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Title: Keeping the Momentum and Nuclear Forensics at Los Alamos National Laboratory

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70 YEARS OF CREATING TOMORROW

Los Alamos NATIONAL LABORATORY

Keeping the Momentum and Nuclear Forensics at Los Alamos National Laboratory

Robert Steiner, Heather Dion, Donald Dry, William Kinman, Stephen LaMont, David Podlesak and Lav Tandon

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

NNSA National Nuclear Security Administration

Keeping the Momentum

Following the conclusion of the 2016 Nuclear Security Summit 5 organizations were entrusted with ensuring the legacy created by the NSS process:

- IAEA
- GICNT
- INTERPOL
- Global Partnership

Nuclear Forensic Science Fundamental Requirement: Is it ours?

- If nuclear material is found outside of administrative controls anywhere in the world, then each country should be able to answer the question:

  "Is this consistent with our material?"

- States have a responsibility to establish a system for identifying if materials found out of regulatory control are consistent with those used, produced, or stored within their borders

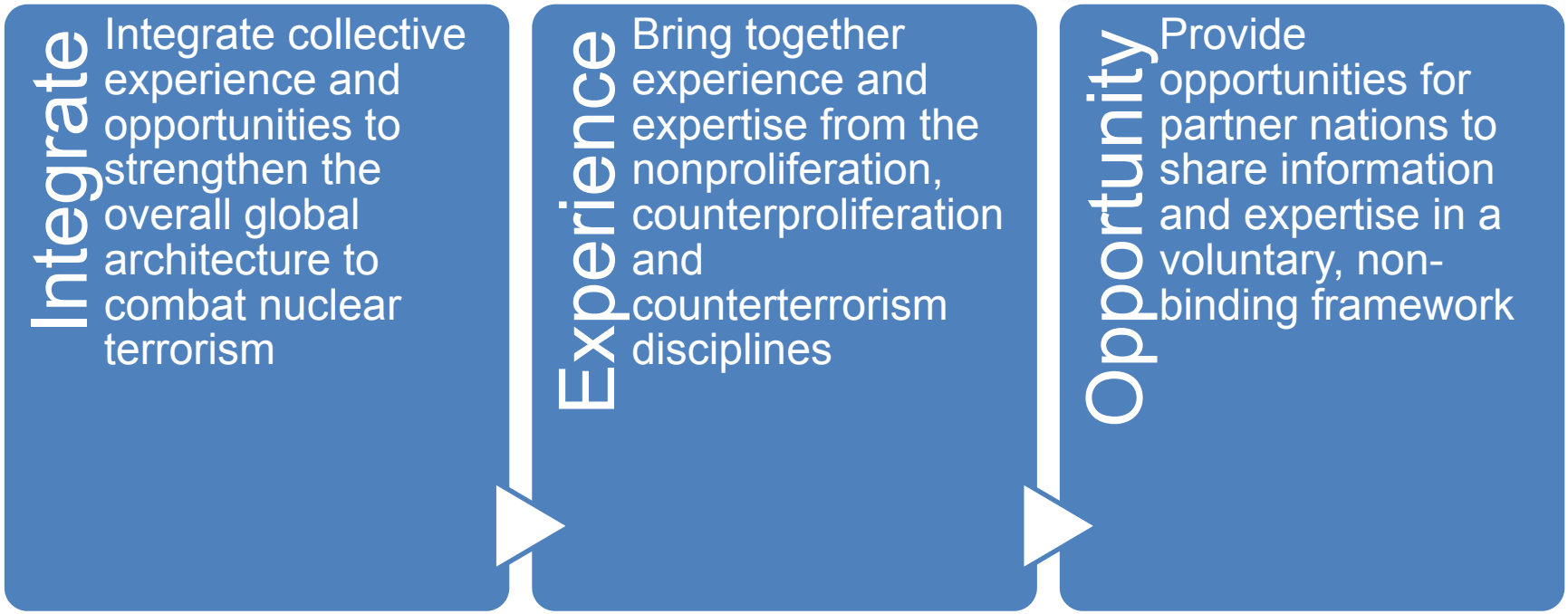
- A national nuclear forensic library is extremely valuable for answering this question with timeliness and confidence

