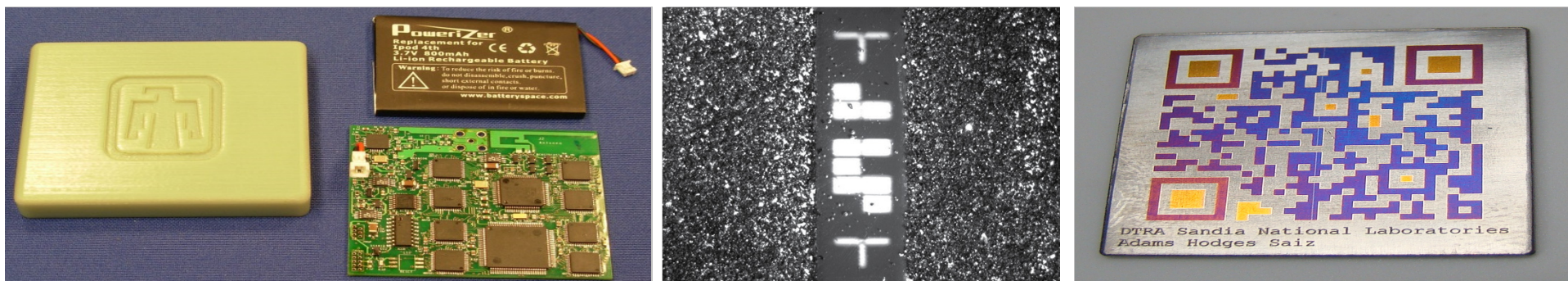


Exceptional service in the national interest



Sandia National Laboratories' Contributions to the International Safeguards Regime

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Global Technical Engagements, Research & Analysis

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Goal for this evening

- Broaden International Safeguards/Verification community
 - Increase understanding of International Safeguards
 - Share SNL's research
- Outline
 - International Safeguards Regime
 - History
 - Context
 - Technical Tools
 - Materials characterization
 - Continuity of Knowledge
 - Sandia's contributions to the field

Timeline

1953



Atoms for Peace

Distributed nuclear technology, materials, and know-how.

Built first reactors in Iran and Pakistan

1957



IAEA

Established with its own treaty: *The Statute of the IAEA.*

It promotes nuclear energy, ensures peaceful use, and promotes safety

1968



INFCIRC/66/Rev 2

Verifies specific materials and facilities not used for military purposes

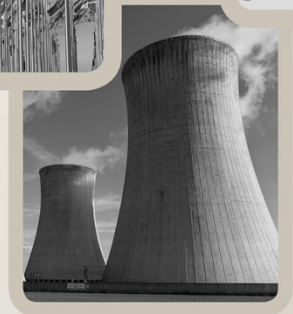
1970



Treaty on the Non-Proliferation of Nuclear Weapons

To prevent spread of nuclear weapons. It divides world into NWS and NNWS

1972



INFCIRC/153

Designed to provide timely detection of diversion of significant quantities of NM (8 kg Pu/ 25 kg U235)

Note: US-IAEA agreement INFCIRC/288 (1980)

PROJECT SAFEGUARDS

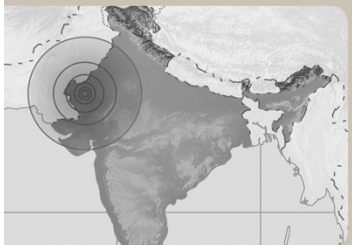
1974

1978

1990

1997

Future



India's first nuclear test



Nuclear Suppliers Group



First Gulf War, North Korea withdraws from NPT



INFCIRC/540 Model Additional Protocol

Assurance declarations are complete as well as accurate

Note: US-IAEA agreement INFCIRC/288.Add.1 (2009)



