National Nuclear Forensics Libraries: A Suggested Approach for Country Specific Nuclear Material Databases

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Outline

- How libraries support the nuclear forensics process
- Types of libraries
  – International or National
- Proposed US approach for National Libraries
- Data dictionary development and description
- Summary

Nuclear Forensics

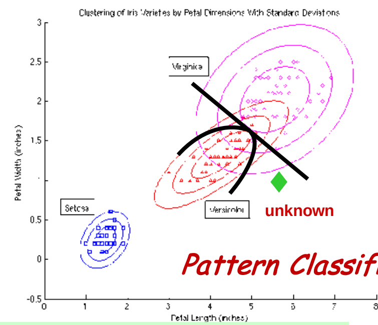
- Nuclear forensics, like conventional forensics, seeks to link people, places, things, and events
- Unlike conventional forensics, nuclear forensics also seeks to identify:
  - The material process history
  - The intended use of the material
  - The location where the material was produced
  - The pathway by which the material traveled

Signature Analysis and Forensic Interpretation

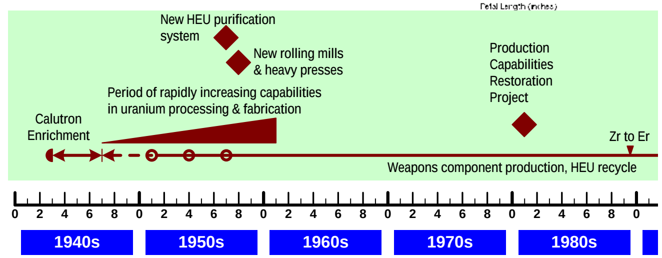
SIGNATURE ANALYSES

- Isotopics
- Major Elements
- Trace Elements
- Microstructure
- Morphology
- Age Dating
- Pathways Analyses

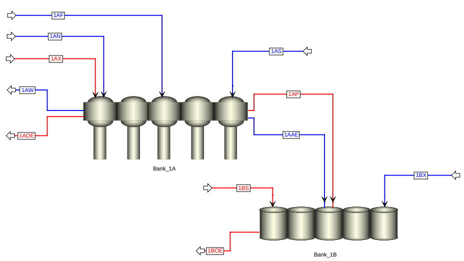
Mining & Linking Signature Data



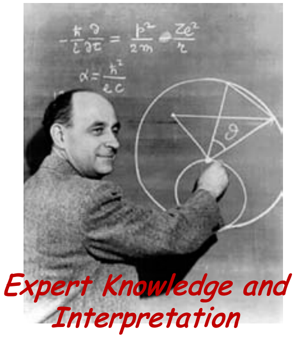
Pattern Classification



Material Production Timelines



Signature Modeling & Validation



Expert Knowledge and Interpretation

EVALUATION PROCESS

TECHNICAL CONCLUSIONS

- Reveals patterns in technical nuclear forensics (TNF) data
- Resolves unanticipated and novel findings
- Enables signature discovery
- Links TNF signatures to processes, locations, facilities based on sound science

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Applications of Nuclear Forensics

- Law enforcement support for combating the illicit trafficking of nuclear material
  - Identification of material origin
  - Connecting individuals to an interdicted material
- Verification of international treaties and regimes
  - Use of material signatures to monitor adherence to declared operations

- *Successful nuclear forensic analysis requires access to pertinent nuclear material data*

Effective Nuclear Forensics Evaluations

- Nuclear forensics is a comparative science
  - Nuclear material characteristics from an unknown are compared to known material or process signatures
  - Can include both empirical and modeled data (eg. measured isotopics vs. calculated reactor burn-up)
  - Requires nuclear material production, characterization, and forensic evaluation expertise

- *Centralized libraries for capturing nuclear material characteristics enable timely and accurate nuclear forensic assessments*

Two Proposed Models for Libraries

- International nuclear material library
  - Countries would contribute data
  - Excellent deterrent to the theft, loss, diversion, and illicit trafficking of nuclear material
  - Set of mutually agreeable characteristics included in database very limited, and therefore of limited use for forensic assessments
  - More appropriate for strong MPC&A than forensics
  - *Generally not acceptable to most countries*
- National nuclear material libraries
  - Each country collects data on their domestic materials
  - Attractive alternative