GICNT: Building Global Nuclear Forensics Awareness

Multilateral and regional awareness raising efforts

- **IAEA Nuclear Security Series**
  - NSS #2-G Nuclear Forensics in Support of Investigations
  - NST018: Development of a National Nuclear Forensics Library
  - NST015: Analytic Measurements for Materials out of Regulatory Control in Support of a Nuclear Forensics Investigation
- **IAEA Training**
  - **Introduction to Nuclear Forensics**
  - **Nuclear Forensics Methodologies**
- **ASEAN Regional Forum engagement**

Global Initiative to Combat Nuclear Terrorism



Implementation and Assessment Group

Nuclear Detection Working Group
Nuclear Response and Mitigation Working Group
Nuclear Forensics Working Group

LANL Participation in NFWG Activities

LANL has supported the NFWG Chair (D.Hill and T.Bull since the inception of the IAG)

- Support to Plenary and IAG Meetings
- Documents
  - Fundamentals Document
  - Information Sharing
  - Exercise Playbook
- Exercises
  - Iron Koala (2012)
  - Blue Beagle (2014)
  - Tiger Reef (2014)
  - Mystic Deer (2015)
  - Radiant City (2015)
  - Maple Sunrise (2015)
  - Northern Lights (2015)
  - Kangaroo Harbor (2016)

Bilateral Projects: Expand the understanding of nuclear attribution and signatures

Bilateral projects of interest to the international nuclear forensics community

Partners Engaged

- China
- France
- Japan
- EURATOM
- Canada
- Australia
- South Korea

Radiochronometers provide insight into separation date and quality

Areas for improvement

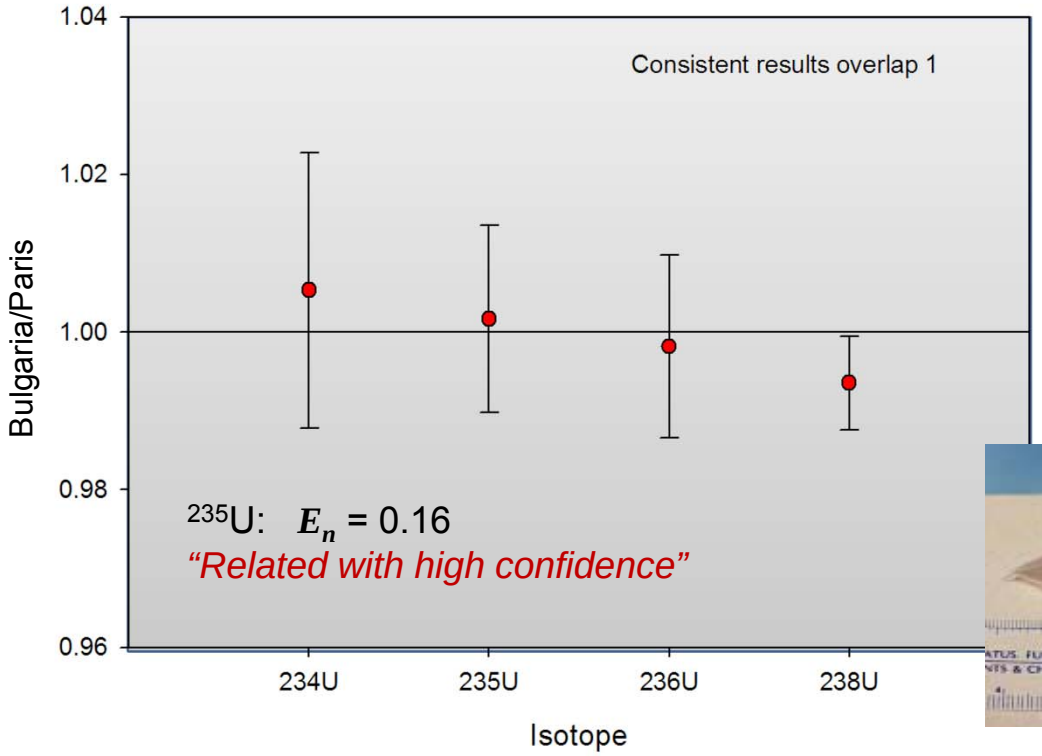
- Certified Reference Materials
- Development of ^{229}Th
- Measurement and interpretation of multiple parent-progeny pairs
- $^{230}Th/^{234}U$ and $^{231}Pa/^{235}U$

