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Title:	Nuclear Forensics in Support of National Response Plans
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Nuclear Forensics in Support of National Response Plans

Briefing to GMS Familiarization Seminar LANL & SNL

19-22 September 2022

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Nuclear and Radiochemistry (C-NR)

19 September 2022

LA-UR

Goal and Objectives

Goal

Become familiar with nuclear forensics methodologies in support of nuclear security investigations and how Los Alamos National Laboratory supports the development of sustainable global nuclear forensics capacities

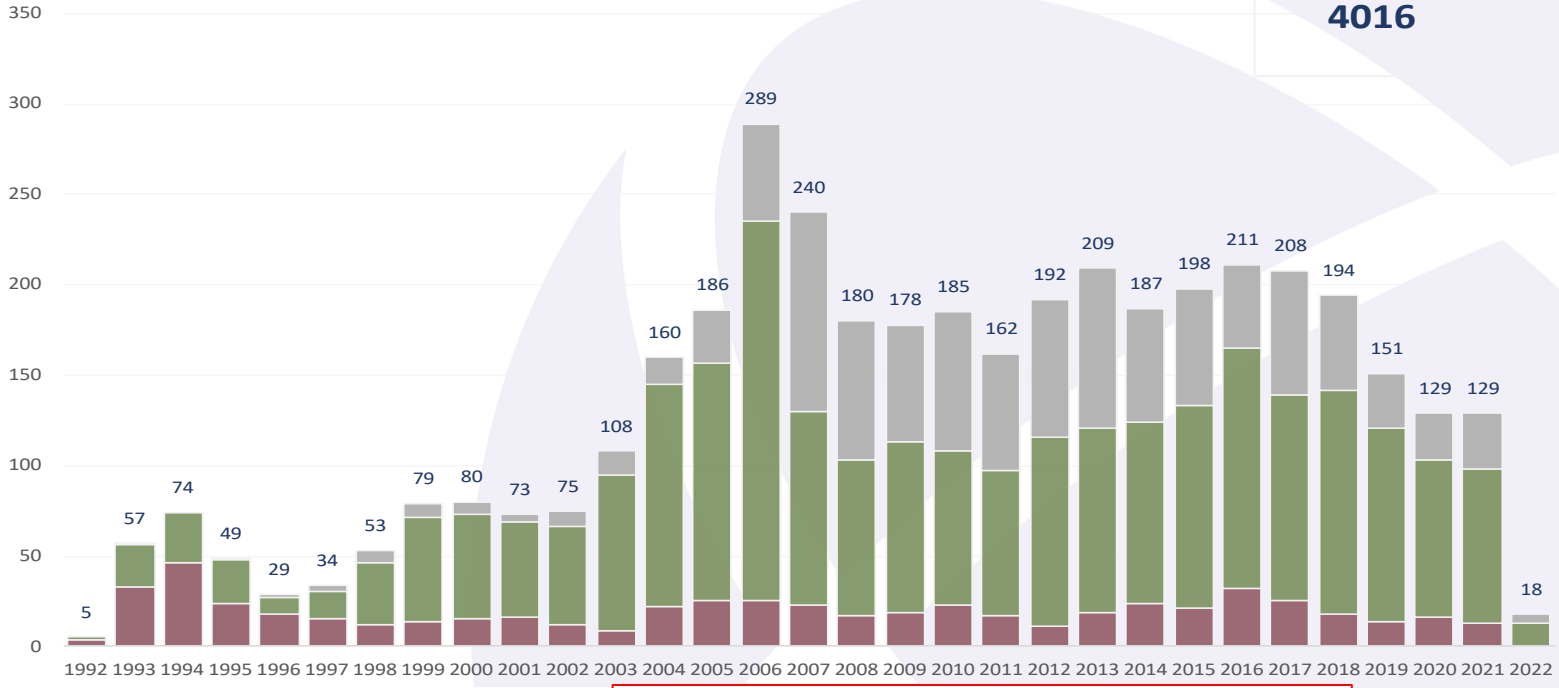
Objectives

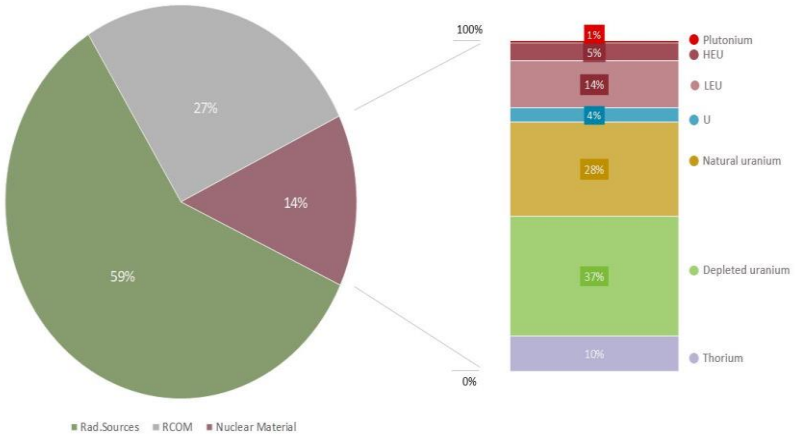
- Define nuclear forensics
- Explain scope and application of nuclear forensics in support of nuclear security investigation
- Demonstrate the use of nuclear forensics in protection and detection of, and response to a nuclear security event
- Describe Los Alamos National Laboratory support to the development of sustainable global nuclear forensics capacities

ITDB by Numbers: 1992-2022*

Confirmed Incidents: by Type of Material

Total
4016

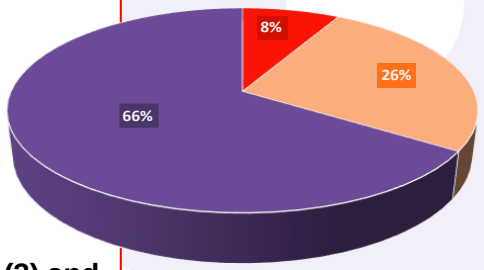




Group 1: Incidents of <u>trafficking or malicious use</u>
- **highly enriched uranium (12), plutonium (3) and plutonium beryllium neutron sources (5)**

Group 2: Incidents of <u>undetermined</u> intent
- **highly enriched uranium (3) and and plutonium beryllium neutron sources (3)**

Group 3: Incidents <u>not connected</u> with trafficking or malicious use
- **highly enriched uranium (20), plutonium (3) and plutonium neutron sources (10)**

