INL/MIS-24-77429-Revision-0

Nuclear Forensics - Pre-Detonation & Post-Detonation

April 2024

Changing the World's Energy Future

David L Chichester

Idaho National Laboratory

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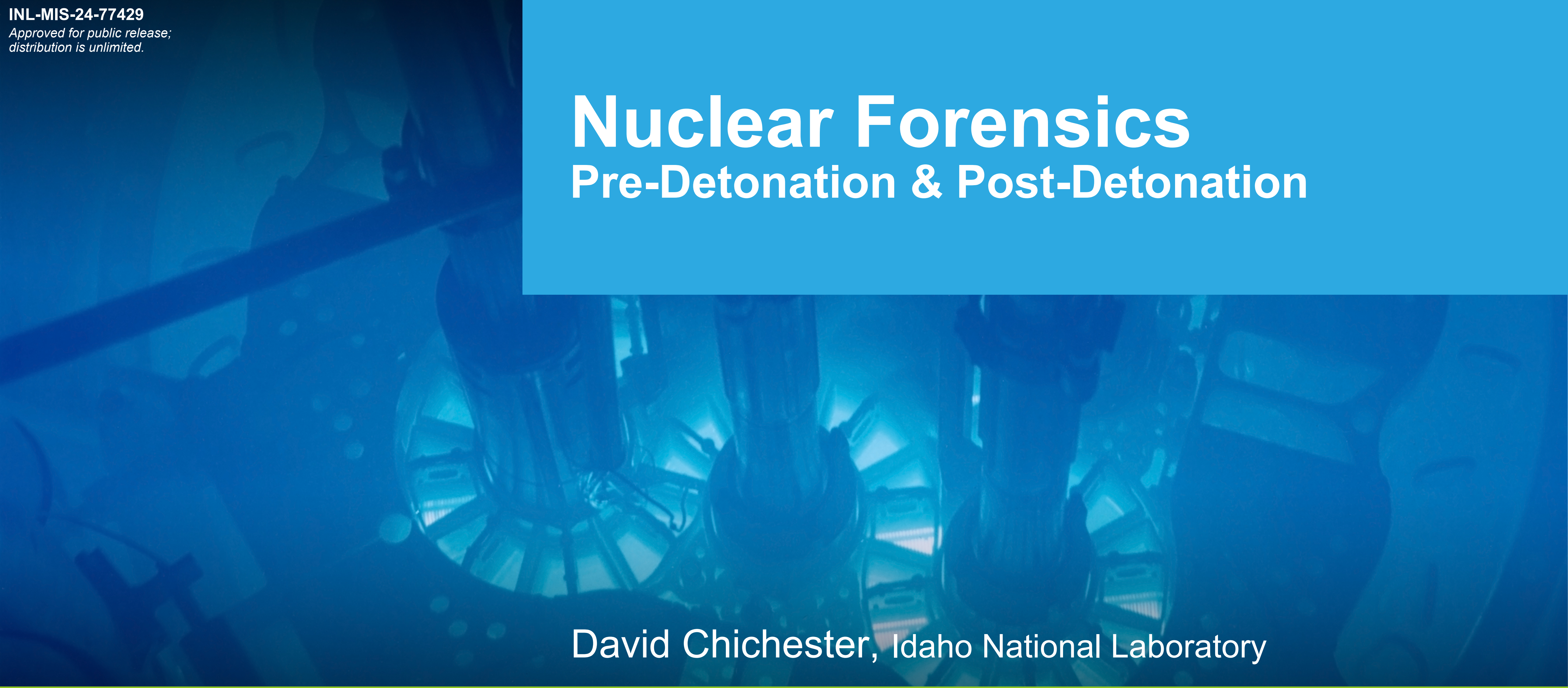