National Library Advantages

- Tailored for each country’s NM holdings
  - Simple, limited functionality libraries for countries with relative static, and small nuclear material inventories
  - Complex, searchable databases for countries with large quantities, variety, and frequent changes to inventory (eg. full or partial fuel cycle)
- Does not require transfer of sensitive or proprietary nuclear material characteristics
- Builds international confidence that countries would properly identify interdicted domestic material
- Deters illegal trafficking of nuclear material
  - Incentive for material producers and users to implement good MPC&A and address insider threat of material theft

Benefits for International Engagement

- National library design and implementation is a mechanism for international cooperation
  - Develop consensus for material characteristics important for inclusion in libraries
  - Opportunity to build confidence through technical exchange
    - Data query tools
    - Quality assurance
    - Process signature discovery
  - Encourages, but does not require cooperation during nuclear forensics investigations
    - Selective data or material exchanges

United States Status

- Suggested list of material characteristics for inclusion in libraries developed
  - “Material Characteristics Data Dictionary for Forensics Applications”
  - US Starting point for encouraging discussion
- Generic construct for a National Library based on the Data Dictionary developed
  - Transferrable to partner countries
  - Model for indigenous database development

Data Dictionary Development

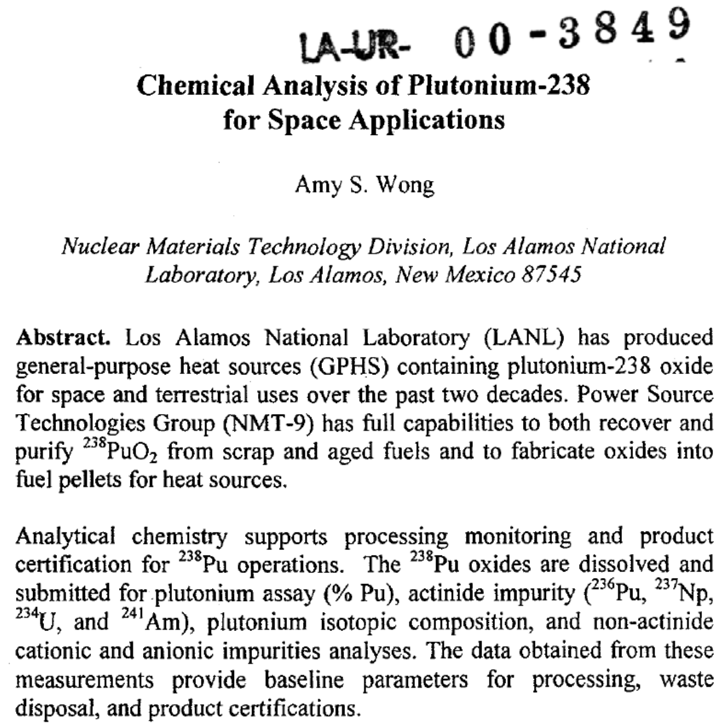
- Complete list of nuclear material characteristics relevant to nuclear forensics
  - Over 250 parameters suggested that are beneficial for uniquely identifying and differentiating nuclear materials
  - Working document based on current understanding and knowledge
  - Not all characteristics are appropriate or available for all materials

Eight Categories of Dictionary Information

1. Material Identity
2. Analysis Laboratory
3. Material Packaging and Container
4. Sample or Item Physical Characteristics
5. Sample or Item Chemistry
6. Sample or Item Morphology
7. Material Process or Location History
8. Data Vetting and Quality Assurance

Material Identity

- Material identification
  - Sample or object identifying numbers
  - Collection location
  - Current location
  - Connections with other samples or materials
  - Supporting information (pictures, reports, etc.)