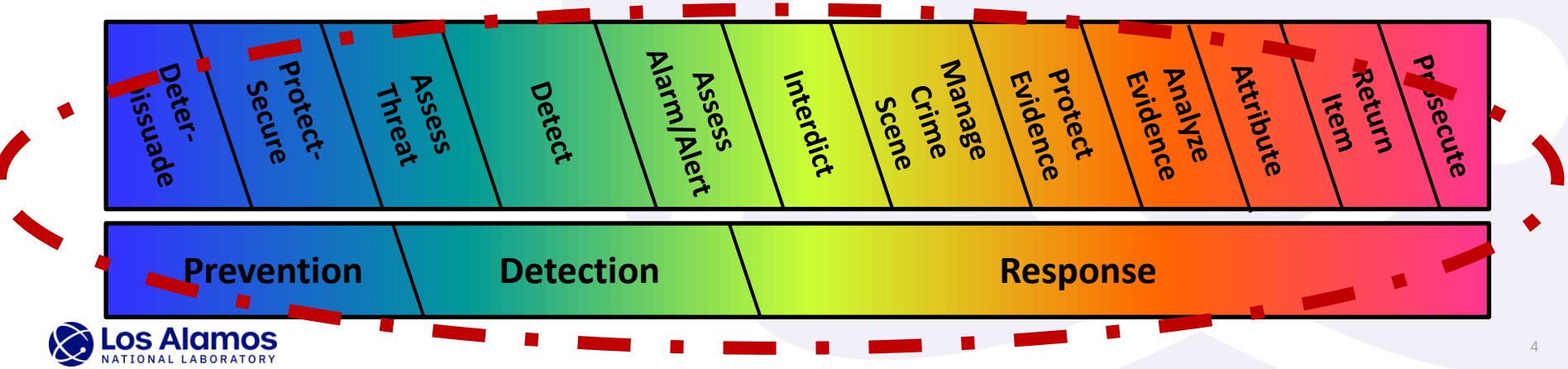


*IAEA ITDB Factsheet

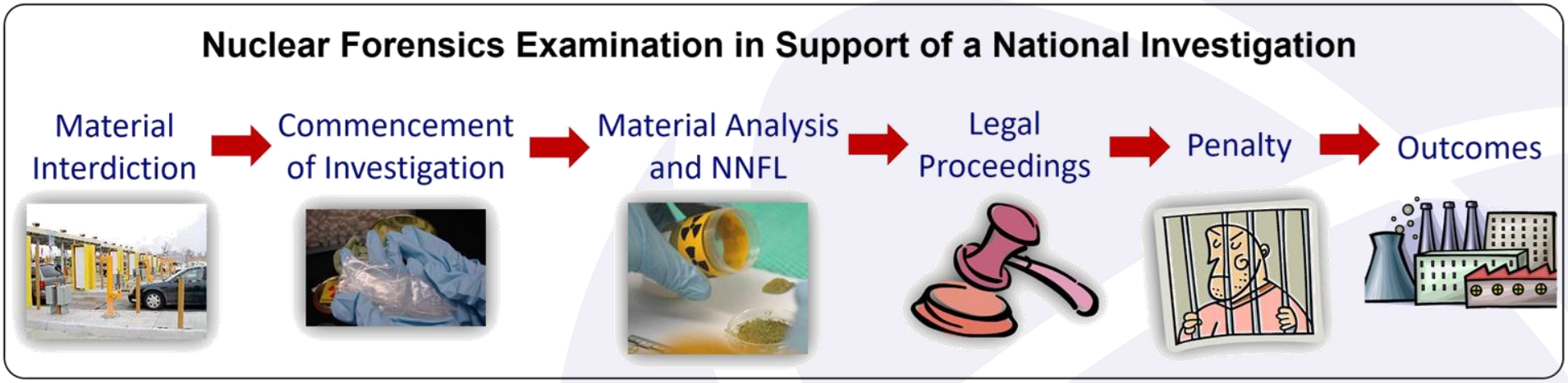
What is Nuclear Forensics?

Nuclear forensics is the examination of nuclear or other radioactive material, or of evidence contaminated with radionuclides, in the context of legal proceedings under international or national law related to nuclear security

- The goal of forensic science is to discover **linkages among people, places, materials, and events**
- Nuclear forensics is an essential component of national response plans to events involving nuclear or other radioactive materials out of regulatory control and **informs prevention, detection and response**



What is Nuclear Forensics Used for?
Part 1: Evidence in Support of Prosecutions



Support to law enforcement and prosecutorial bodies

- Technical evidence for judicial proceedings
- Requires high-quality, legally defensible analyses
  - What is it?
  - How much is there?
  - Was a law violated?
- Does not generally require a detailed analysis of all material attributes

Most countries have the technology, equipment and expertise for these analyses

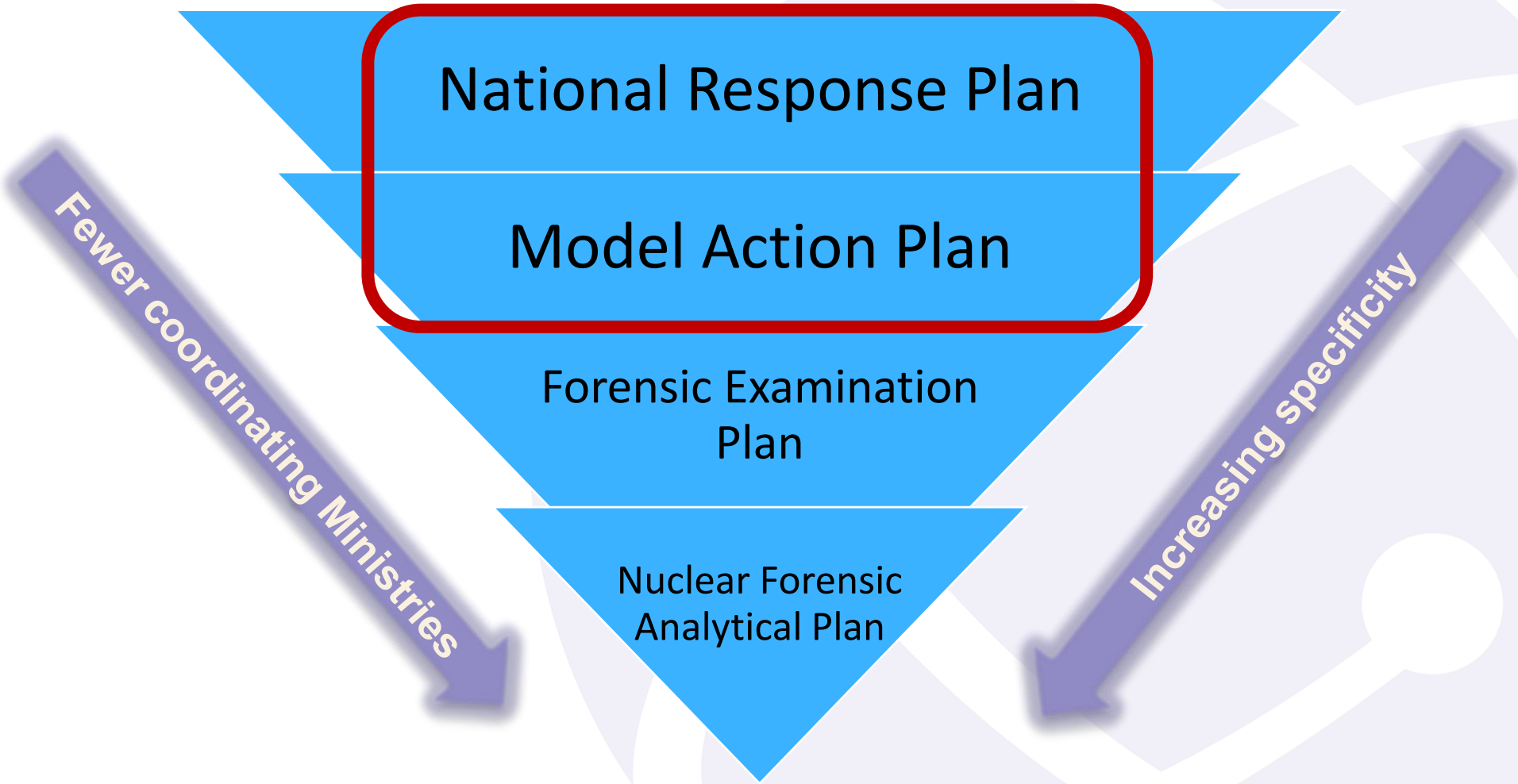
What is Nuclear Forensics Used for?
Part 2: Nuclear Security Investigation

