Nuclear Forensics and the requirement of Certified Reference Materials

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Goals of Forensic Science

- Associate an item of physical evidence with a person, place, or event.
- Associate two items of evidence with each other.
- Associate an item of evidence with information from existing data base.
Traditional Forensics

- Firearms example
  - Recovered bullet matches gun
  - Two bullets match each other
  - Bullet exam provides indication of what type of weapon.
Traditional Forensics

- Firearms example
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Lead and trace metal analysis is calibrated with NIST CRM solutions.
Traditional Forensics

- Firearms example
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  - Two bullets match each other
  - Bullet exam provides indication of what type of weapon.

Microscope is calibrated with optical standards for color and size determination
Traditional Forensics

- Firearms example
  - Recovered bullet matches gun
  - Two bullets match each other
  - Bullet exam provides indication of what type of weapon.

The cartridge case can be queried in the national database (NIBIN) which was compiled from a large number of standardized examinations.
Legal Standard

- Frye (293 F. 2d 1013 - D.C. Circuit 1923):

  Two-step analysis:

  - Is the underlying theory generally accepted in the relevant scientific community?
  
  - Are there procedures available that can produce reliable results and are the procedures accepted in the relevant scientific community?

    - Problem: “general acceptance” in the scientific community is difficult to define.
Legal Standard

- Daubert v. Merrell Dow Pharmaceuticals [113 S. Ct. 2786 (1993)]
  - Has the technique been validated?
  - What is the existence and maintenance of standards controlling the technique’s operation?
  - Were the results peer reviewed?
  - Does the method lead to any erroneous results, if so how often? (false positives and/or negatives)
  - Has the technique been generally accepted in the scientific community?
Legal Standard

- Rule 702 (2002)
  - If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education may testify thereto in the form of an opinion or otherwise, if
    - (1) the testimony is based upon sufficient facts or data,
    - (2) the testimony is the product of reliable principles and methods, and
    - (3) the witness has applied the principles and methods reliably to the facts of the case.
FBI Laboratory Expectation

- FBI Laboratory is accredited by American Society of Crime Laboratory Directors, Laboratory Accreditation Board (ASCLD/LAB)

- ASCLD/LAB adds a forensic QA component to the basic ISO-17025 requirements.

- ISO-17025 requires the use of traceable certified reference materials to calibrate instruments and validate methods.

- FBI Laboratory expects affiliated laboratories which provide analysis to the FBI, to be ISO-17025 accredited
Nuclear Forensics vs. Nuclear Analysis/Research

- **Similarities**
  - Validating measurement sensitivity and selectivity
  - Insuring sample integrity
  - Sample tracking -- Chain of custody
  - Multiple independent methods as orthogonal evidence

- **Differences**
  - Legal Standard
  - National Security; Dire Consequences
  - Unique specimens of limited quantity
  - Timely analysis
  - A repeat or defendant’s analysis is problematic
# Forensic questions in Radiological investigations

## Technical Nuclear Forensics
- Material Analysis
- Irradiation
- Physical Composition
- Engineering Design
- Enrichment
- Reprocessing
- Chemical form
- Date of reprocessing

## Traditional Forensics Examinations
- Chemistry
- Latent Prints
- Document Analysis
- DNA
- Trace Evidence
- Tool Mark Analysis

## Field Investigation
- Shipping routes
- ID of traffickers
- Capability for large quantities
- Search for bulk R/N
- End-user application
- Environmental samples
Targets of nuclear forensic measurements

- **Design and Composition:**
  - Radionuclide
  - Isotopics
  - Metal,
  - Salt,
  - Oxidation State,
  - Purity, Trace Elements,

- **Chronology:**
  - $^{60}\text{Co}/\text{Ni}, \, ^{90}\text{Sr}/\text{Zr}, \, ^{137}\text{Cs}/\text{Ba},$
  - Am, Pu, U, Th + daughters
Radiochemical Analysis

- Cm-(242, 244)
- Am-(241, 242m)
- Pu-(236, 238, 239, 240, 241, 242, 244)
- Np-(237)
- U-(232, 233, 234, 235, 236, 238)
- Pa-(231)
- Th-(228, 229, 230, 232)
- Ac-(227)
- Ra-(226)
- Eu-(155)
- Ce-(144)
- Cs-(134, 137)
- Sn-(125, 126)
- Ag-(110m)
- Tc-(99)
- Nb-(94)
- Co-(60)
# Chronometers

- **Pu**: Pu236, Pu241, Pu238, Pu239, Pu240
- **Am**: Am, Am241
- **Np**: Np, Np237
- **U**: U, U232, U233, U238, U234, U235, U236
- **Pa**: Pa, Pa231
- **Th**: Th, Th228, Th229, Th230, Th232
- **Ac**: Ac, Ac227
- **Ra**: Ra, Ra226, Ra228
- **Pb**: Pb, Pb210
<table>
<thead>
<tr>
<th>Chonometer Pair</th>
<th>Age (yrs ± 2s)</th>
</tr>
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<tbody>
<tr>
<td>$^{232}$U/$^{228}$Th</td>
<td>6.1 ± 1.0</td>
</tr>
<tr>
<td>$^{233}$U/$^{229}$Th</td>
<td>7.7 ± 1.7</td>
</tr>
<tr>
<td>$^{234}$U/$^{226}$Ra</td>
<td>5.93 ± 0.26</td>
</tr>
<tr>
<td>$^{234}$U/$^{230}$Th</td>
<td>6.40 ± 0.28</td>
</tr>
<tr>
<td>$^{235}$U/$^{227}$Ac</td>
<td>6.83 ± 0.24</td>
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<tr>
<td>$^{235}$U/$^{231}$Pa</td>
<td>6.50 ± 0.42</td>
</tr>
<tr>
<td>$^{236}$U/$^{232}$Th</td>
<td>&lt;16</td>
</tr>
<tr>
<td>$^{241}$Pu/$^{237}$Np</td>
<td>~132</td>
</tr>
<tr>
<td>$^{241}$Pu/$^{241}$Am</td>
<td>7.13 ± 0.55</td>
</tr>
<tr>
<td>Wt Mean Age</td>
<td>6.46 ± 0.14</td>
</tr>
</tbody>
</table>
Nuclear Forensics CRM Partners

- US National Laboratories –
  - LLNL, SRNL, LANL, ORNL, PNNL,

- International Laboratories
  - NPL, CEA, IRMM, ITU

- NIST, Ionizing Radiation Division

- Reference Laboratory –
  - NBL (CRM Coordinator)

- DHS, National Technical Nuclear Forensics Center.

- FBI Laboratory, CBRN Sciences Unit
CRMs and Metrology tools are required to meet the Legal Standards

- Calibrations with CRMs
- Method validation
- 17025 Quality System
- Third Party Traceability Testing
- External Technical Assessment
- Accreditation