State-Level Concept

Evolving from risk based on material and facility to State specific

DECLARED NUCLEAR MATERIALS

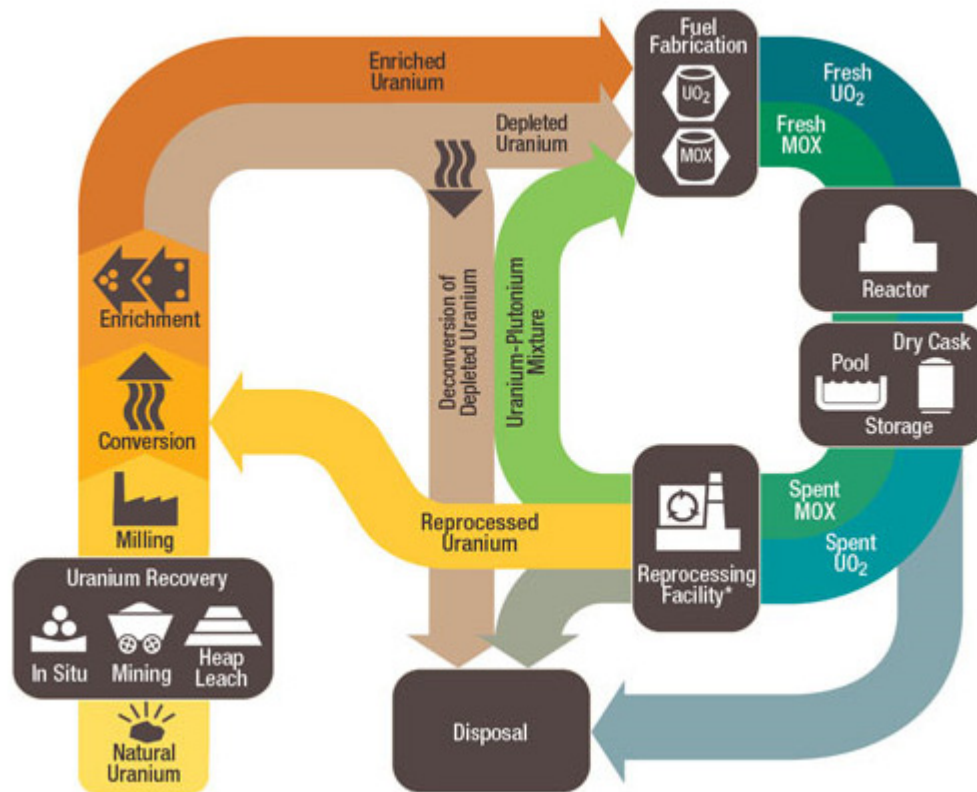
UNDECLARED NUCLEAR MATERIALS

WEAPONIZATION

International Safeguards

- Technical measures used by the International Atomic Energy Agency (IAEA) to provide credible assurances that States are complying with their international obligations to use nuclear material only for peaceful purposes
- Basic verification measure
 - Nuclear material accountancy
- Technical objective
 - “Timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by risk of early detection”

Nuclear Fuel Cycle



www.nrc.gov/materials/fuel-cycle-fac/stages-fuel-cycle.html

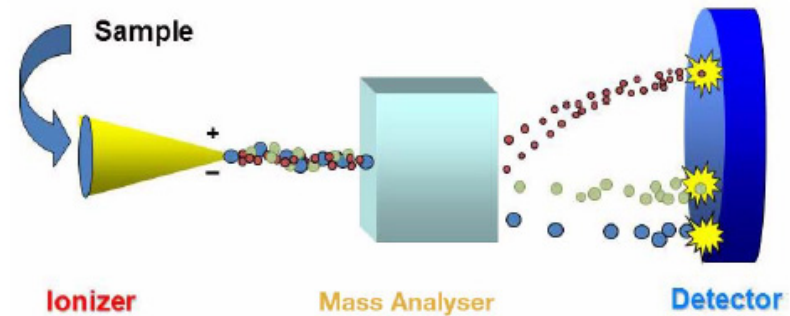
Basic verification measure: Nuclear Material Accountancy



- Gross defects-missing items
 - Count items
 - Measure attributes
- Partial defects-fraction of material missing
 - Weighing of items
 - Measure attributes
- Bias defects-protracted diversion
 - Sampling
 - Measurements
- Continuity of Knowledge
 - Preserve knowledge gained through verification
 - Containment and surveillance measures deployed

Technical Tools: Destructive Analysis

- Typically used for bulk handling nuclear plants
- Used for element and isotopic compositions
 - Solids and liquids



Technical Tools: Non-Destructive Analysis

- IAEA uses more than 100 different NDA systems
 - Predominately
 - γ and/or neutron systems
 - Vary in size and complexity
 - Portable
 - Unattended
 - Facilities
 - Enrichment
 - Fuel fabrication
 - Power reactors and storage facilities
 - Reprocessing plants