Support to law enforcement and regulatory investigators

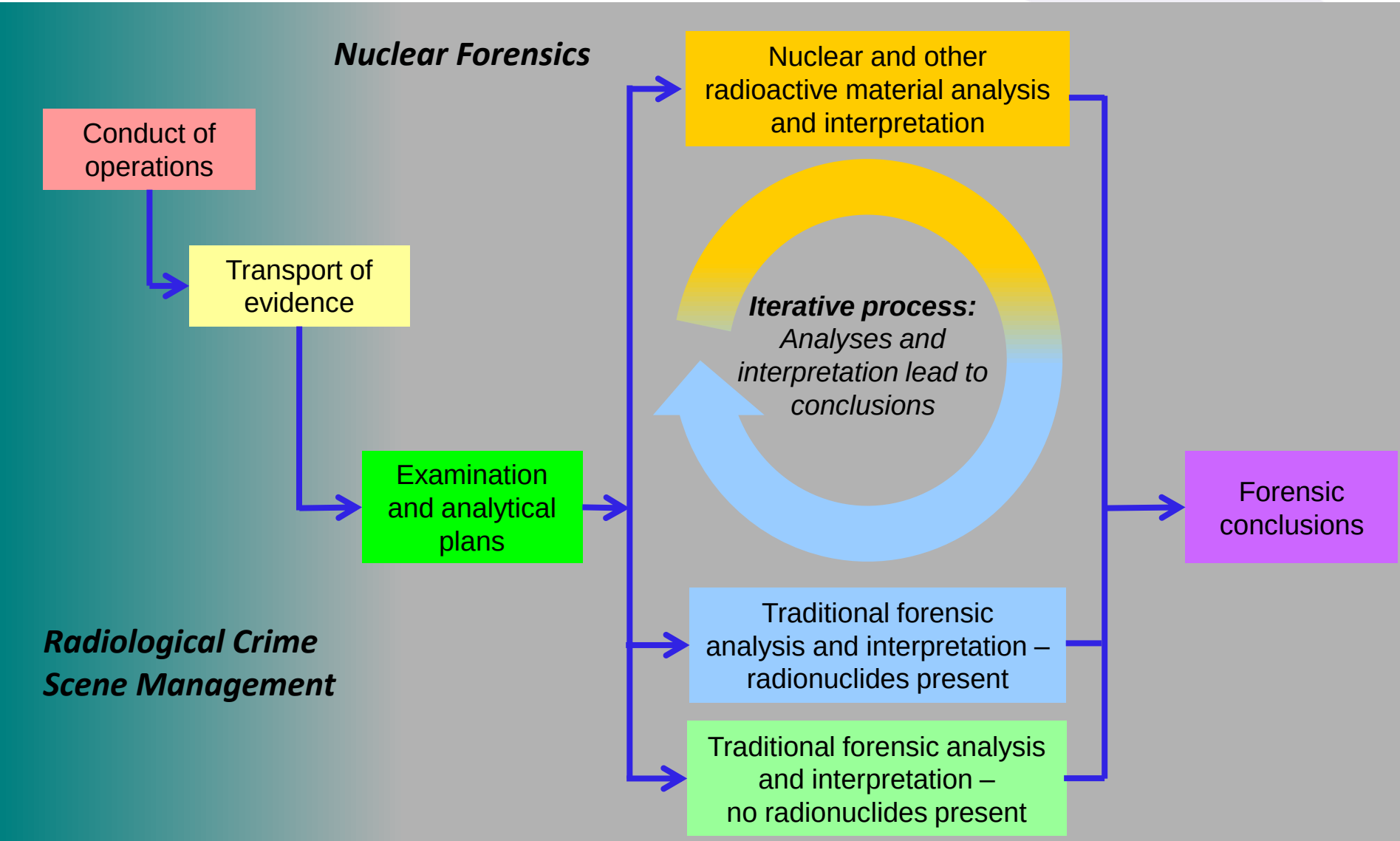
- Detailed analysis of material attributes & expert evaluation and comparative analysis
- Assessment of material origin
- Assessment of connection to previous cases
- To address questions of prevention, detection, and response to nuclear security events
  - Weaknesses in physical protection and control
  - Vulnerabilities at borders and other nodal points
  - Insider involvement

***Often** requires advanced capabilities, e.g. laboratory analysis, data interpretation, national nuclear forensics library*

How Does Nuclear Forensics Support National Response to Nuclear Security Events?



What is the Nuclear Forensics Process?



How is Nuclear Forensics Applied?

Utilizes physical, chemical, elemental and isotopic signatures inherent to nuclear and other radioactive material

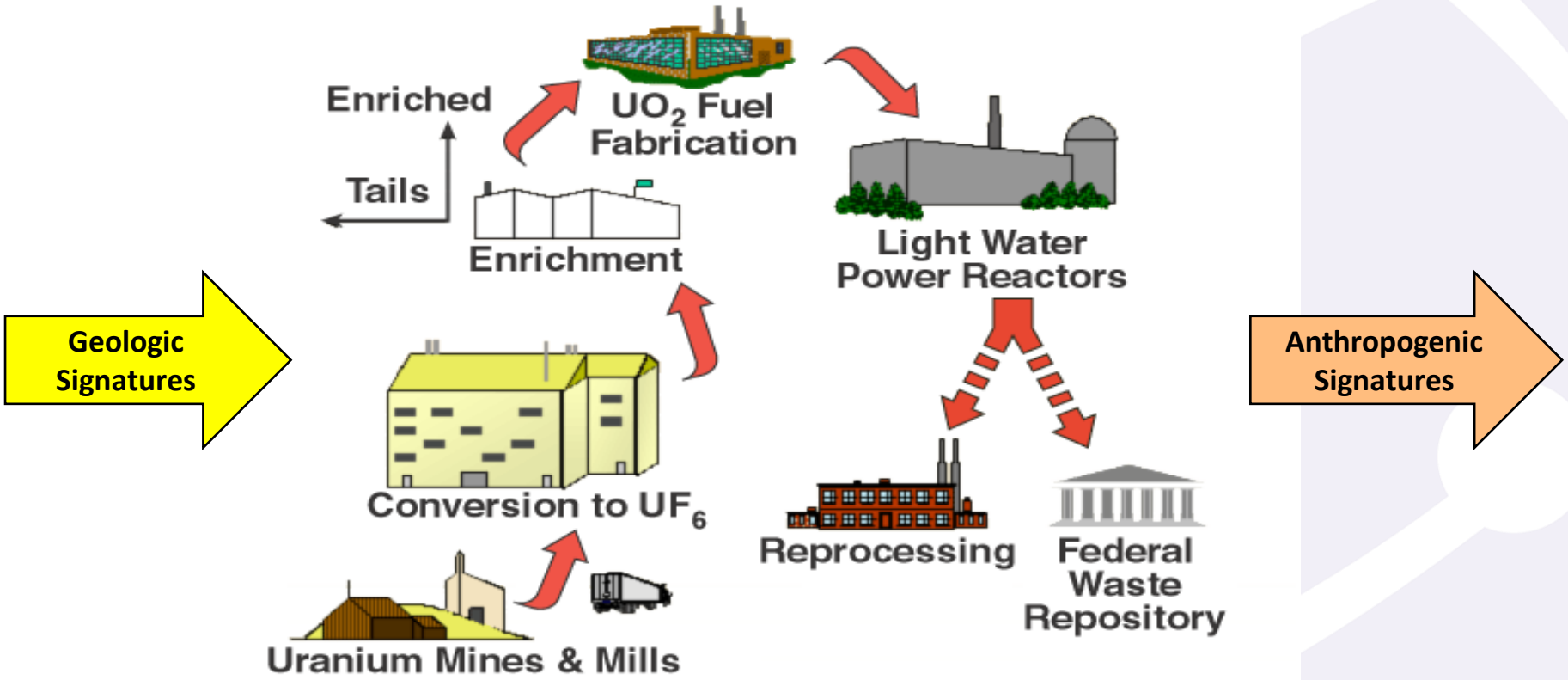
AND

Examines traditional forensic evidence contaminated with radionuclides, *inter alia*:

- Pollen (geolocation)
- Soil/dust/debris
- Toolmarks
- Digital data
- Body fluids (DNA)
- Hairs/fibers
- Fingerprints

How Do Signatures Have Bearing on Origin and History of Material?

