may have been made etched, stamped, or engraved in stone or clay.
- Wax Seals represent a popular practice that has been used to authenticate documents since the 16th century.

Present: Some Common Types of Wire Loop and Metal Cable Seals

- Most commonly used
- Some multi-piece types
- Some require special tools

Present: Some Examples of Bolt-Type Seals

Typically are two-piece seals with a matching serial number on each piece

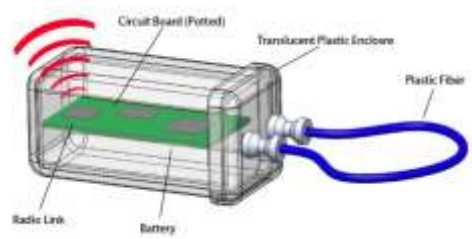
Present: Examples of Adhesive-Based Seals

- Typically used on containment that do not have hasps
- Clean-up and durability issues exist
- Most uses should be short term

Present: Other Types of Passive Seals

- Shrink wrap
- Fiber optic
- Image patterns

Photos of Active Seals



Some Words of Wisdom on Seals

- TIDs must be selected with the application, the environment, and the requirements in mind.
- TIDs that score well in one area may not score as well in other equally important areas.
- High Tech does not always mean better.
- There is no such thing as Tamper- Proof!
- Active seals do require physical inspection!
- All seals require an effective use protocol!
- Cost is not a measure or indicator of seal performance!

Additional Comments

- Manufacturers routinely modify their products (and they may not tell you)
- Active technologies can improve overall system effectiveness.
- Reducing human factors can improve system effectiveness.
- Defeating a tag or seal is different than defeating a system.

Future Seals: Electronic, Sensor Based, Nano-Engineered

- Anti-evidence methodologies
- Log and report open/close events
- Tamper resistant packaging
- Nano-engineered random features
- Wireless communications
- May trigger other devices
- Support tracking
- Detect and record motion, physical changes, etc…

Containment & Surveillance

- **Surveillance systems** are basically technologies and methodologies designed to watch and record as many activities and attributes as possible associated with nuclear materials and processes. The goal for these systems is essentially to be the "**inspector's eyes in the field**" or to provide verification that activities are occurring as declared.
- It is desired for many arms control regimes that C/S systems be designed to support remote unattended monitoring. This can minimize inspector presence at a facility and allow systems to be installed for long term applications such as near real-time monitoring of stored assets, dismantlement of weapon components, and to verify current and future facility use.

Surveillance Systems

- Cameras
- Two-person rule
- Unattended operation (can be remote)
- Attribute Monitoring
  - Measuring physical attributes
  - Location
  - Tracking
- Involve Integrated approaches

C/S Technologies are the original Unattended Monitoring systems:

- Remote – from a distance
- Unattended – without people
- Monitoring – surveillance

Unattended monitoring *does not have to be conducted remotely!*

Some methods to accomplish design goals

- Data authentication and encryption
- Tamper Indicating Enclosures
- Continuous (near) real time data collection
- Redundant and Integrated Layers of Technologies
- Site specific and remote performance testing

Some of the things that influence system designs

- Level of perceived threat (Nyquist Theory Approaches)
- Resources
- Need to Protect Information
- Culture "negotiate with adversary"
- How much is enough?

CAVIS™

- Continuous Automated Vault Inventory System
- An embedded sensor system that continuously monitors the physical attributes associated with stored nuclear materials.
- Allows Remote Unattended Monitoring
- Provides timely detection that can be used to initiate appropriate response(s).