Current Focus: Uranium Chronometry

- Work with partners to increase precision and accuracy in uranium age dating
- Focus on a single topic to maximize INFC's investment

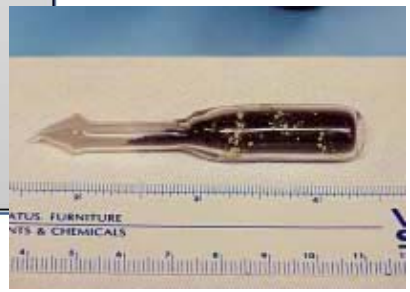
1999 Bulgaria and 2001 Paris Comparison

Comparison of Bulgaria and Paris Uranium Isotopic Composition Results



Demonstrated:

- Connections between cases
- Value of libraries
- Importance of international cooperation



Bulgaria sample results from: *Forensic Analysis of a Smuggled HEU Sample Interdicted in Bulgaria*, Lawrence Livermore National Laboratory, U.S. Dept. of Energy, UCRL-ID-143216, 2001.

France sample results from the proceedings of: *International Conference on Illicit Nuclear Trafficking: Collective Experience and the Way Forward*, IAEA-CN-154/062, November, 2007.

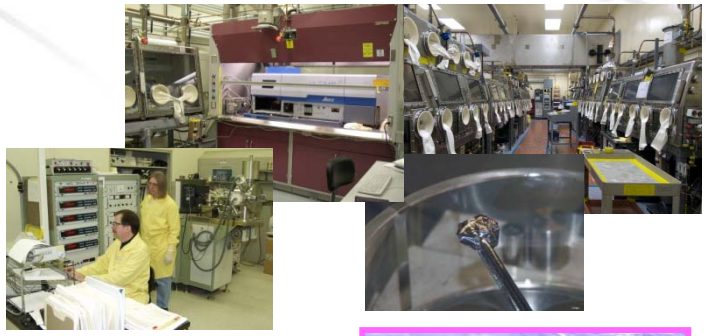
Nuclear Forensics Partner Organizations

- United States
  - Lawrence Livermore National Laboratory
  - Los Alamos National Laboratory
  - Pacific Northwest National Laboratory
  - Argonne National Laboratory
  - Department of State
  - Department of Homeland Security
  - Federal Bureau of Investigation
- Algeria
  - Commissariat à l'Energie Atomique
- Australia
  - Australia Nuclear Science and Technology Organization
- Canada
  - Canada Nuclear Safety Commission
- China
  - China Institute for Atomic Energy
- European Commission
  - Joint Research Center-Institute for Transuranium Elements
- France
  - Commissariat a l'Energie Atomique
- International Atomic Energy Agency
  - Division of Nuclear Security
- Japan
  - Japan Atomic Energy Agency
- Kazakhstan
  - Kazakhstan Atomic Energy Commission
- Republic of Korea
  - Korea Atomic Energy Research Institute
  - Korea Institute of Nuclear Nonproliferation and Control
- Russia
  - ROSATOM
- South Africa
  - Nuclear Energy Corporation of South Africa

How does LANL Provide Sound Technical Support to the International Community?

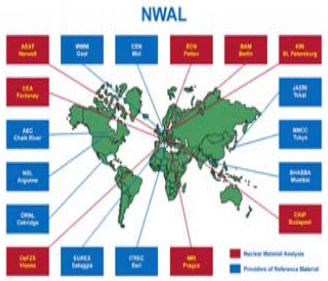
Our ability to characterize nuclear materials and processes relies on analytical methods from:

Certification of materials in pit production



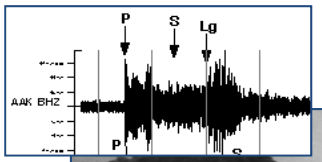
Our ability to characterize signatures of worldwide nuclear materials production relies on skills built in:

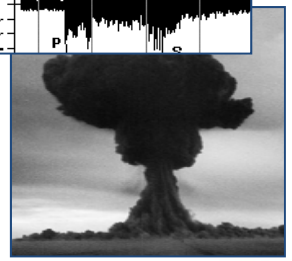
Support for international safeguards programs



Our ability to characterize the origins of a nuclear explosion is based on:

Underground test experience

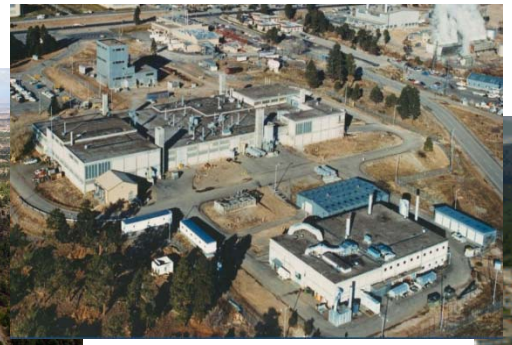




Facilities to Work with Materials of all Quantities

All facilities house ongoing missions that exercise analytical capabilities routinely

TA-48



Sigma

CMR

TA-55

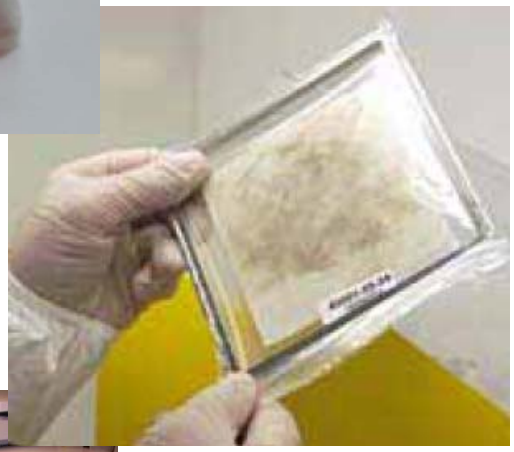
RC-45 — < 10^{11} atoms Pu-239

RC-1, Sigma — 10^{9} – 10^{22} atoms Pu-239

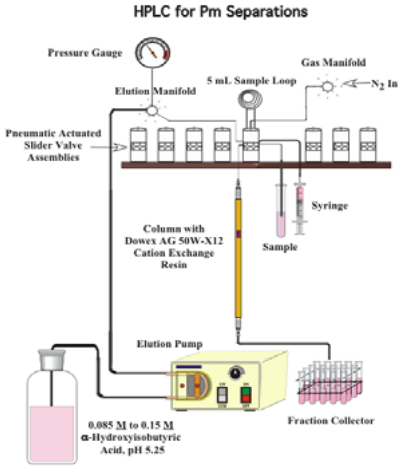
Nuclear facilities (CMR, PF-4) — > 10^{22} atoms Pu-239

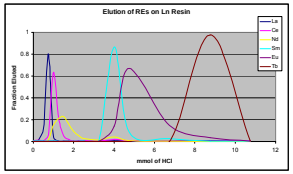
Sample Types

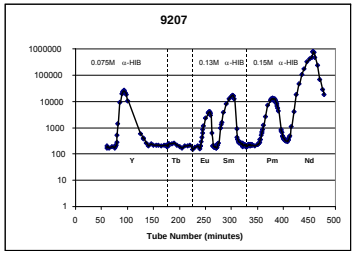
- Swipes
- Soil
- Water
- Vegetation
- Biological (urine, bone, tissue)
- Geological
- Radiological Materials



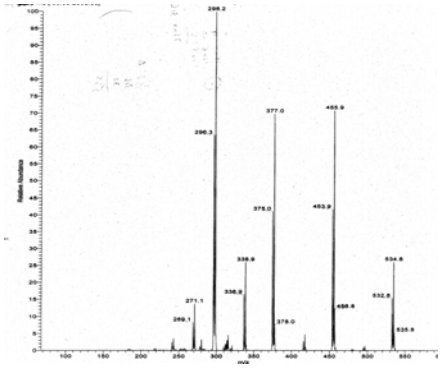
Radiochemistry

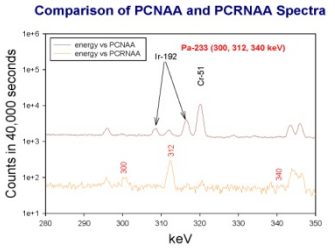






- Single or multi-element
- Elementally separated radiochemistry
- Standardized procedures
- Refractory matrices





Bulk Analysis

Multi-collector ICP-MS
(MC-ICP-MS)
High precision, high accuracy
Isotope ratios (U, Th, Sr, Pb, Fe, B…)
ng to <fg sample requirements