Nuclear forensic signatures are observable physical or chemical characteristics that have forensic value to distinguish origin and history of material

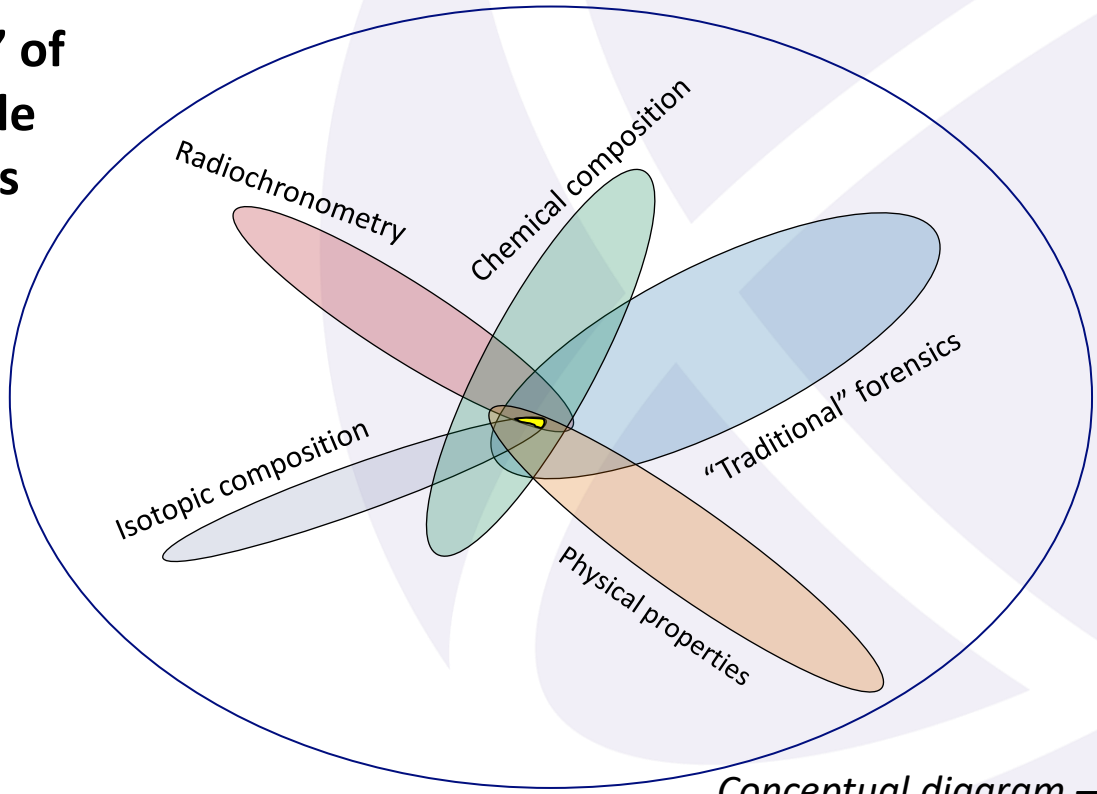


* Graphic does not represent the comprehensive nuclear fuel cycle

How Do Signatures Have Bearing on Origin and History of Material? Cont.

Understanding how signatures are imparted throughout the nuclear fuel cycle enables understanding of linkages to the origin and history of smuggled nuclear material

"World" of possible origins



Conceptual diagram – forensic signatures

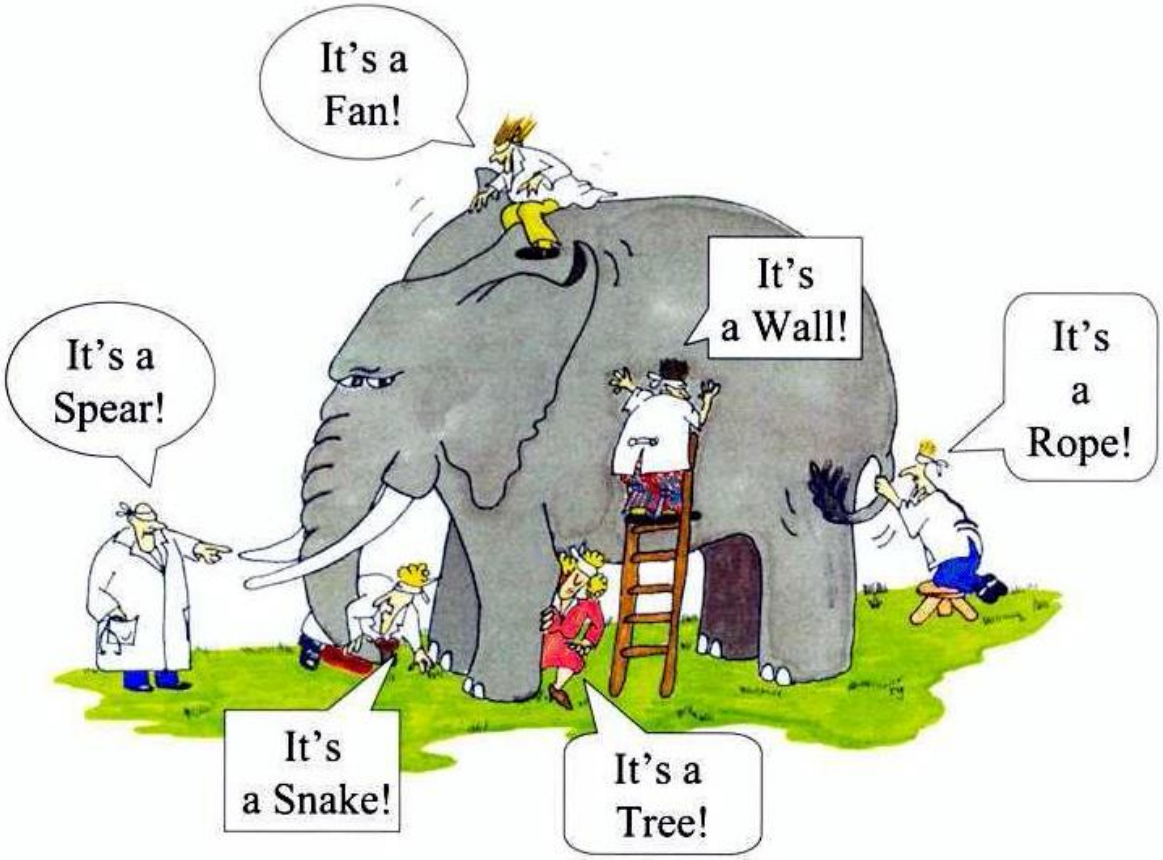
11

What Does One Do with Nuclear Forensics Results?

Use a National Nuclear Forensics Library to Interpret Data

and

Help Formulate Findings!