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Chemical Analysis of Plutonium-238 for Space Applications

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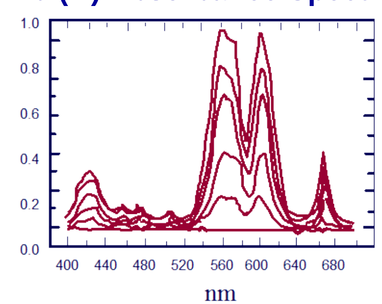
Abstract. Los Alamos National Laboratory (LANL) has produced general-purpose heat sources (GPHS) containing plutonium-238 oxide for space and terrestrial uses over the past two decades. Power Source Technologies Group (NMT-9) has full capabilities to both recover and purify $^{238}PuO_2$ from scrap and aged fuels and to fabricate oxides into fuel pellets for heat sources.

Analytical chemistry supports processing monitoring and product certification for ^{238}Pu operations. The ^{238}Pu oxides are dissolved and submitted for plutonium assay (% Pu), actinide impurity (^{236}Pu, ^{237}Np, ^{234}U, and ^{241}Am), plutonium isotopic composition, and non-actinide cationic and anionic impurities analyses. The data obtained from these measurements provide baseline parameters for processing, waste disposal, and product certifications.

Pu (III) Absorbance Spectra



Analysis Laboratory Information

- Sample splitting and analytical laboratory information
  - Chain of custody
  - Analyses performed at each facility

Date: Los Alamos National Laboratory Batch #:

C-INC, Clean Chemistry Team

Primary Chain of Custody

COC Category = ____________________ Submission Id: ____________

Sample Id	**Sample Type**	**Sample Matrix**	**Container**	**Sample Date**

Relinquished to Custodian or Lock Box By (Sign, Date &Time):	**Received from Custodian or removed from Lock Box by (Sign, Date & Time):**

Received for disposal: ☐ or Consumed In Analysis: ☐ Sign: ________________________________ Date: ______________

The following numbered Samples IDs ____ have been returned for re-processing to:

______________________________ and the secondary COC has been completed.

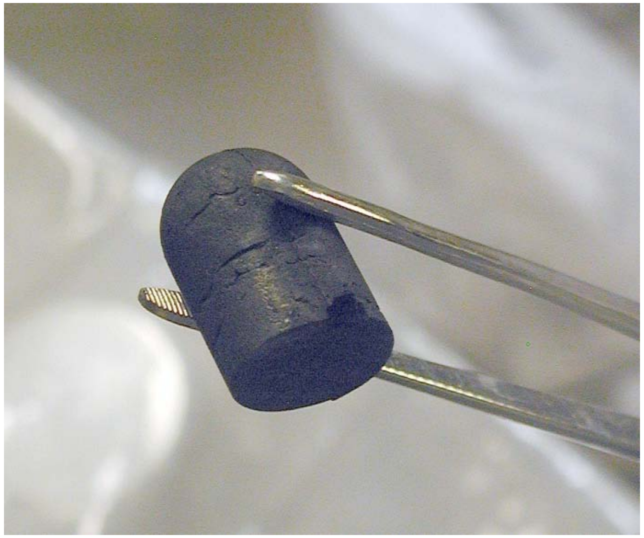
Sign: ____ Date: _______________ Time:______________

Material Packaging and Container Description

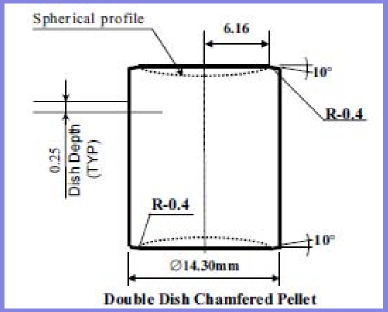
- Packaging / container serial numbers
- Physical container description, dimensions, and mass
- Dose rate information
- Other materials stored in the same container