Sector Field ICP-MS
(SF-ICP-MS)
Ppq – ppm elemental concentrations

Multi-collector TIMS
Pu, other actinides, Sr, Nd

Summary

- LANL has 70 years of experience in nuclear forensics and supports the community through a wide variety of efforts and leveraged capabilities
  - Expanding the understanding of nuclear forensics
  - Providing training on nuclear forensics methods
  - Developing bilateral relationships to expand our understanding of nuclear forensic science

- LANL remains highly supportive of several key organizations tasked with carrying forth the Nuclear Security Summit messages
  - IAEA
  - GICNT
  - INTERPOL

Back up slides

Analysis and Characterization of Actinide Materials

Onsite Analytical Chemistry and Sample Management

Coordinate sample receiving, shipping, and distribution at TA-55 and CMR

Onsite radiochemical and trace analysis

Assay and Classical Chemistry

Coulometric titration
Ceric titration
Pu (III) and Pu (IV)
U Assay by Davies Gray
Fe and Si determination
Loss on Ignition (LOI)
Free acid determination
Standard preparation

Plasma Spectroscopy

Inductively Coupled Plasma-Mass Spectrometry
Inductively Coupled Plasma- Atomic Emission Spectrometry

DC Arc Emission

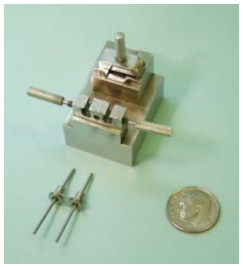
Cold-Vapor Atomic Fluorescence

X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD)

Fingerprint Detection Technology

Analysis and Characterization of Actinide Materials

Mass Spectrometry

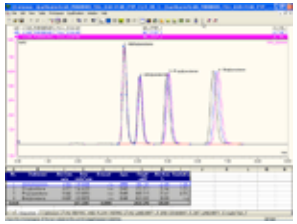


High-Precision
Gas Mass Spectrometry

Radiochemistry and Nondestructive Analysis

Alpha and gamma spectrometry
Gross alpha, liquid scintillation

Interstitial Analysis & Ion Chromatography



Fluoride, chloride, nitrite
nitrate, phosphate, sulfate
oxalate and perchlorate

carbon, oxygen, hydrogen
sulfur, moisture, and tritium

Laboratory Information Management System and Quality Assurance

Oracle SQL*LIMS

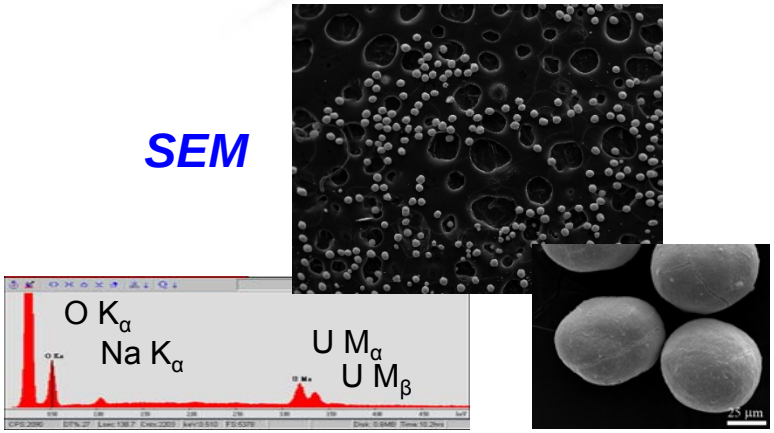
Sample/nuclear material tracking and data management

PIÑON Recognition
2002 New Mexico Quality Awards

Quality Assurance and Control
Record Management
Document Control
Training

Physical Characterization Tools for Bulk Materials

SEM



XRD

Micro-XRF

Electron Probe

EDAXS

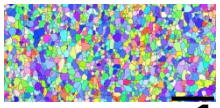
SEM

Auger

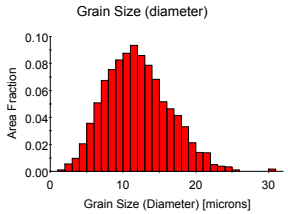
XPS

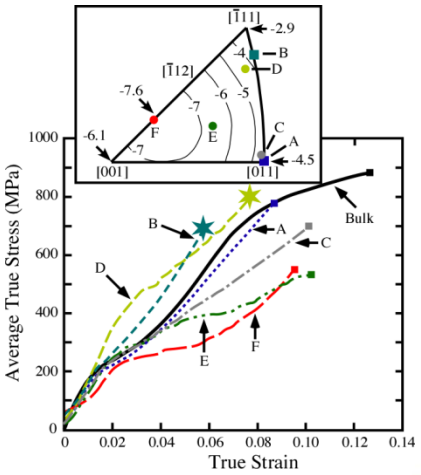
Materials processing techniques leave unique signatures in microstructures:

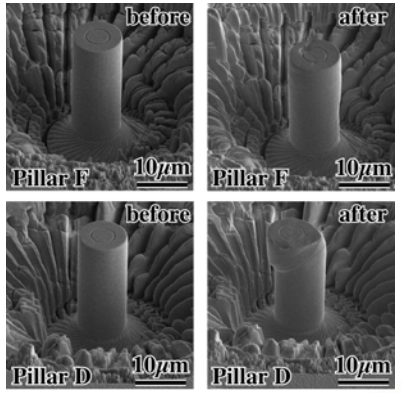
- Grain Size/Morphology
- Inclusion Distribution/Morphology
- Microstructural Texture
- Mechanical Properties
- Surface Features



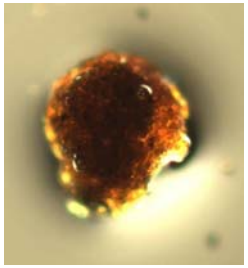
100 µm







Materials Analysis



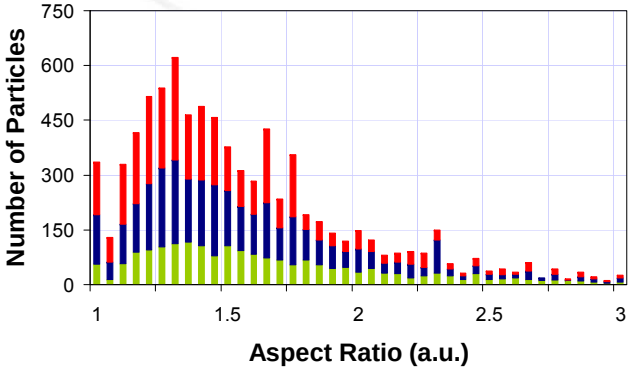
Origin?

Production Method?

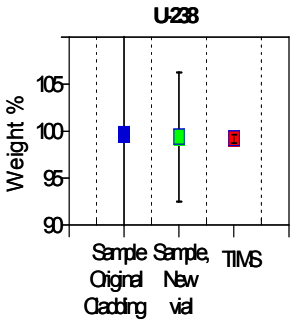
Age of Material?

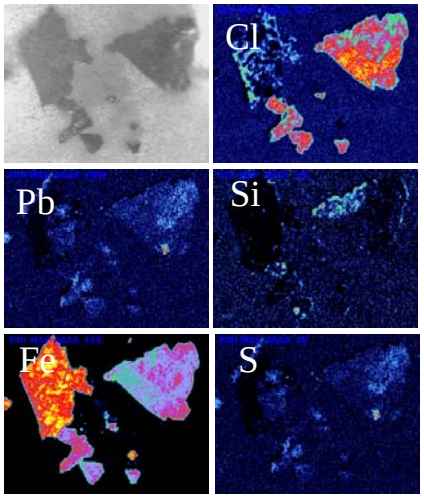
Intended Use?

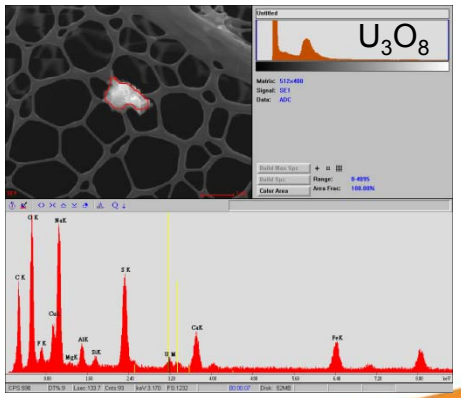
History



Nuclide	Sample (μg/g)
^{234}U	5.5×10^{1}
^{235}U	5.7×10^{3}
^{238}U	7.9×10^{5}
^{238}Pu	7.4×10^{-4}
^{239}Pu	2.5×10^{1}
^{240}Pu	1.0×10^{-2}
^{242}Pu	2.5×10^{-4}