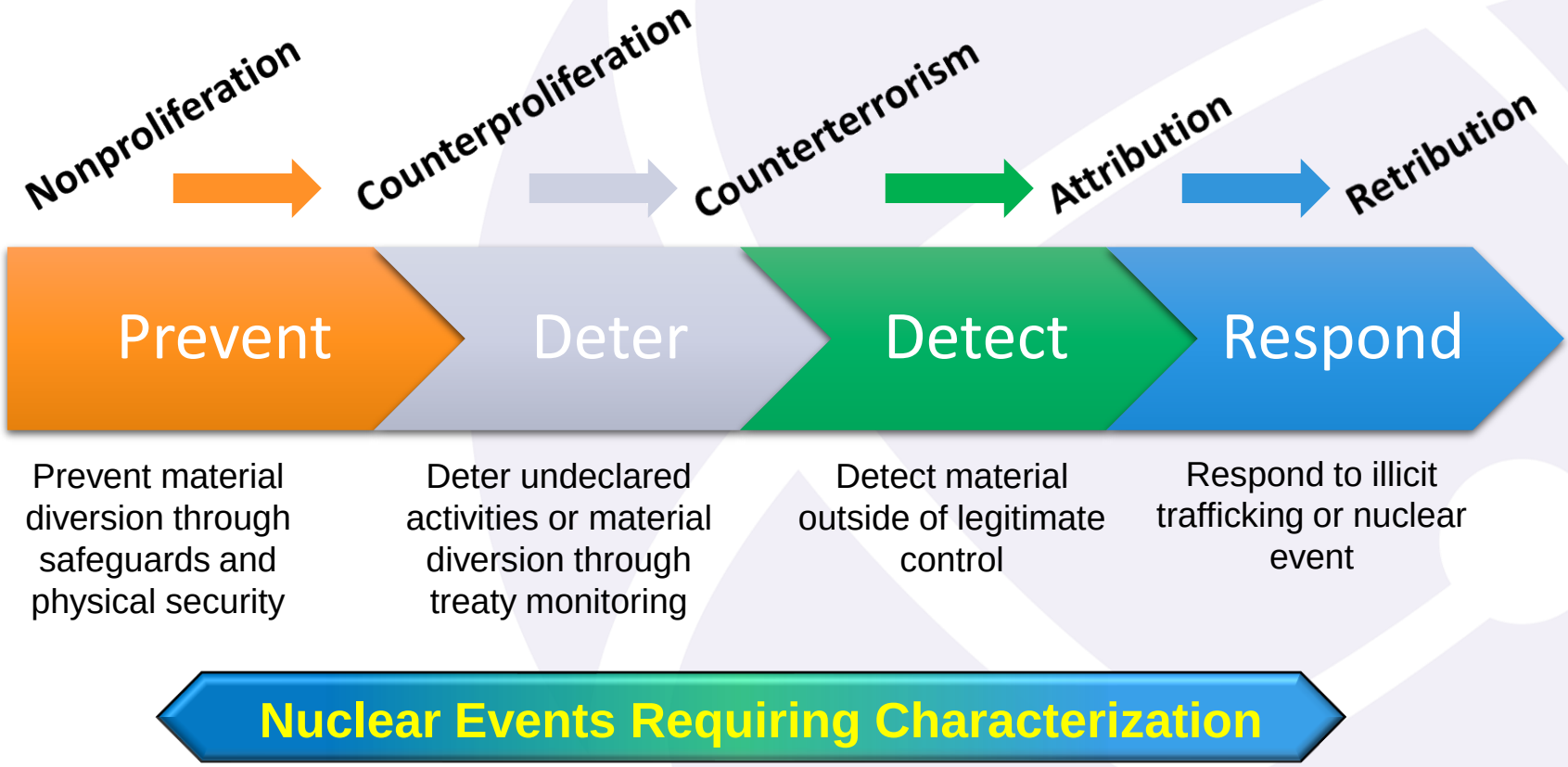
Summary

- Nuclear forensics in support of investigations involves a comprehensive approach undertaken by States to determine the origin and history of nuclear or other radioactive material in support of investigations
- **Model action plan** provides a bases to an appropriate response to incidents, when nuclear forensics is required to support investigations
- **Traditional forensic** and **nuclear forensic analysis** are both required in a nuclear forensic examination and complement each other
- **Interpretation** of nuclear forensic results requires existing knowledge and data. A national nuclear forensics library can be a useful tool.
- **Nuclear forensic findings** combined with findings and information from other disciplines are used to advance the investigation

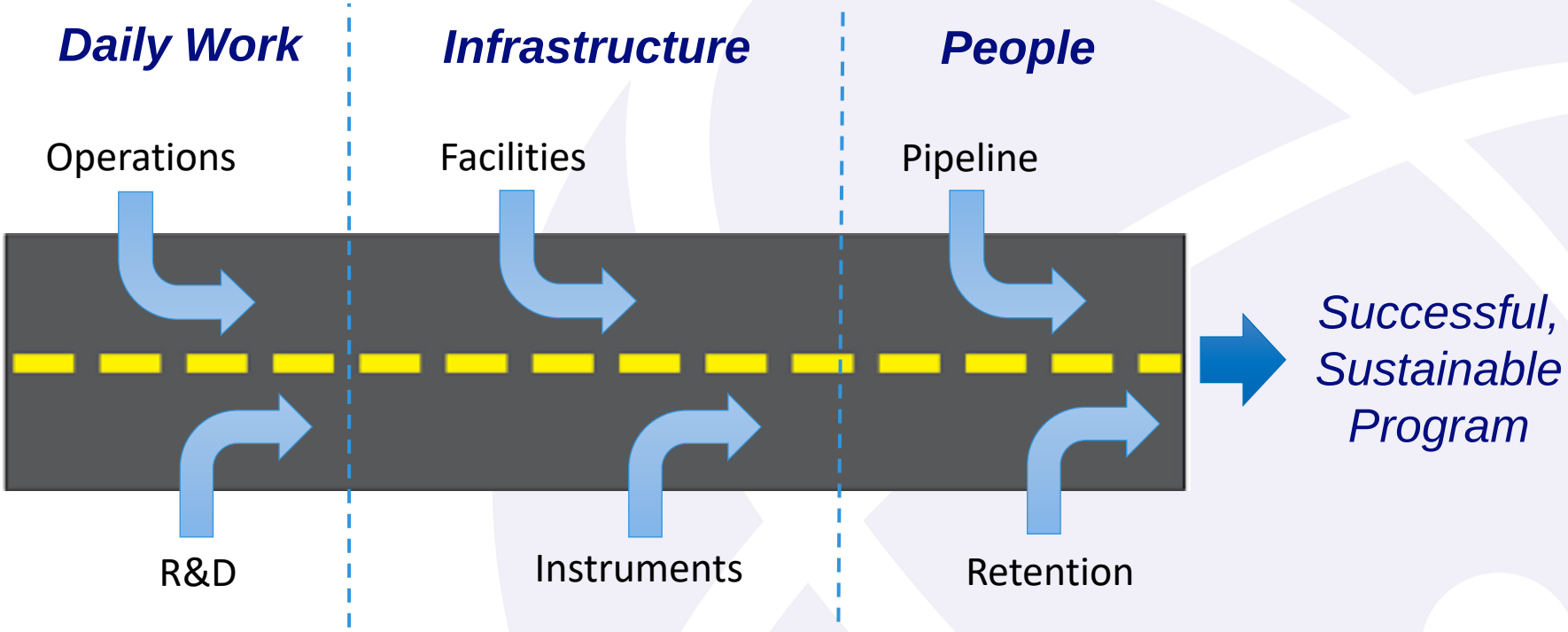
Nuclear Forensics at the Los Alamos National Laboratory

Nuclear Forensics is Important to LANL

LANL supports the entire range of nuclear security activities through operational programs, R&D and capacity building to further US needs, requirements and interests



NF Implementation Strategy at LANL: Road to Success



By taking a holistic approach to nuclear forensics, we are able to successfully execute on the full set of mission activities

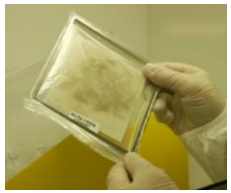
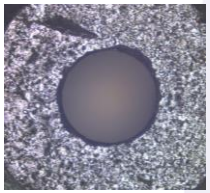
Nuclear security programs in Chemistry Division across the pre- and post-detonation spectrum

Prevent

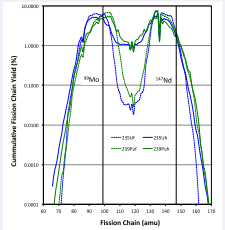
Nuclear Nonproliferation
- Nonproliferation treaty compliance
- IAEA Environmental Safeguards Lab (NWAL)

R&D to improve detection of undeclared activities

Nuclear Test Monitoring
- Nuclear test ban treaty compliance
- Nuclear Debris Collection and Analysis (NDC&A)

Material Measurement Nuclear Security Programs

Respond

Pre-det Nuclear Forensics
- Operational samples
- International engagement
- Capacity building – policy, legislation and technical analysis
- US National Nuclear Forensics Library support

R&D to identify signatures and improve timelines

Post-det Nuclear Forensics
- Analysis of ground and air particulate debris
- Debris diagnostics
- Material attribution and design provenance

Pre-detonation ***Post-detonation***

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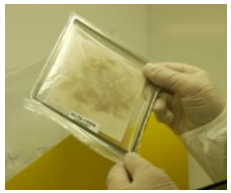
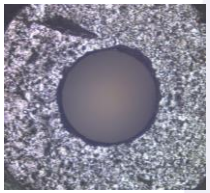
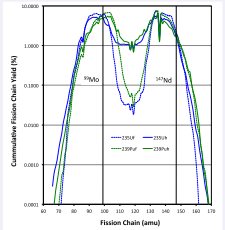