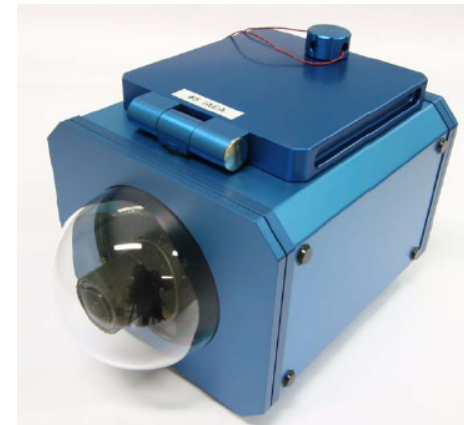


Surveillance

- Optical surveillance-unattended systems
 - Monitor access to materials/items of significance
 - Identify items during unattended NDA
 - Indicate tampering on instruments in use



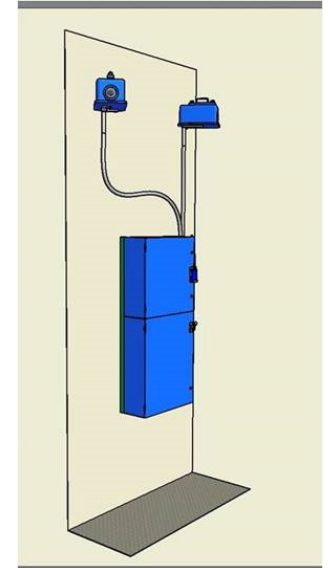
All in one surveillance (ALIS) unit



Next Generation Surveillance System (NGSS)

Surveillance

- Modular Integrated Video System (MIVS) – 1980s
 - Included tamper indicating enclosure and tamper indication of video and power line from main unit to camera unit
- Secure Video Surveillance System (SVSS) to support unannounced inspections for regional authority “ABACC” (Brazil/Argentina) – COTS components in TIE
- Standoff video
 - Some environments unsuitable for standard safeguards cameras (radiation, underwater)
 - Solution may be to deploy remote objective lens and pipe an image over some standoff optical path
 - E.g. mirrors, lenses, fibers
 - Cryptographic authentication of digital data does not suffice



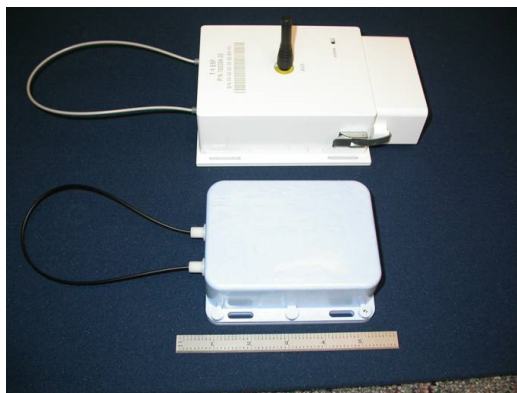
Containment (Seals)

- Designed to detect access to
 - Nuclear material
 - Data signals
 - Equipment
- Operational requirements
 - Unique ID
 - Impervious to tamper
 - Counterfeit, removal/reapply, compromise
 - Verifiable



Active fiber loop seals

- Multiple opening/closing of seal wire (time stamped, logged, authenticated), in-situ verification
- SNL has developed family of seals since 1980's
 - Domestic safeguards at Hanford site, Authenticated Item Monitoring System (AIMS)
 - Evolved into T1, T1a, RMSA
 - Built upon unattended seismic stations expertise at SNL



