IPNDV Working Group 3: Technical Challenges and Solutions
Chain of Custody (10)—Technology Data Sheet

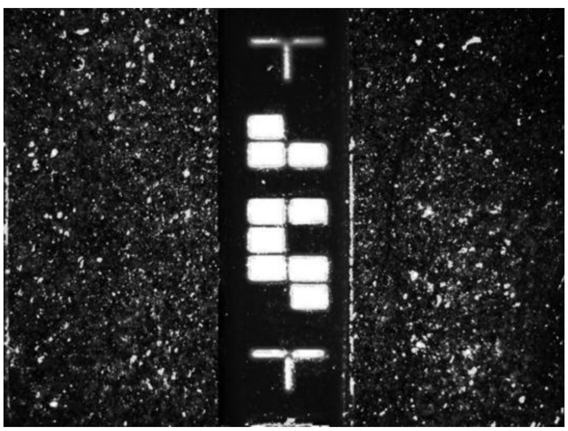
August 3, 2017

Chain of Custody (CoC) Technology Name: Unique Identifiers (UIDs)

Physical Principle/Methodology of Technology:

A unique identifier (UID) is a fingerprint or signature of an item that is difficult to counterfeit or transfer from one item to another without detection. UIDs may be applied to the item, such as a tag, or may be intrinsic to the item i.e., crystalline structure of metal or composite material at a specific location. Applied seals usually also include a unique identifier, such as the output of a cryptographic hash function or public key for an active seal, to be able to distinguish items and seals. In the case of an intrinsic UID, the unique identifier is a unique feature or characteristic of the item itself.

The simplest UID would be a reference number painted, stenciled, or engraved on a container. The problem with reference or serial numbers is that they are usually applied by the host and therefore, the host can apply the same number to another item to use as a substitute. An example of a more secure applied UID is the Reflective Particle Tag (RPT). The tag is composed of specular hematite particles in a clear, adhesive polymer matrix. The tag is applied to the item in the field and then imaged using a special optical reader to record the complex pattern of light reflections unique to the tag. Reflective particles are also used in the Cobra Seal to provide unique identification beyond just the random pattern of optical fibers.



(1)

(2)

Figure 1: (1) Reflective Particle Tag image. (2) Cobra Seal image. (Photo Credits: (1) Sandia National Laboratories, (2) Oak Ridge National Laboratory)

Intrinsic UID technologies can include contact or non-contact techniques and can be acoustic, electromagnetic, or optical. An acoustic system, the Ultrasonic Intrinsic Tag (UIT), captures an image of the sub-surface material structure at about 1 mm. By comparing a reference image and a new image from the same location on an item, the identity of an item can be confirmed. The UIT signatures are relatively insensitive to surface feature changes such as scratches or paint.

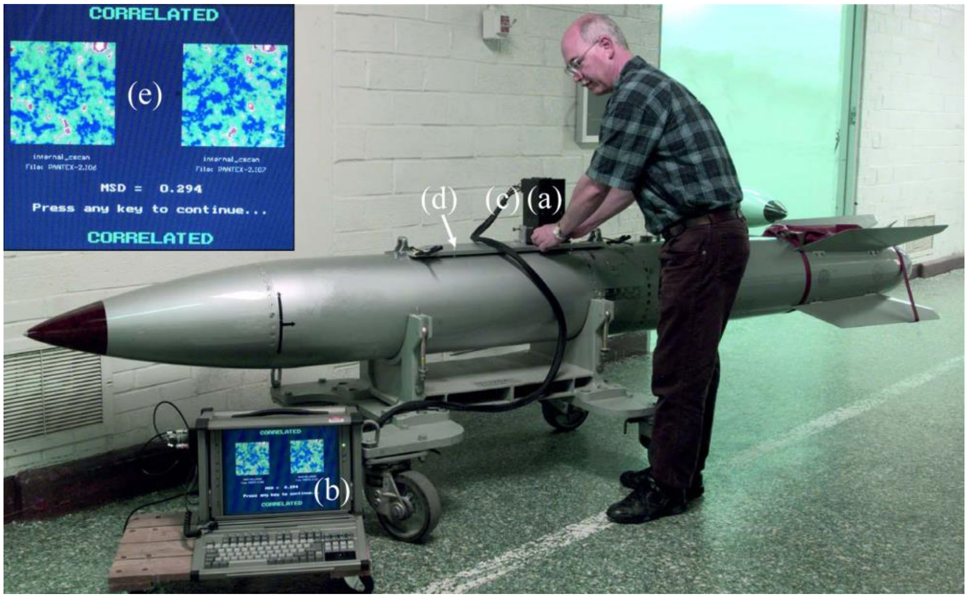
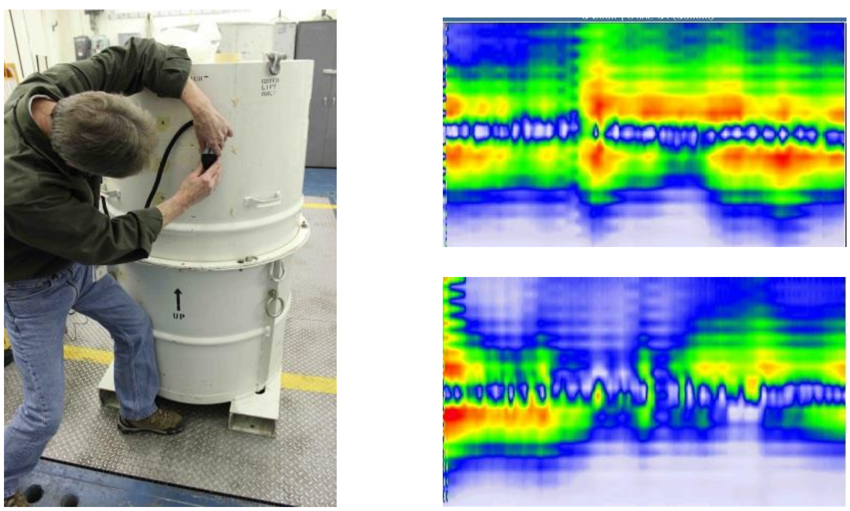