Sample or Item Physical Characteristics

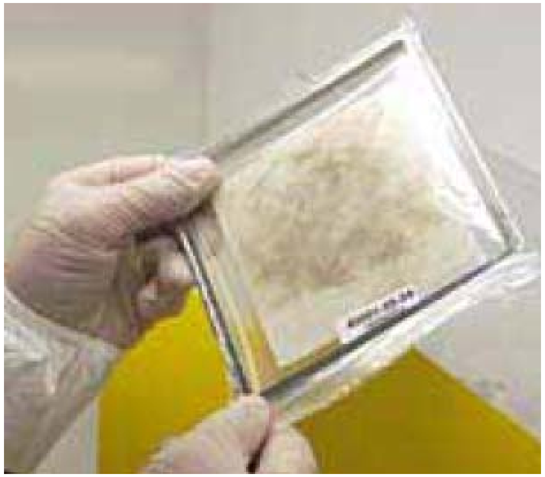
- Shape and dimensions
- Density
- Overall material use descriptions
  - eg. Fuel pellets, fuel pin or assembly cladding and dimensions



PHWR Fuel Pellet Dimensions*



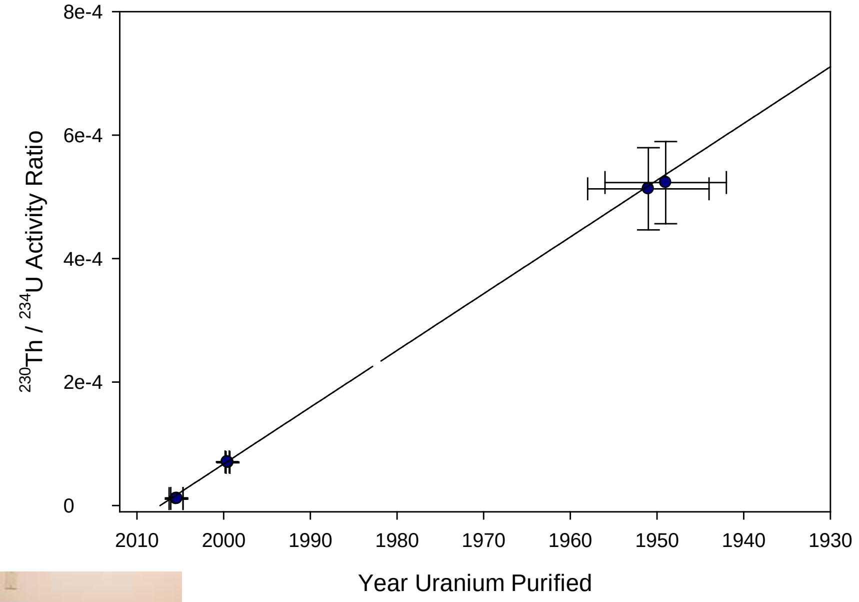
***R.N.Jayraj & C. Ganguly IAEA-TECDOC-1416**

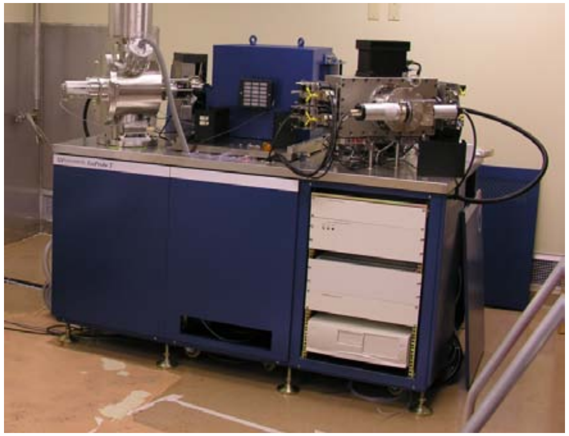


Sample or Item Chemistry

- Chemical form
- Elemental composition
- Isotopic composition
- Minor and trace constituents
- Material age information (separation date, discharge date, etc.)
- Specific activity
- Fuel burn-up

Uranium Oxide Sample Age





IsotopX IsoprobeT Thermal Ionization Mass Spectrometer (TIMS)