Early CAVIS™ Technology installed at VNIIEF in 1997-98

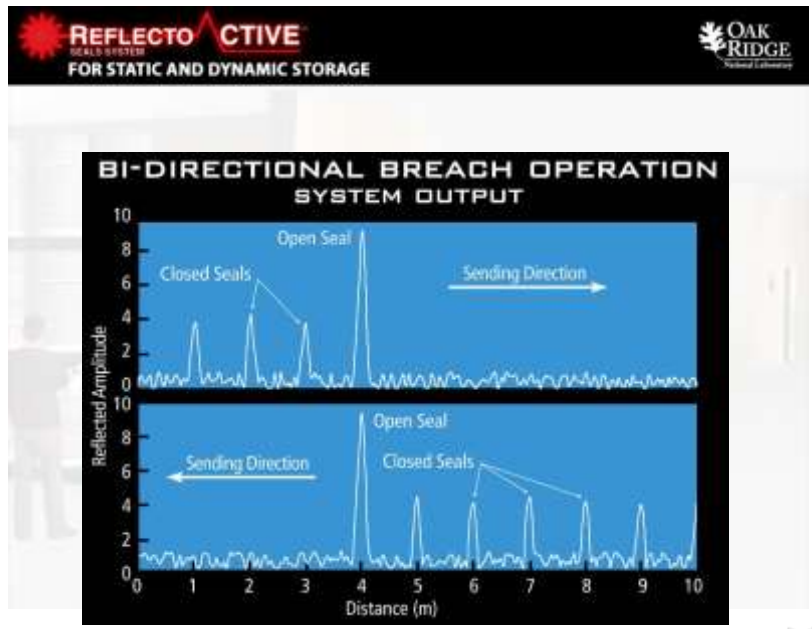
CAVIS™ Weight sensors at Kurchatov Institute in use 1997- 2007

ReflectoActive Seals System

- Monitors large active storage
- Reusable active seal
- Continuous real-time monitoring
- Ability to trigger external devices
- (e.g., security cameras)
- Hardware can be tied into LANs for remote monitoring

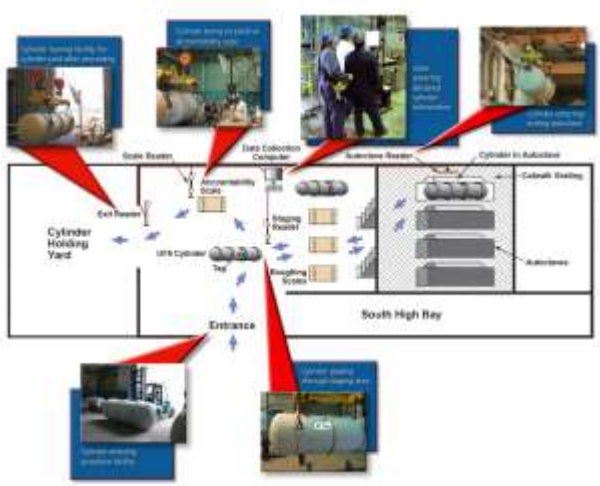
Open Seal

Acknowledge Event



Cylinder Accounting & Tracking System

Project Team: Chris Pickett, Jim Younkin, Don Kovacic, Nathan Rowe, Ben Peters, Terrance McGuire

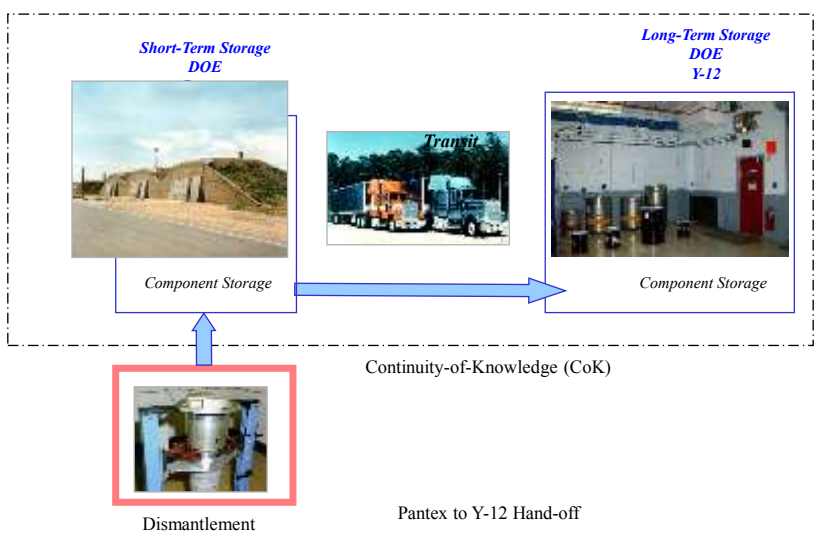


- **Demonstrated the feasibility of using RF-based technologies to track UF_6 cylinders in a operating facility.**
- **Designed a *"rules-based" architecture* that supports the implementation of situation specific monitoring and layering with other safeguards technologies.**
- **Effort has led to new project work to evaluate the technology in reprocessing facility**

A feed and withdrawal (F&W) system test bed for integrated safeguards monitoring

- ORNL has developed an approach to provide continuous load cell monitoring during feed and withdrawal operations.
- Continuous Load Cell Monitoring is being tested to validate transfers occur as declared.
- Will soon be installed at Portsmouth for full system evaluation.