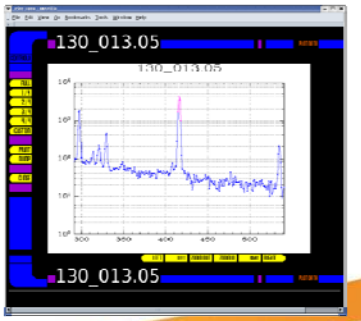


Count Room Capabilities

Provides qualitative and quantitative assay of gamma, beta, and alpha-emitting radionuclides in a variety of matrices and over a wide range of activity levels,

- Trace levels to >10^{13} fissions

- Specializing in fission product measurements,
- Operates 24x7x365
- Sample receipt and handling protocols
- Makes ~ 70,000 measurements annually
  - 30,000 high resolution gamma collections
- 30 non-automated high-resolution gamma-ray spectrometers, some highly specialized
- 10 custom automated high-resolution gamma-ray spectrometers,
- 6 custom automated beta counters.
- 6 custom non-automated beta counters (3 ~0.2 CPM Bkg)
- ~ 90 Alpha spectrometers,
- Batch and interactive analysis codes,
- Relational database with web-based visualization tools.



RC-45 Clean Chemistry and Mass Spectrometry Facility

- Annually certified clean laboratories
- Perchloric acid capability
- Ultra low-level sample handling
- Co-located clean radiochemistry and analysis capability
- Isotopic and elemental analysis

Clean Sample Preparation

Cleanroom compatible sample ashing
Class 100, low insulation ashing equipment for particle control

Radiochemistry processing
Class 10-100, glassware cleaning, sample dissolution and digestion, ion exchange chemistry, sample dry down

Sample loading areas
Class 10 -100, electroplating, carborizing, direct loading

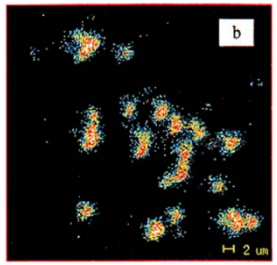
New Additions

NuWave Micromill
Small scale spatial sampling for Analysis by TIMS or ICP-MS

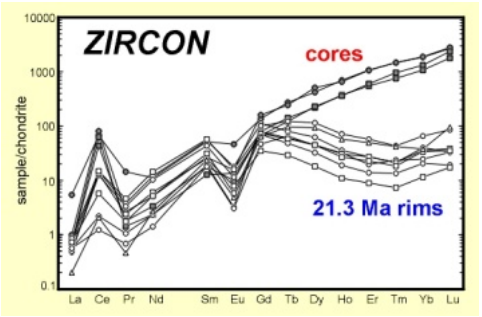
Quad ICP-MS and ICP-OES
Trace analysis and coupling to on-line separations techniques and laser ablation for method development

Investments in Modern Capabilities

- Neptune MC-ICP-MS
- IsotopX Isoprobe-T MC-TIMS
- FEI SEM w/WDS & EDS
- Element XR ICP-MS



- Dual-Clover high resolution gamma-ray spectrometers



Instruments Available

- Multi- Collector TIMS, 5 - IsotopX Phoenix instruments, 1 VG Sector 54
- Multi-Collector ICPMS - 2 Thermo Neptune Pluses, 1 Thermo Neptune, 1 Nu Instruments Plasma II.
- HR ICPMS - 2 Thermo Elements
- Quad ICPMS - 1 Thermo ICapQ, 1 PE Elan DRC, 1 Agilent 7700
- ICP-OES - Thermo ICap 6500
- XRF - Bruker S8 Lion
- SEM - FEI Field Emission Instrument
- Capillary electrophoresis and HPLC
- Several laser ablation systems
- Stable Isotopes - Thermo MAT 253 and Thermo Delta V
- Laser spectroscopy instrumentation

Summary

- Analytical chemistry measurements on plutonium and uranium matrices are critical to numerous programs including safeguards accountancy verification measurements.
- Los Alamos National Laboratory operates capable actinide analytical chemistry and material science laboratories suitable for nuclear material and environmental forensic characterization.
- Los Alamos National Laboratory uses numerous means to validate and independently verify that measurement data quality objectives are met.
- Numerous LANL nuclear facilities support the nuclear material handling, preparation, and analysis capabilities necessary to evaluate samples containing nearly any mass of an actinide (attogram to kilogram levels).