T1, T1a

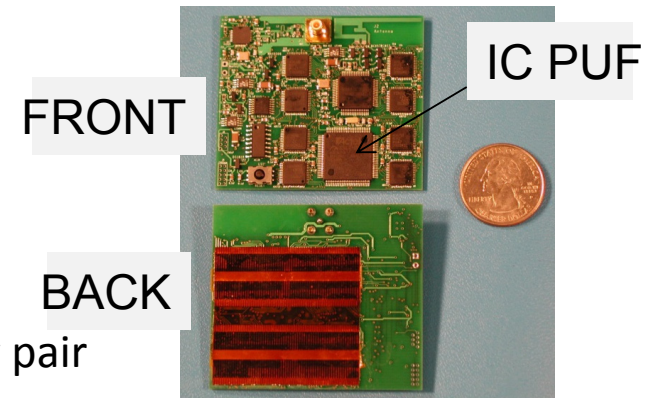


RMSA

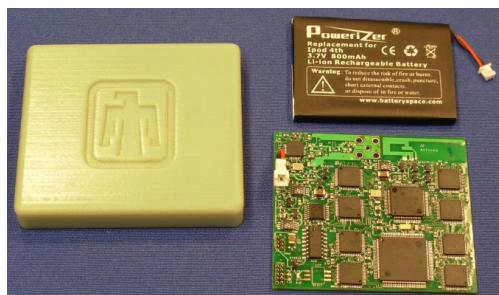
SecuritySeal

- Exploit intrinsic randomness of parts to create unique identifier

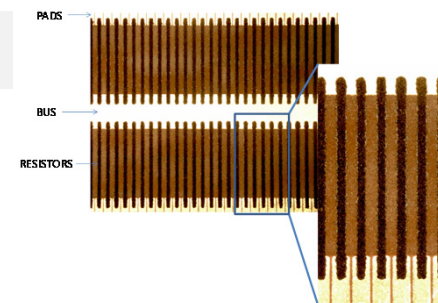
- Electrical parameters of IC
- Physical Unclonable Function (PUF)
- Use for cryptographic authentication
 - Use PUF bitstream as seed for asymmetric key pair
 - Mitigates known attack scenarios



- Incorporate tamper-detecting and IC PUFs to form a system-level fingerprint



TAMPER-DETECTING PUF



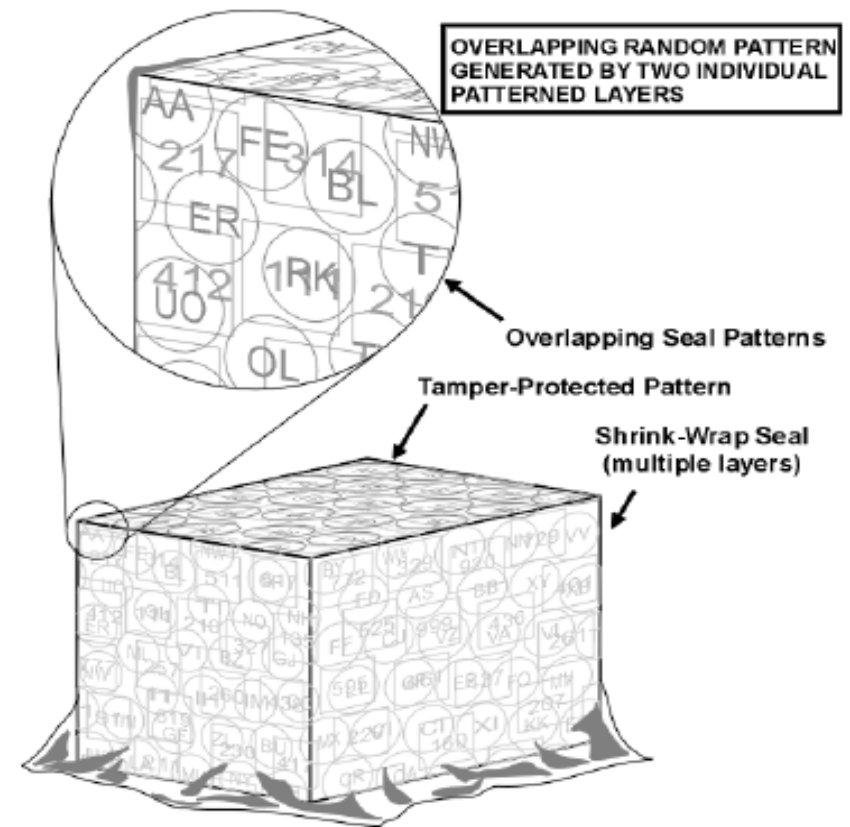
Tamper-Indicating Enclosure (TIE)



- Some items not amenable to seal containment
 - Equipment
 - Some material storage containers
- TIEs provide volumetric containment for items
- Same operational requirements as Seals