Monitoring of Material in Transit



What to expect from a 21st Century Inspections

- **Negotiations** – will be continuous and include seemingly trivial details
  - **Procedures will be need to be established for:**
  1. **Equipment Failure**
  2. **Equipment maintenance**
  3. **Sharing data or equipment**
- **Managing monitor access** –Will be disruptive, Equipment is easier to manage than people,
  - **Short Notice Random Inspections (SNRI) are sometimes used in place of some authentication measures**
- **You can't always get what you want** – Operators will have to accept changes to the way things are done.

Attaining and Maintaining a Continuity of Knowledge to Draw Safeguards Conclusions with Confidence

Robert S. Bean

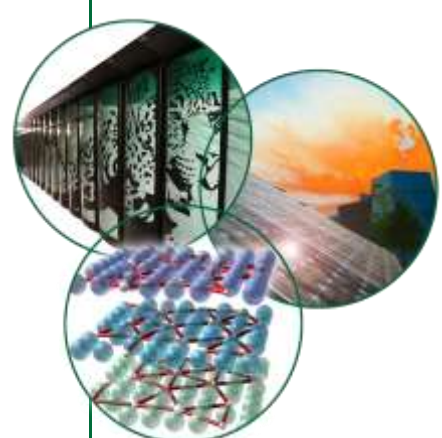
Idaho National Laboratory

Dianna S. Blair

Sandia National Laboratory

Chris A. Pickett

Oak Ridge National Laboratory



Presented at 35th Annual ESARDA Symposium on International Safeguards, 27 - 30 May 2013, Bruges, Belgium

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Outline

- CoK: A Definition
- CoK: Where It Applies
  - State-Level Approach
  - Lots of Data from Lots of Sources
  - Growing & Changing Global Fuel Cycle
- Drawing Conclusions
  - An Example
- Technology Opportunities
- The Future

Continuity-of-Knowledge (CoK)

<u>CoK for Safeguards Purposes:</u>

- is the outcome of a system of data or information regarding an item or activity that is uninterrupted and authentic that provides the IAEA with adequate insight to draw definitive conclusions that nuclear material is not being diverted from peaceful purposes.

It is important to note that:

"CoK is an outcome, not a process"

State-Level Approach-Background

- State Declarations
  - Traditional safeguards addressed correctness
  - Additional Protocol addressed completeness
- State-Level Approach (SLA)
  - Profile country based on nuclear capacities, capabilities, and activities
  - Improve transparency
  - Focus resources on areas of concern
  - Custom approaches
  - Provides new level of flexibility

Safeguards knowledge is a function of many things:

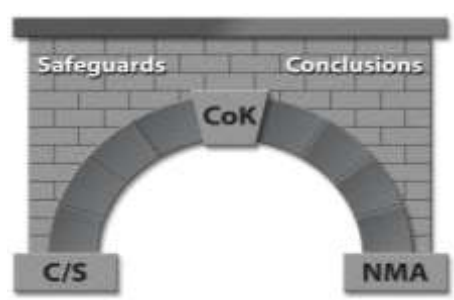
- Prior Knowledge – Quality of our original information
- Technical Capabilities – Our ability to collect, authenticate, and verify information
- Time – Age of our information
- Capabilities to Monitor– What we know and do not know

Characteristics for CoK

- System for data or information regarding an item or activity
  - Integrated
  - Represents a Fusion of Data and Information
- Uninterrupted and authentic
- Information from cradle-to-use
- It is an outcome, not a process
- Provides the IAEA
  - Adequate insight to draw definitive conclusions
  - Nuclear material is not being diverted from peaceful purposes

CoK is the Keystone for Drawing Safeguards Conclusions

Built on a foundation of nuclear material accountancy (NMA) and containment and surveillance measures (C/S), Continuity of Knowledge (CoK) provides the confidence to support a safeguards conclusion.