Figure 2: The UIT instrument is shown acquiring a signature from an inert Trainer. (Photo Credit: Pacific Northwest National Laboratory)

Eddy-current induction is an electromagnetic technology that is used to scan a weld, series of rivets/screws, or other area of interest to create an image of the unique subsurface structure of the container by monitoring the condition of the conducting materials (metals).



(1) **(2)**

Figure 3: (1) Eddy Current Array System for Monitoring Warhead Containers. (2) Typical reference and test images. (Photo and Image Credits: Pacific Northwest National Laboratory)

An example of an optical technique is non-contact laser interrogation. 3D laser techniques are used for various applications but in this application, a system is needed with micron-level resolution to discern small changes in container surface characteristics. Non-contact laser interrogation is based on a family of commercial eye-safe laser profilers used in manufacturing for quality control. The system projects a laser line on the surface of the item being interrogated and when scanned, produces a 3D image of the dimensional changes of the surface. The technique has been used on the bolts and flanges of warhead containers where the top and bottom come together.

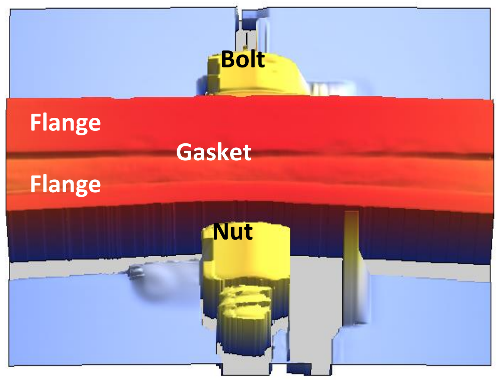


Figure 4: 3D image of a storage container flange used as an intrinsic feature to establish a unique identifier. (Image Credit: Pacific Northwest National Laboratory)

Potential Monitoring Use Cases (e.g., chain of custody, nuclear material detection, explosives detection, etc.): Chain of Custody, Staging/Storage Monitoring, Monitored Dismantlement

Used as part of chain of custody to maintain continuity of knowledge of accountable items on an individual basis. The items can be components of monitoring systems, containers with special nuclear material or warheads, and bombs. Even the tailfin numbers on aircraft could be considered unique identifiers for the purpose of counting delivery vehicles. In New START, the UID is the production serial number of a missile and tailfin number of a heavy bomber. In addition to providing a mechanism for counting items, UIDs also allow the tracking of items, such as weapons, through various lifecycle stages from deployment to storage to dismantlement. An inspector would probably want to use a UID as early as possible in a monitoring regime.

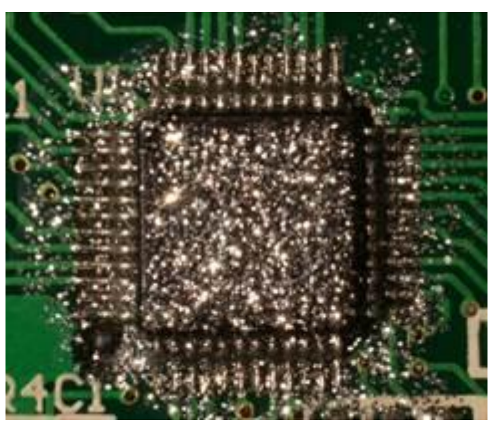


Figure 5: Reflective particles used to tag an electronic component on a printed circuit board. (Photo Credit: Milagro Consulting)

Physical Description of Technology (e.g., approximate size, weight):

Equipment used to check unique identifiers usually consists of hand-held devices that read the tag, label, or seal or scan a small exterior area of the item under inspection. Sometimes these devices are connected to a laptop that stores the UIDs and can compare the current UID with previous data for the same item to make sure it is the same item. Most of these sensors and instrumentation are typically designed for nondestructive inspection of components and therefore are designed to be man-portable and to meet size, weight, and power constraints in typical field inspections. Most of these instruments are generally available with a battery option.