Material Measurement Nuclear Security Programs

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Pre-detonation ***Post-detonation***

USG Partnerships key to the success of our nuclear forensic programs

NSDD Partnership
Working Together to Prevent Nuclear Trafficking
The Office of Nuclear Smuggling Detection and Deterrence

Peer-to-peer

NSDD Partnership
Working Together to Prevent Nuclear Trafficking
The Office of Nuclear Smuggling Detection and Deterrence

Capacity building

Understanding signature transit through fuel cycle

1 2 3 4 5 TRL 6 7 8 9 10

Advanced analysis techniques to access new signatures

Validating measurements and signature tradecraft

NFX OFFICE OF NUCLEAR FORENSICS
U.S. Department of Energy
National Nuclear Security Administration

AIR FORCE TECHNICAL APPLICATIONS CENTER

DEPARTMENT OF JUSTICE FEDERAL BUREAU OF INVESTIGATION

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

NNSA National Nuclear Security Administration
NA-22 DNN R&D

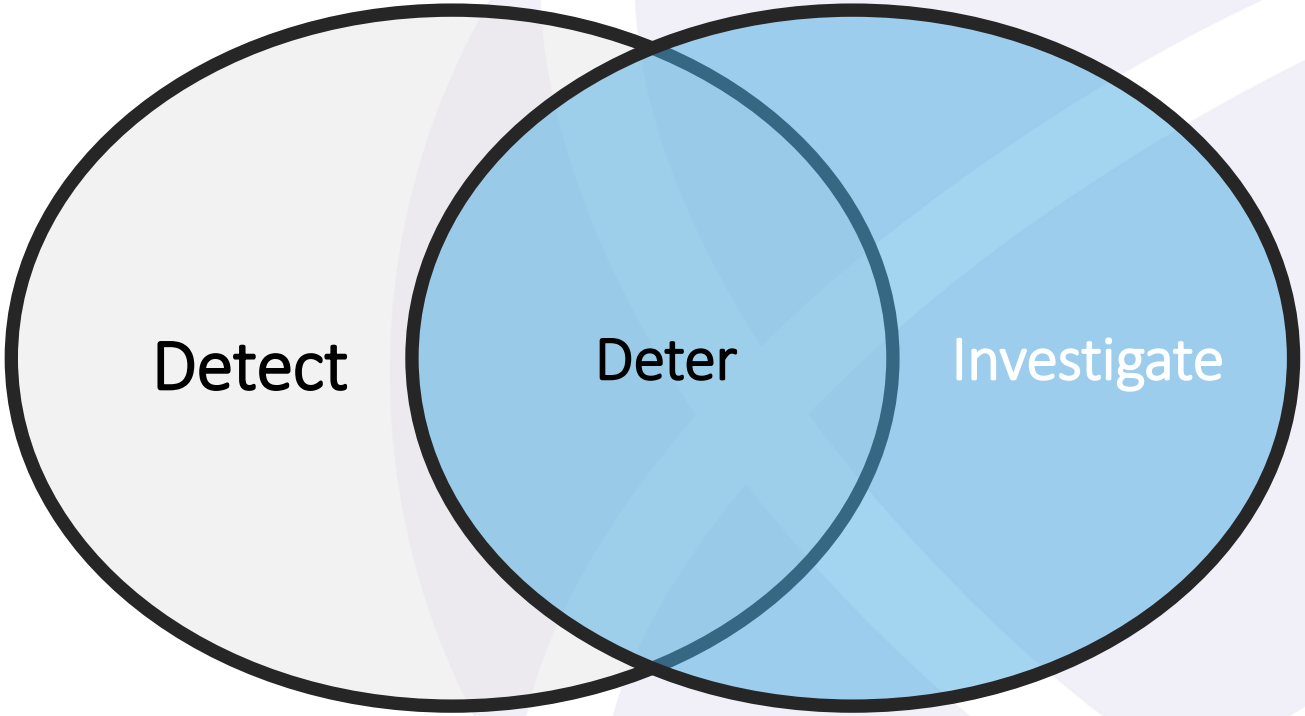
ASSISTANT SECRETARY OF DEFENSE NCB

NUCLEAR MATERIALS NMIP INFORMATION PROGRAM

Los Alamos NATIONAL LABORATORY

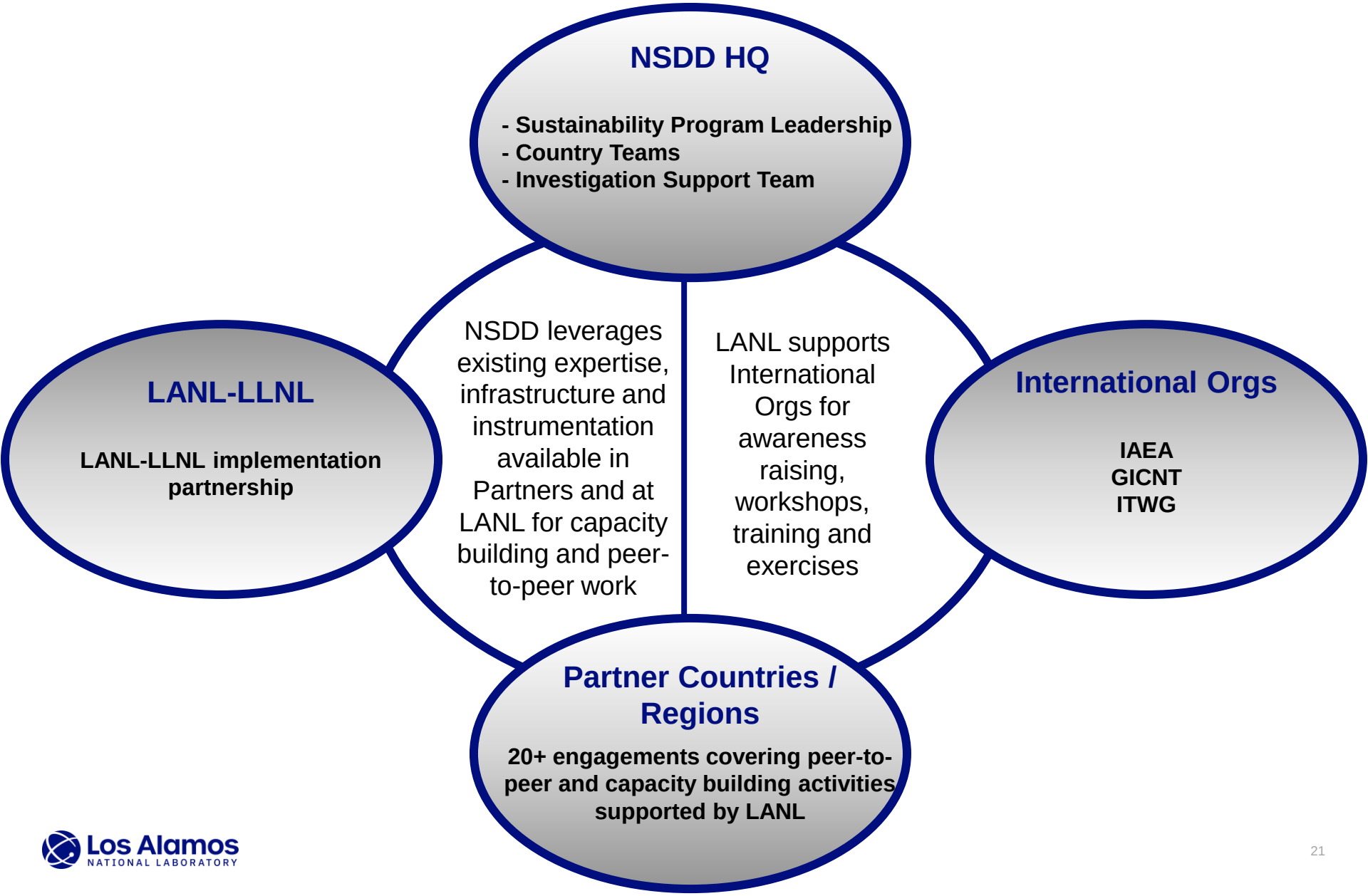
NA-213: Nuclear Smuggling Detection and Deterrence (NSDD) Mission Statement