Shrink-wrap laminar

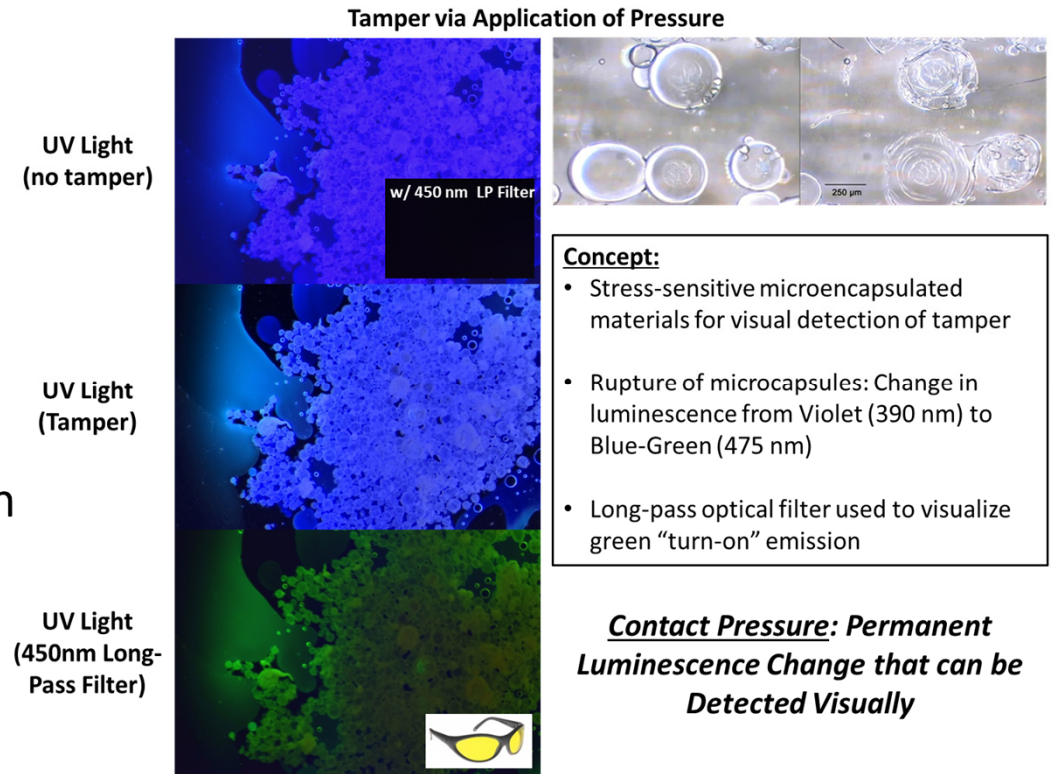
- Sheets of film printed with differing ink patterns
- Article of interest is enclosed with multiple continuous layers and a heat source is applied
- Reference photograph is taken for authentication during subsequent inspections
- Advantages – ease of use in field, easy to install, few tools are required, no surface preparation
- Disadvantages – not very durable
- Best use is for odd geometric shapes; otherwise use as a compliment to other seals



Picture courtesy SNL
SAND99-2455

TIE: Bleeding materials

- No tamper-indicating enclosures currently exist with strong visual response to tamper, passive, low cost, extremely flexible in application
- SNL LDRD researched and developed a material that upon tamper, creates a strong visual response that an adversary cannot repair without detection
- Embodied the material in custom enclosures (3d printed) and spray coatings
- Still need to optimize response

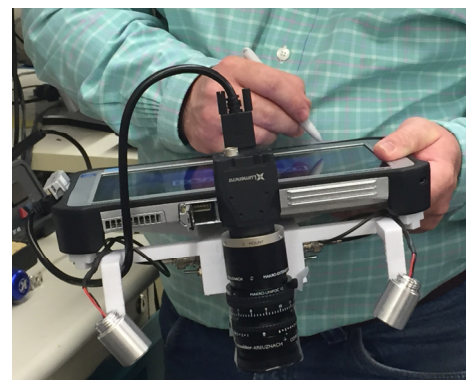
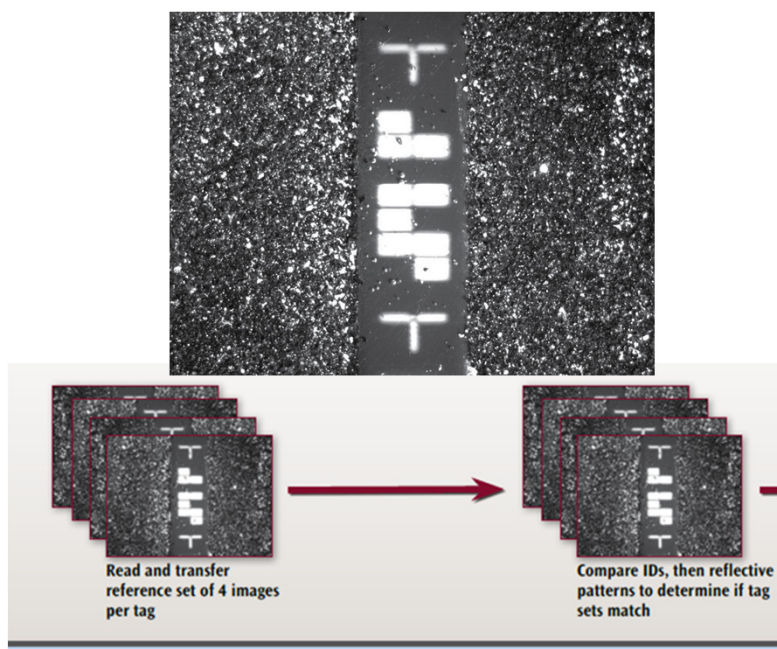