Time Constraints (e.g., measurement times, time to install the equipment):

Establishing the unique identifier, whether it is applied or intrinsic, usually takes only a matter of minutes. In some cases, a mechanical fixture may be used to make the scanning process more repeatable. Such fixtures can usually be installed and dismantled in less than 10 minutes. Inspecting the unique identifier takes about the same amount of time, including any data analysis. The UID inspection equipment is not permanently installed in a facility; rather, the equipment is stored between inspections.

Technology Complexity (e.g., hardware, software, and ease of use by personnel):

The complexity of the technology is a function of the measurement phenomenology, with typical optical and acoustic systems relatively simple to operate but with complex data analysis methodologies whereas laser-based systems are more complex to setup, measure, and analyze. In all cases, personnel training will be necessary to operate the UID systems.

Infrastructure Requirements (e.g., electrical, liquid nitrogen, etc.):

All systems usually require a power supply in the form of an electrical connection to 110V–240V mains or batteries. This includes any reader and any data processing module such as a laptop or integrated computer. Depending on the system, materials for improved coupling to the container or for enhancing the response may be needed. For instance, liquid gel-like materials are usually used to improve the measured signal quality for acoustic technologies.

Technology Limitations (e.g., detection limits for nuclear material, operational temperature range):

Unique identifiers do not take the place of seals, TIEs, or container integrity technologies to determine if an item has been opened or breached, it merely distinguishes the item from other items. For warheads and special nuclear material in containers, the UID identifies the container and not what is inside.

Applied UIDs such as tags may be affected by environmental and operational conditions whereas intrinsic UIDs are typically unaffected by conditions such as exposure to sunlight, hot and cold temperatures, and rough handling, but may require touching the weapon or container. There may also be operational concerns with the application of an applied UID to a weapon or container that is part of the active stockpile.

Technology Development Stage (e.g., commercially available, development stage):

UID technologies, while mature for certain applications, are mostly at the prototype stage for testing in a relevant environment for unique identification in a treaty monitoring regime. The RPT and eddy current systems are assessed as being at a Technology Readiness Level (TRL) 5 whereas the more complex technologies such as acoustic and laser scanning systems still require adaptation for the specific application and are around a TRL 4.

Cost Estimate:

Most UID inspection systems cost approximately USD $20,000 or more. For example, an eddy current scanning system used for inspecting welds and joints in metals costs about USD $25,000 and includes the sensor and instrument for measurement. Acoustic inspection systems for the same application are also in the same ballpark range. While the physical tags of the RPT system may be relatively inexpensive, the camera and computer system with software for alignment, image recording, and image feature extraction and comparison will still cost around the same as acoustic and electromagnetic inspection systems. Laser scanning systems with the required resolution needed for unique identification are USD $35,000 or more, not including software.

Additional System Functionality (e.g., outside the monitoring use case):

In addition to being able to identify and track items of interest, applying unique identifiers or characteristics to monitoring equipment could assist in any ongoing authentication throughout the monitoring regime. The unique identifier can aid in making sure a piece of equipment is authentic, and has not been replaced with an identical piece of equipment that has not been checked out.

The UIDs used to identify and track weapons can potentially provide a significant source of historical information. Data collected when confirming UIDs during inspections at multiple locations and over a long period of time may indicate the provenance of the weapon and the operations associated with the weapon, thereby increasing confidence in the authenticity of the weapon.

References:

P. Ramuhalli, *Eddy Current Identifier for Intrinsic Unique Identification,* Flyer, PNNL-SA-115229 Rev.1, (Richland, WA: Pacific Northwest National Laboratory, 2016).

K.M. Tolk, "Reflective Particle Technology for Identification of Critical Components," in *Proceedings of the 53rd Annual INMM Meeting, Orlando, FL, July 15–19, 2012* (Richland, WA: Pacific Northwest National Laboratory, 2012). Also published as SAND92-1676C (Albuquerque, NM: Sandia National Laboratories).

G.E. Thompson, C.W. Wilson, C.Q. Little, and D.K. Novick, P. B. Merkle, "Reflective Particle Tag System Performance Evaluation," in *Proceedings of the 53rd Annual INMM Meeting, Orlando, FL, July 15–19, 2012*, available at https://www.osti.gov/scitech/servlets/purl/1117133.

M.S. Good, J.R. Skorpik, B.E. Simpkins, J.A. Willett, and J.L. Kirihara, *Ultrasonic Intrinsic Tagging for Nuclear Disarmament: A Proof-of Concept Test,* PNNL-14462 (Richland, WA: Pacific Northwest National Laboratory, October 2003).

M.S. Good, J.R. Skorpik, L.J. Kirihara, K.L. Gervais, and J.E. Tanner, *Ultrasonic Intrinsic Tagging for Unique Item Identification*, PNNL-SA-61396 (Richland, WA: Pacific Northwest National Laboratory).

B. Bernacki, *Non-Contact Laser Interrogation,* Flyer, PNNL-SA-115700 (Richland, WA: Pacific Northwest National Laboratory, 2016).