Nuclear Forensics
Pre-Detonation & Post-Detonation

David Chichester, Idaho National Laboratory

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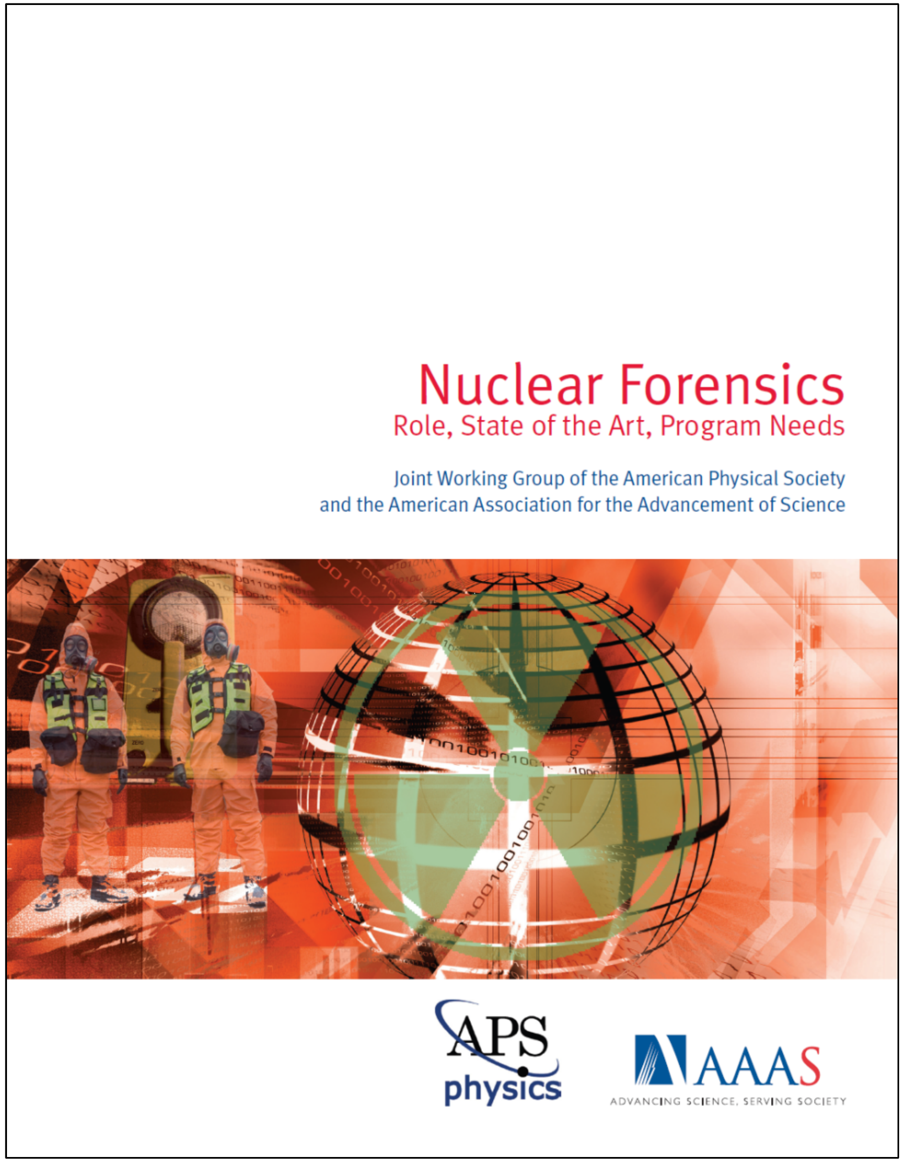
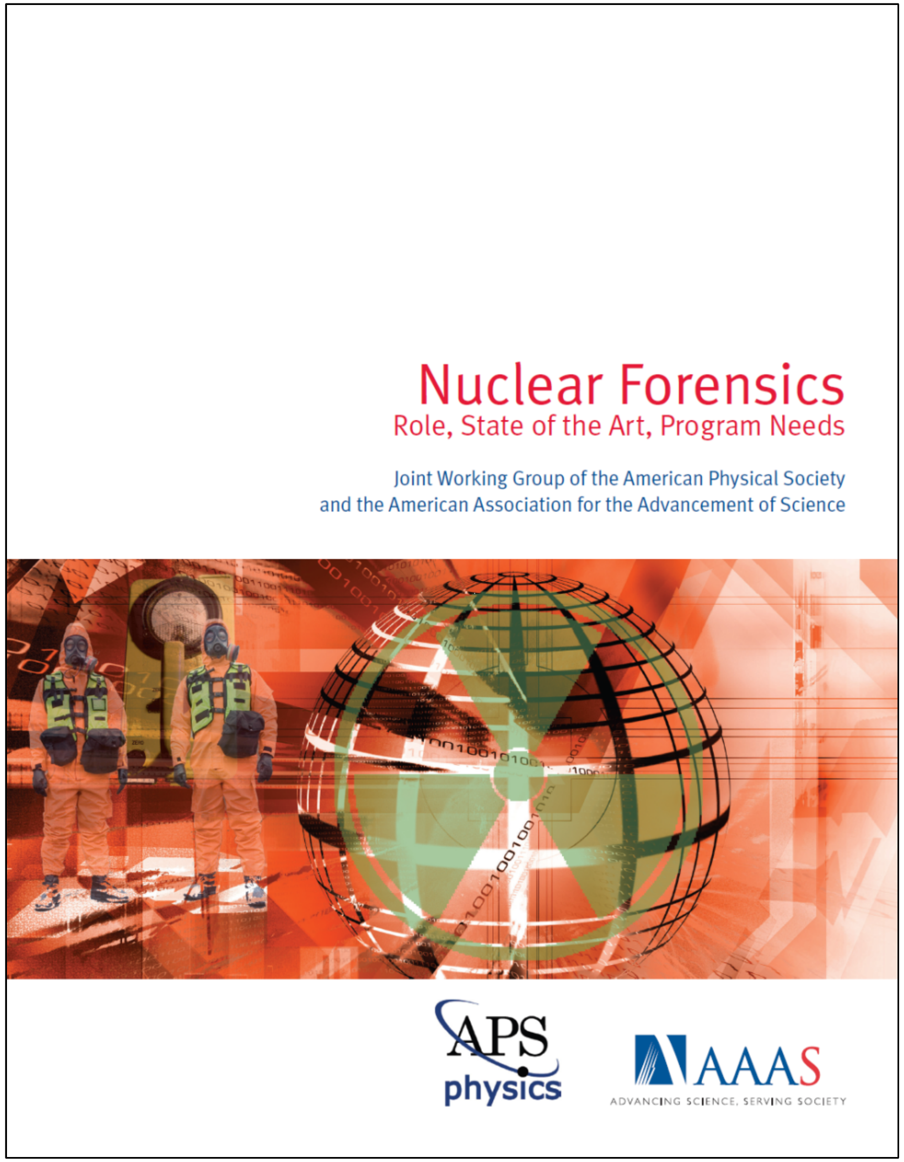