As reliance shifts to CoK information takes on equal or even primary role to NMA in drawing safeguards conclusions

Safeguarding the 21st Century Fuel Cycle

- **Safeguards Challenges**
  - Earlier in the nuclear fuel cycle
  - Increased number of facilities
  - Facilities in more locations
  - New types of facilities
  - New information technologies
  - Evolving adversary threat

http://infcis.iaea.org/NFCIS/Background.cshtml?page=background&RightP=Background , International Atomic Energy Agency (IAEA), NFCIS Nuclear Fuel Cycle Information System web site.

Safeguarding the 21st Century Fuel Cycle

- **Safeguards Challenges**
  - Earlier in the nuclear fuel cycle
  - Increased number of facilities
  - Facilities in more locations
  - New types of facilities
  - New information technologies
  - Evolving adversary threat

http://infcis.iaea.org/NFCIS/Background.cshtml?page=background&RightP=Background , International Atomic Energy Agency (IAEA), NFCIS Nuclear Fuel Cycle Information System web site.

CoK will need to play an ever larger role in supporting IAEA inspectors.

Sampling Theorem: A Bounding Method for determining how much data is needed

Sampling Theorem says:

"If the original signal contains high frequency components, we must sample at a rate higher than the highest frequency component in the original signal to avoid losing information."

$$f_s > 2B$$

Vulnerability and Diversion assessments can be used to set the data acquisition or data sampling rate such that a diversion attempt will be discovered.

CoK Sampling – Nested Systems

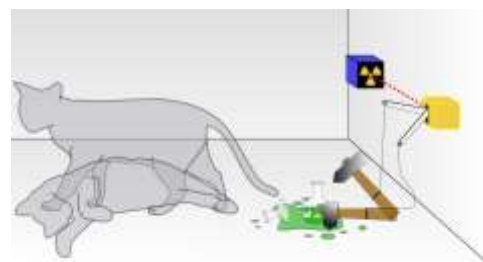
- There is no single "ideal" sampling rate to maintain CoK
  - Electronic/Internal tamper checks
  - Observation of large equipment or items
  - Visual inspection
- Nested functions of technology and inspections
  - A single technology may have multiple steps with different optimal sampling rates
  - Defense in Depth: CoK is maintained by multiple technologies and activities

Why is CoK Important: The "Schrodinger's Cat" Analogy:

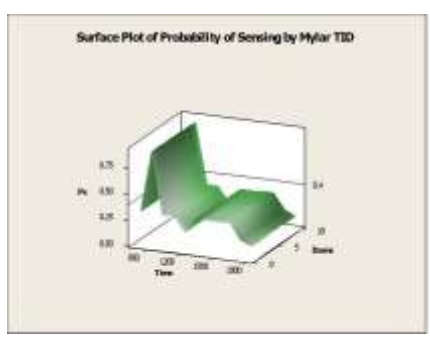
After measured nuclear material has been sealed in a container:

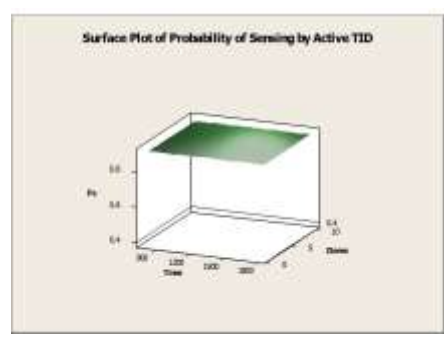
How well do we really know (as a function of time) the status of that material?

- ***We know what was put in the container***
- ***Our confidence in our prior knowledge has uncertainty***
- ***There may have been equipment failures***
- ***There may have been changes to the location of the container***



Drawing Conclusions: *An example of maintaining CoK*





Passive Adhesive Seal Active Seal

* Results from a **Real-Time Effectiveness Approach to Protecting Nuclear Materials;** Pamela Dawson, Sandia National Laboratories & Patrick Hester, Vanderbilt University

The Future is Now!

- We will continue to see more unattended monitoring!
- There will be a need to establish CoK *earlier in the fuel cycle* (to improve detection of undeclared activities).
- The importance of CoK for drawing safeguards conclusions with confidence will continue to increase.
- Rigorous systems analysis of CoK technology is needed to assess confidence that CoK has been maintained.

"Establishing and Maintaining CoK"