To strengthen the capabilities of partner countries to **detect**, **deter**, and **investigate** the smuggling of radiological and nuclear materials



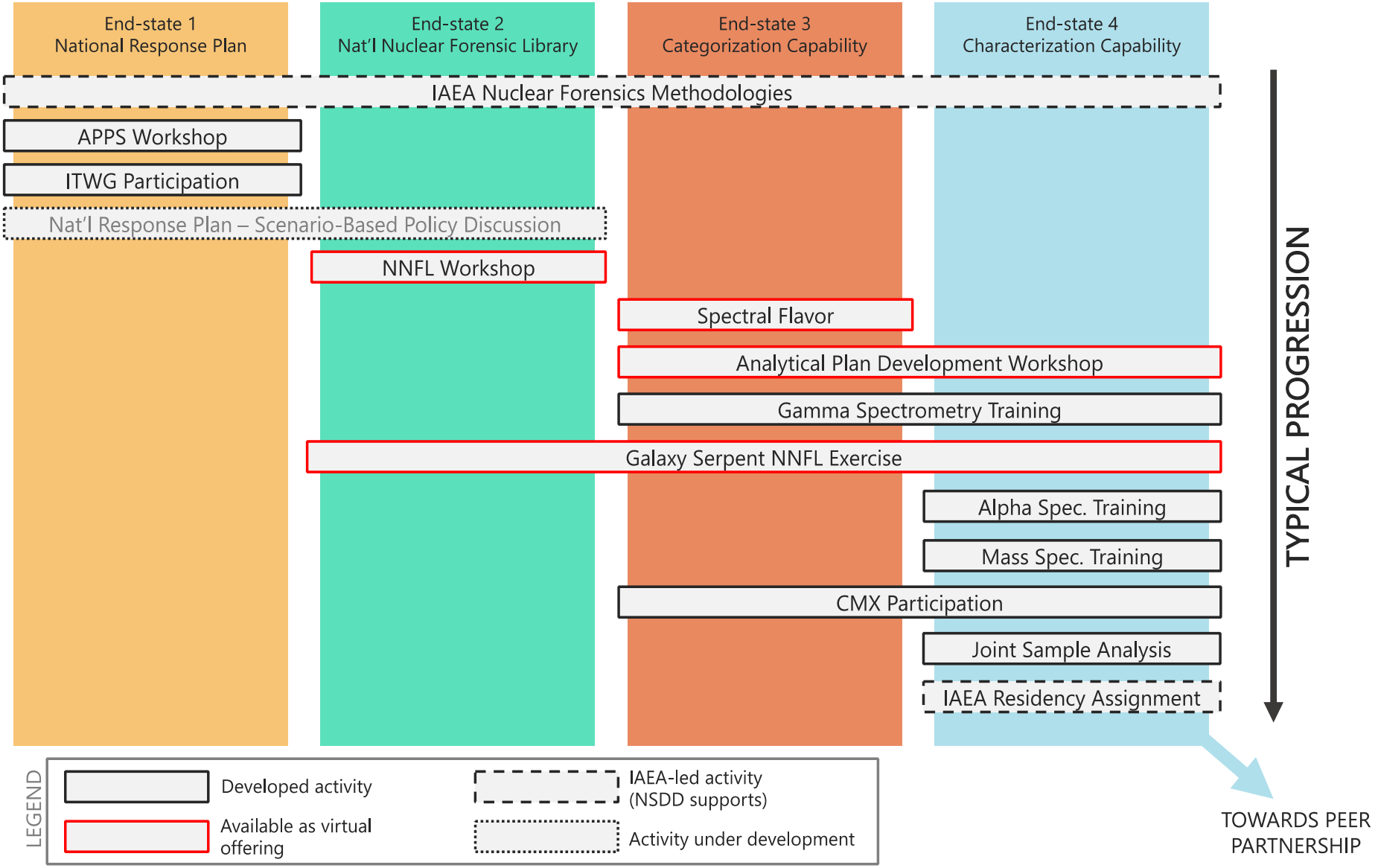
NSDD is the primary USG entity involved in **international, pre-det nuclear forensics capacity building**

Where does LANL fit into all of this?



Investigation Support Capacity-Building Toolbox

The four pillars of NSDD Investigation Support



Los Alamos NATIONAL LABORATORY

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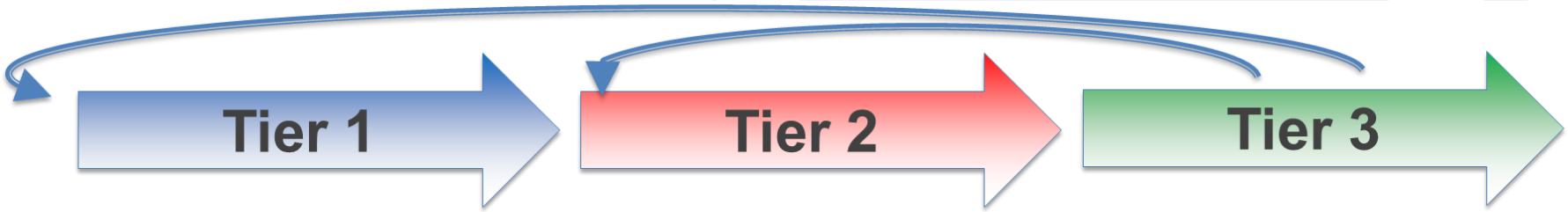
Three levels of engagement



Generating nuclear forensics awareness

- Outreach visits
- APPS course
- Multilateral engagements (e.g. IAEA, GICNT, etc)

Building confidence in foreign nuclear forensics capabilities

- Analytical plan development workshop
- Advanced instrument-specific workshops
- Sample exchanges and joint sample analyses

Peer-to-peer signature development

Advancing the science of nuclear forensics in areas such as:

- Radiochronometry
- Stable isotope signatures
- Morphology analysis
- UOC analysis

Peer-to-Peer Highlights:
ADVANCING NUCLEAR FORENSIC SCIENCE

- Peer-to-Peer engagements are focused on the partner countries with sophisticated analytical capability that can help the United State advance the understanding of signatures relevant for nuclear forensic science
- **Helps our partner countries by**:
  - Assists national competent authorities in **making determinations of interdicted R/N material origin (or, ruling out of possible origins) using material data**
  - Providing R/N material data to law enforcement for the **investigation and prosecution of malicious acts involving smuggling/trafficking**
- **Benefits to our partners include:**
  - **Advancing the science** in a manner that can be shared with all NSDD partner countries
  - **NSDD retains international leadership** over the direction of nuclear forensics globally
  - **Highlights the deterrent effect** when R/N material out of regulatory control can be identified and linked to an “owner”
  - **NSDD retains and supports a committed team of SMEs** to support all NSDD Investigation Support partnerships *(especially in light of changed priorities and USG reorganizations)*

Who are Our Peer-to-Peer Partners?