Nuclear forensics is the technical means by which nuclear materials, whether intercepted intact or retrieved from post-explosion debris, are characterized (as to composition, physical condition, age, provenance, history) and interpreted (as to provenance, industrial history and implications for nuclear device design).

This characterization and interpretation results from field work to obtain representative samples of the device materials, laboratory analyses, computer modeling and comparison with databases that contain empirical data from previous analyses of materials samples or that may be the result of numerical simulations of device performance or both.

It requires a combination of technical data, relevant databases, and specialized skills and knowledge to retrieve, analyze and interpret the data.

AAAS (2008)



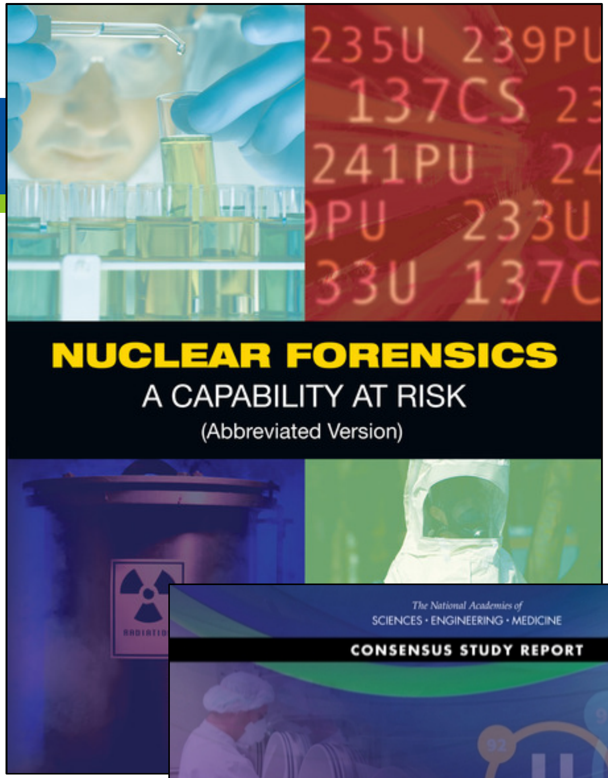
*Nuclear forensics, when combined with law enforcement and intelligence data, can suggest or exclude the origin of materials and of nuclear devices or device designs, and thereby **contribute to attribution** of the material or device to its source.*

Attribution

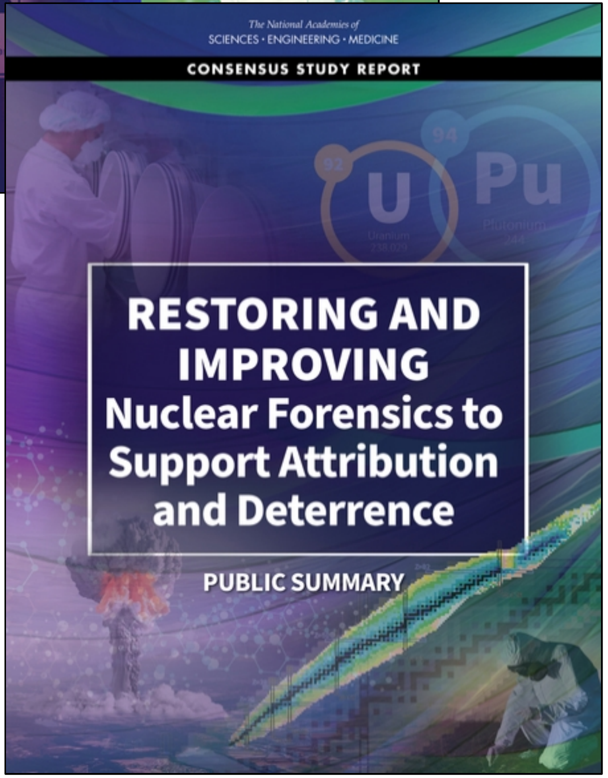
Nuclear forensics is part and parcel of the overall attribution process; it may be more or less helpful, depending on circumstances.

Recognition of the role and limitations of nuclear forensics and nuclear attribution is necessary if errors in both understanding and expectations are to be avoided.

AAAS (2008)



NAS 2010



NAS 2021

When the U.S. government interdicts significant special nuclear or radioactive materials, the President of the United States wants answers to several questions:

- *What is it?*
- *Where did it come from and whose is it?*
- *Who had it and how did they get it? Did they have help?*
- *What were they going to do with it? Is there more of it out there?*
- *What should we do about it?*

If the United States were attacked with a nuclear or radiological device, the political environment would be extraordinarily intense, and the pressure for the nation to respond would be great. The president would seek answers to a similar set of immediate and urgent questions,
including:

- *What was it?*
- *How bad is the damage, and how much worse will it get?*
- *Who did it? Did they have help?*
- *Are there more out there?*
- *Where did it come from? Was it ours?*
- *What should we do about it?*