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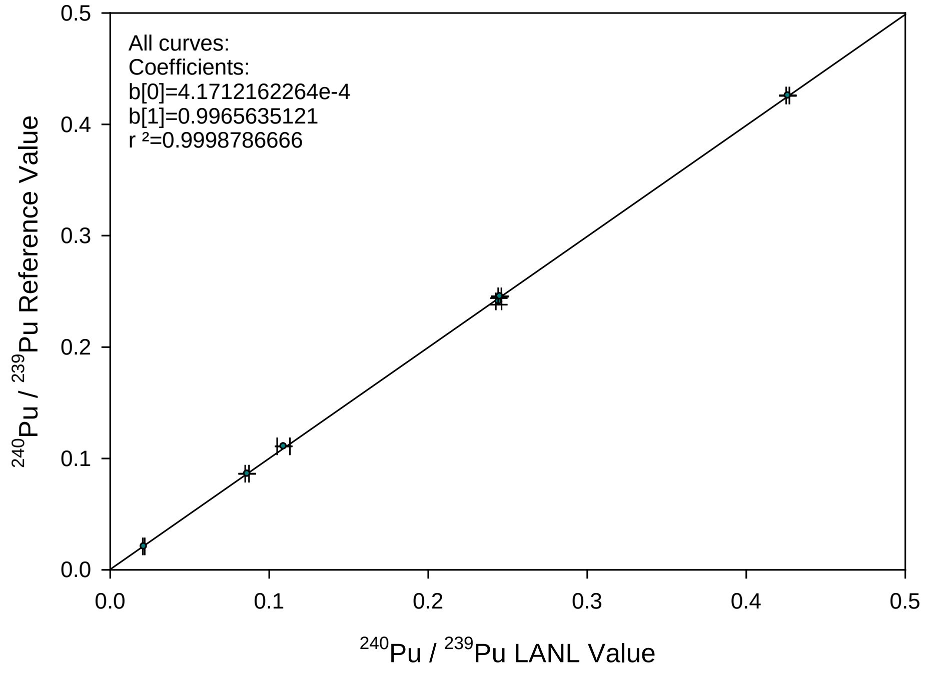
Sample Chemistry Measurement Quality

- For each reported analysis:
  - Method used and reference
  - Calibration information
  - Uncertainty estimates and type
  - Supporting data QA and technical review

Performance on Isotope Ratio Blind QC Standards



Pu Isotopic Calibration QC

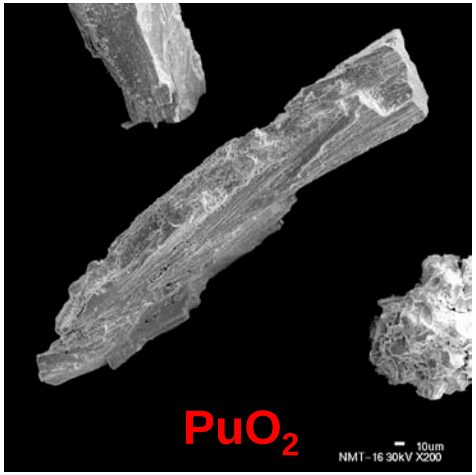
					Certified value	Certified Uncertainty
	n	$^{240}Pu/^{239}Pu$	1σ			
CRM 138 (NBS 948)	11	0.08636	0.00036		0.08618	0.00011
CRM 126 (NBS949F)	13	0.02901	0.00013		0.02881	none

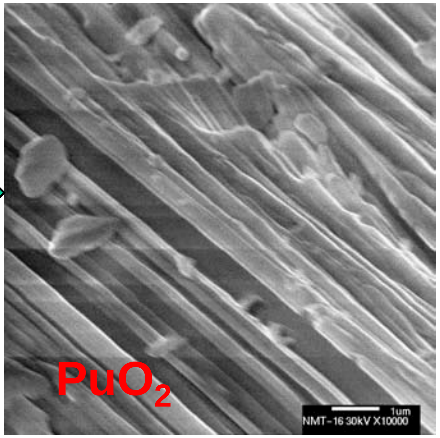
Sample Chemistry Example: $^{240}Pu/^{239}Pu$