Unique Identifiers (ID)

- Tracking of individual items requires unique IDs
 - Improves efficiency
 - Prevents tampering/substitution
- Seals incorporate “tags” or “unique identifiers” but tags are not necessarily seals
- SNL developed the reflective particle tag (RPT) in the 1980’s as a passive, robust, low cost, difficult to substitute or counterfeit tag

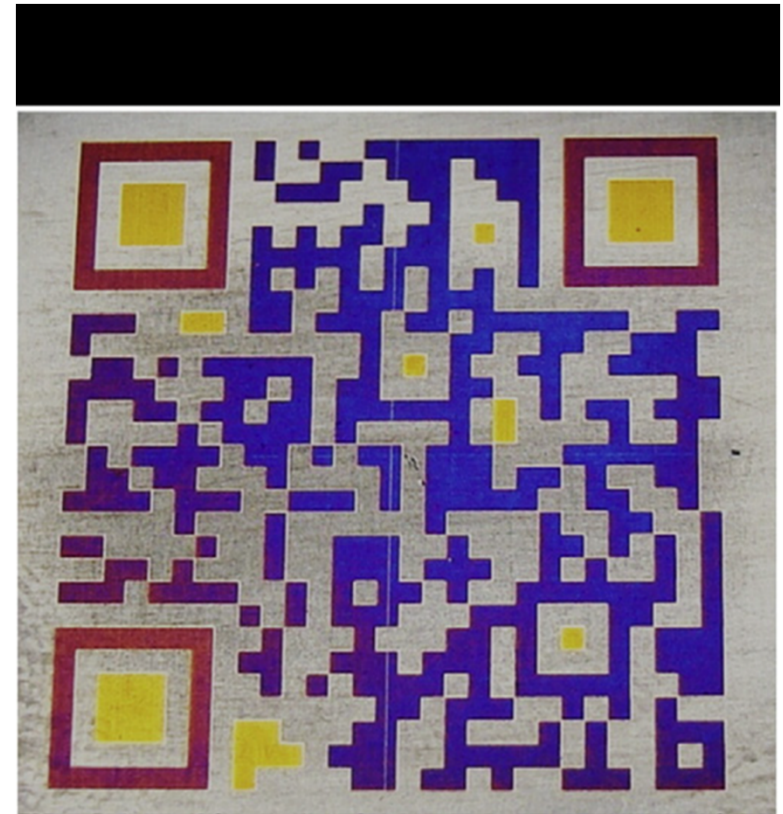
Tags: Reflective Particle Tag

- Hematite particles embedded in acrylic matrix
- Create unique and complex speckle pattern
- Application is relatively simple and field verifiable
- Currently developing stand-off authentication tool



Unique Surface Encoded (USE) tag

- Unique, non-transferrable tags created on surface
- Verification features tailored to need
 - Macro pattern provides for easy identification
 - Micro patterns provide non-reproducible features for verification
- Scribing not expected to impact item integrity
 - Depth of pattern 10-120 nm
- Metals that have been scribed include:
 - Titanium, SS304, and SS316
 - Any metals that include Fe, Cr, Ti could be scribed



Conclusions

- International Safeguards requires technologies
 - Improves both efficiency and effectiveness
- Containment and Surveillance technologies are critical
 - Provide Continuity of Knowledge between inspections
 - Used to monitor access to inspection equipment
- As technology advances, so must Safeguards equipment
- Sandia leverages its physical protection experience to better inform research and needs of the International Safeguards community

THANK YOU FOR YOUR ATTENTION

QUESTIONS?