THE NATIONAL INTEREST

Published on *The National Interest* (https://nationalinterest.org)

Home > The Evolving Missions of Technical Nuclear Forensics

The Evolving Missions of Technical Nuclear Forensics

July 3, 2021 *Topic:* Nuclear War *Region:* Americas *Tags:* Nuclear, War, Technology, Policy, Nuclear Attack

First developed for nuclear test monitoring and treaty verification purposes during the Cold War, modern nuclear forensic capabilities are now used to determine the provenance of nuclear materials found outside of regulatory control, such as those seized from nuclear smugglers.

by Jay A. Tilden Dallas Boyd

Although the link between nuclear forensics and the prevention of nuclear terrorism is widely understood —and embedded in numerous policies and legislation—there exist many less familiar but equally vital functions of these tools.

Nuclear forensics can be used to attribute or resolve ambiguities about a wide range of what might be termed “unattributed nuclear events,” both malicious and unintentional.

- Undisclosed accidents at civil or military nuclear facilities
- Nuclear weapon mishaps in denied geographic areas, or perhaps even an accidental nuclear detonation

Other ambiguous scenarios may involve a state’s limited use of nuclear weapons in a regional conflict and subsequent denial thereof or an attempt to blame a clandestine nuclear attack on non-state actors.

Each may create conditions in which uncertainty about what happened and who was responsible could lead to cascading effects of far greater magnitude.