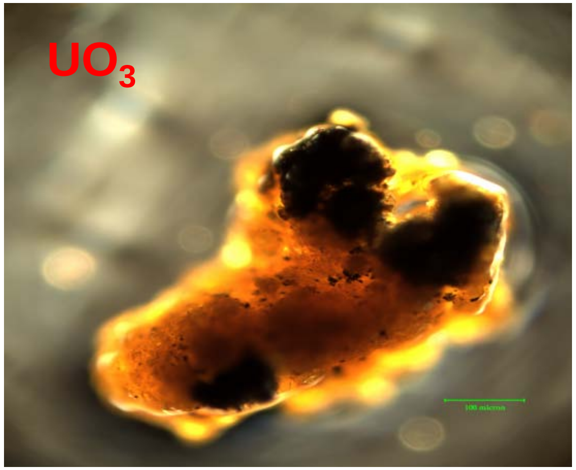
Parameter	Description	Value
Analysis ID	Number or descriptor associated with analysis	ISOTEST251
Material	Material description	PuO_2 sample from reprocessed LWR fuel
Analysis Date	Date analysis performed	05/23/2010
Destructive Analysis Method	Analytical chemistry method (eg. TIMS, titration, etc.)	Radiochemistry + TIMS
Isotope Ratio	$^{240}Pu/^{239}Pu$	0.26535
Uncertainty	Method to evaluate uncertainty (GUM, 1 sigma, etc.)	0.00012
Calibration Process	Brief summary, identify reference materials used and purpose	CRM 137 used for detector calibration; CRM 126-A used for mass bias correction
Documents	References to analytical procedures, methods, pictures, spectra, etc.	Data reduction file ISOTEST251.xls attached. CC-SOP-31 "Determination of Pu Isotopic Ratios by TIMS" attached.

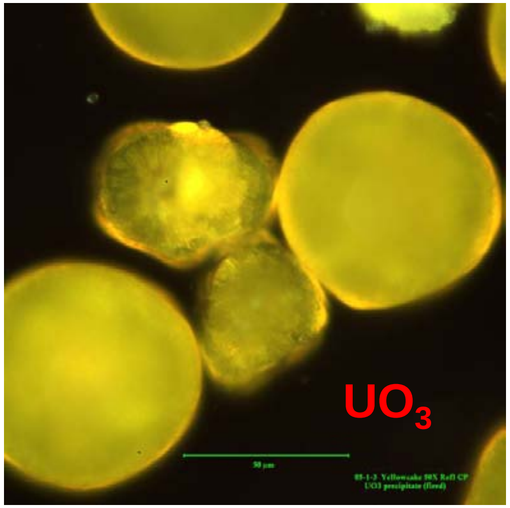
Material Morphology

- Grain mean size
- Grain size histogram
- Shape description
- Homogeneity
- Aspect Ratio
- Inclusions
- Crystal Structure
- Porosity
- Friability









Process and Location History

- Production facility name
  - Geographic coordinates
- Facility purpose (eg. enrichment, fuel fabrication, reactor, etc.)
  - Process description (eg. gas centrifuge, PUREX, etc.)
- Chemical form (Yellowcake, UF_4, PuO_2, MOX, etc.)
- Intended purpose (eg. LWR fuel)
  - Intended use location (eg. US BWR reactors)
  - Intended use notes (eg. designed for 50,000 MWD/MT burn-up)
  - Transportation comments (eg. routes, frequency, etc.)

Data Vetting Information

- Peer-review of data quality and confidence in reported results
- Describe and document the original purpose of the analytical data (eg. material specification verification, forensics assessment)
- Assign a confidence of High, Medium, or Low based on analytical protocol knowledge and / or provenance of the data
- Describe why confidence level was chosen

Path Forward

- Beginning international outreach
  - Get peer country feedback on Data Dictionary
- Engaging with ITWG
  - Discussion of National Libraries concept at June 2010 ITWG Annual Meeting
- Ensure IAEA support for National Libraries concept
- Roll-out concept at appropriate international forums including GICNT and technical conferences

Summary

- Utility of nuclear forensics
  - Understanding material history and origin
  - Deter illicit activities involving nuclear material
- Value of nuclear material libraries
  - Critical for timely and informed nuclear forensics assessments
- National Nuclear Forensic Library concept
  - Country specific implementation
  - US developed Data Dictionary designed to facilitate international discussion and partnership