Current peer-to-peer partners

New peer-to-peer partners (2020)

Peer-to-Peer Highlight: Canada

Overview

- Collaboration between **Canadian Nuclear Safety Commission (CNSC)** and USDOE began in 2014 (CNSC-L, CNL, NRC-C, LANL, LLNL)
- **Joint work** focuses/ed on:
  - Algorithms for national nuclear forensic libraries [Paper: **Borgardt *et al.*, (2019)**]
  - Geolocation and provenance assessment for uranium ore concentrates
    Development of novel stable isotope analysis for fuel cycle materials
  - Uranium radiochronometry techniques

Key Successes:

- **Development of a new UOC certified reference materials** improves defensibility of forensic data [Certificates issues, Paper in publication]
- Laid foundation for future investigations

National Research Council Canada | Conseil national de recherches Canada

Certificate of Analysis

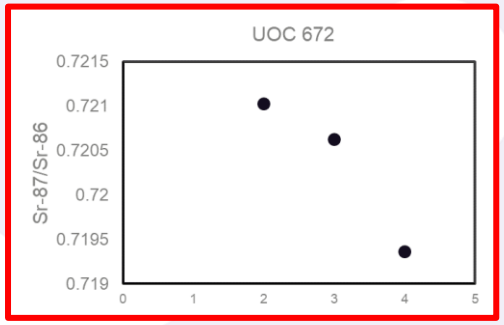
Certified Reference Material

UPER-1

Natural Uranium Ore Concentrate (UO_4) Powder Certified Reference Material for Uranium Content, Uranium Isotope Ratios, and Trace Elements

On the Horizon:

- Unique laboratory analysis capabilities in US and Canada facilitate **investigation stable isotopes and U-236 in UOCs**
  - Success relies on state-of-the-art instruments in each country
  - This advance in nuclear forensic science is only possible through peer-to-peer interaction



Capacity Building Highlights: PHASED APPROACH

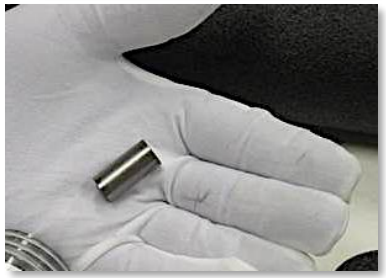
- Capacity Building work typically starts with a **in-country scoping visit & workshop**
- **Subsequent steps** can include:
  - Development of **national response plans for nuclear smuggling incidents**
  - **Workshops** -
    - Applying existing analytical instrumentation in support of nuclear forensics
    - Development of nuclear forensics analytical plans
    - National Nuclear Forensics Library (NNFL) development and use
  - **Training on specific analytical techniques** (gamma spec, mass spec, alpha spec…)
  - **Joint sample analyses** on nuclear materials of interest
    - Preparation of joint publications and presentation of results
  - **Participation in international nuclear forensics fora and exercises** (ITWG, GICNT, IAEA)
  - **Workshops hosted by partner country** for national or regional stakeholders
- **Ultimate goal:**
  - Building **long-term, sustainable partnerships**
  - **Confidence in partner country's nuclear forensics findings** in support of investigations
  - Active participation in **international nuclear forensics community**

Who are our capacity building partners?

- Current capacity building partners
- "Idle" capacity building partners

Analytical Plan Development Workshop
Cornerstone workshop for Investigation Support
Scenario-based discussions with NF experts

SCENARIO



READ AHEAD MATERIALS

Narrated PowerPoint Presentations

Gamma Spectrometry

Short-term Physical Measurements

Gamma Spec Data

Identifinder HM-5

Beta/Gamma Probe Data

WEBEX ENGAGEMENT

DAY 1 (example)

Guidelines and concepts

Detection to Forensics

Introduction to Scenario

Exercise 1

Los Alamos NATIONAL LABORATORY

Capacity Building Highlight: ROMANIA

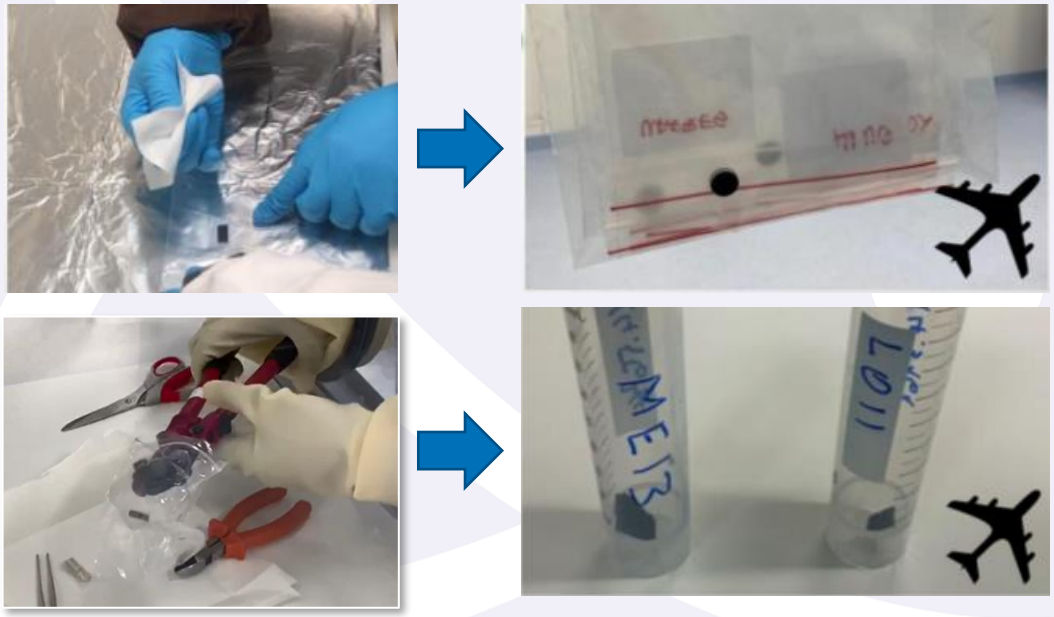
Characterization of legacy HEU samples – LANL, LLNL, and Romania (IFIN-HH)

- Presumed to be historical US material from the Atoms to Peace Program (1960-1970s)
- Two HEU metal samples (~93% enriched) are being prepared for shipment to US for joint analysis
- Five swipe samples received by LLNL and LANL (NDA completed, DA analyses on-going)
- Development radiochronometry capability Romania

Development of Regional Gamma Spectrometry Training – LANL and Romania (IFIN-HH)

- Under development

Analytical Technique	Laboratory			Type of data
	IFIN	LANL	LLNL	
Visual Inspection, photography	x	x	x	Macroscopic features, color
Weighing	x	x	x	Sample mass
Optical microscopy	x	x	x	Sample morphology, microscopic features
Dosimetry	x	x	x	Dose rate, gamma, beta and alpha activity
Pycnometry	-	x	x	Density
Scanning Electron Microscopy (SEM)	x	x	x	Sample morphology, submicron-sized features
Transmission Electron Microscopy (TEM)	-	-	-	Sample morphology, nanometer-sized features
Autoradiography	-	x	x	Homogeneity in activity
Energy/wavelength-dispersive X-ray Analysis	x	x	x	Elemental composition
Gamma-spectrometry	x	x	x	U isotopic ratios, approximate age and ^{234}U %
Alpha-spectroscopy	-	x	x	Specific activity of $^{239+240}Pu$, ^{238}Pu and ^{232}U
X-ray Fluorescence (XRF)	-	x	-	Semi-quantitative major element composition
Davies-Gray Titration	-	-	-	Uranium concentration
Uranium concentration by ID Mass Spectrometry	-	x	x	Uranium concentration
Elemental composition by ICP-MS	x	x	x	Major and trace element concentrations



Challenges and path forward

- **Interagency coordination (State Dept, DOE-IN, NA-22 and NA-83)**

- **Maintain U.S. position as a global leader in nuclear forensics**
  - Leverage experience and expertise in nuclear forensic science and international peer-to-peer engagements for support to high visibility programs from international organizations
  - [go to resource] – Maintain US position as an assistance provider in nuclear forensics
  - Continued robust international coordination with international organizations and initiative (IAEA, ITWG and GICNT)
  - Continued coordination with international nuclear forensics assistance providers (European Commission's Joint Research Centre, ANSTO and Russian Federation)

- **Build confidence in partner countries' analytical capability and nuclear forensics findings in support of legal investigations and nuclear security vulnerability assessments**

- **Continue capitalizing on scientific advancements made through international peer-to-peer collaborations**

- **Establish long-term sustainable partnerships with strategic countries**
  - Policy, legislative, operational and analytical assessments, training, workshops and exercises
  - Joint publications with the US are an attractive incentive to promote collaborative nuclear security work
  - Basis for investigation, judicial proceedings, prosecution and nuclear security enhancements

“It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts.’”

Sherlock Holmes, A Scandal in Bohemia
Sir Arthur Conan Doyle

Thank you!