Trafficking Incidents

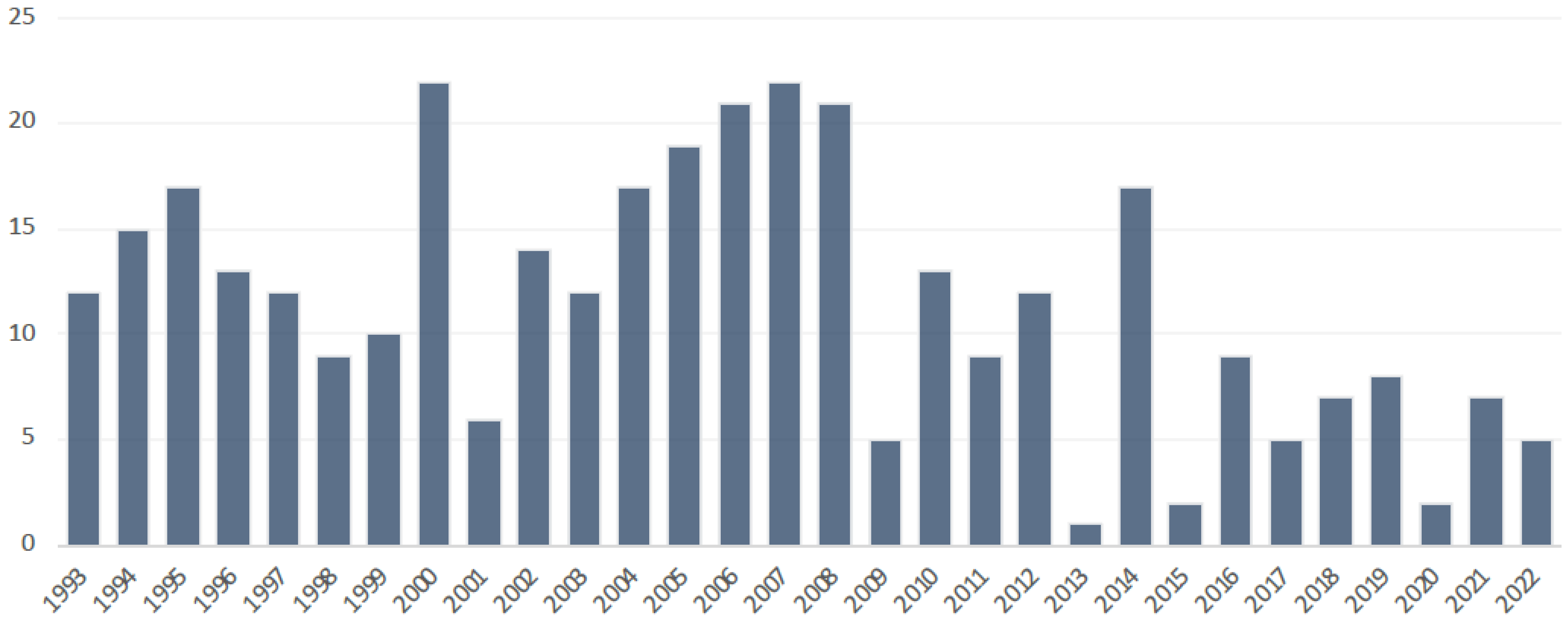
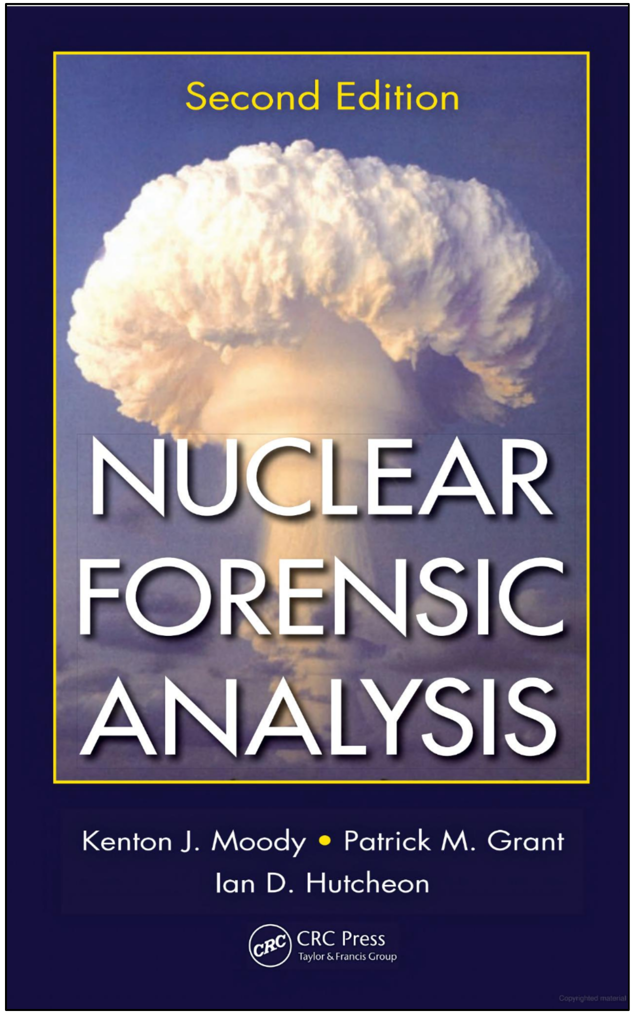


Figure 2. Incidents reported to the ITDB that are confirmed, or likely, to be connected with trafficking or malicious use, 1993–2022.

IAEA Incident and Trafficking Database (ITDB) (2023)
https://www.iaea.org/newscenter/pressreleases/iaea-releases-annual-data-on-illicit-trafficking-of-nuclear-and-other-radioactive-material



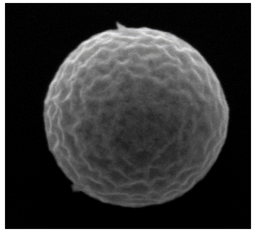
An excellent reference

Nuclear forensics analysis consists of the reliable collection, treatment, analysis, and assessment of evidentiary specimens for elemental, isotopic, chemical, and physical signatures that may provide technical insights into the origins and histories of primary and collateral materials.

The Nuclear Forensics Timeline

A nuclear fallout particle

Materials outside regulatory control (MORC)



A uranium particle

Pre-Detonation

Post-Detonation

Left of Boom

Boom

Right of Boom

Timeline

IAEA swipes, environmental samples, provide early indicators...

Materials interdicted at borders, found in criminal activities

A nuclear device is discovered and interdicted

Fallout

Speed of sound signatures

Speed of light signatures

https://www.fz-juelich.de/en/news/archive/announcements/2020/2020-10-27-nwal

Pre-Detonation NF

A State capable of identifying the origin and history of intercepted nuclear or radioactive material can have a ***deterrent effect***. This is why nuclear forensics - the examination of nuclear and other radioactive material as part of criminal or nuclear security investigations - is an important tool.

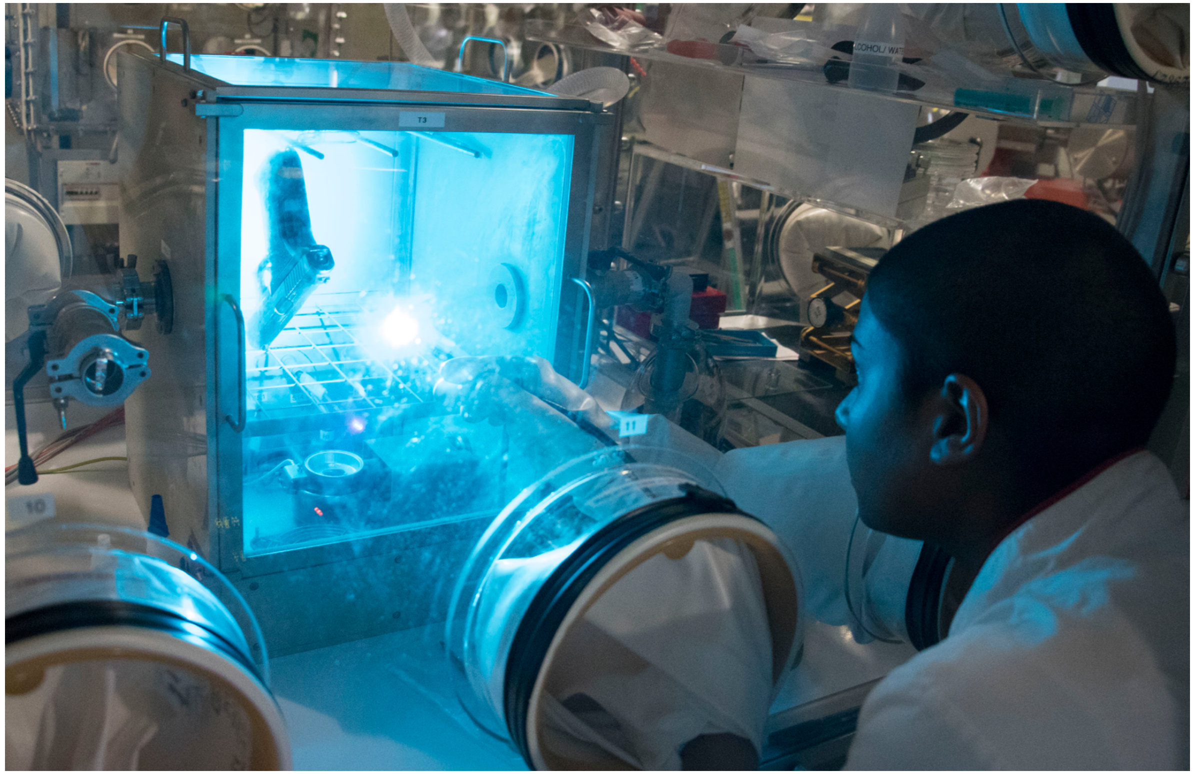
"A country with strong nuclear forensics capabilities is not the best target for terrorist groups."

Éva Kovács-Széles, Head of the Nuclear Security Department at the Hungarian Academy of Sciences' Centre for Energy Research.

IAEA Bulletin , December (2016) 9-11.

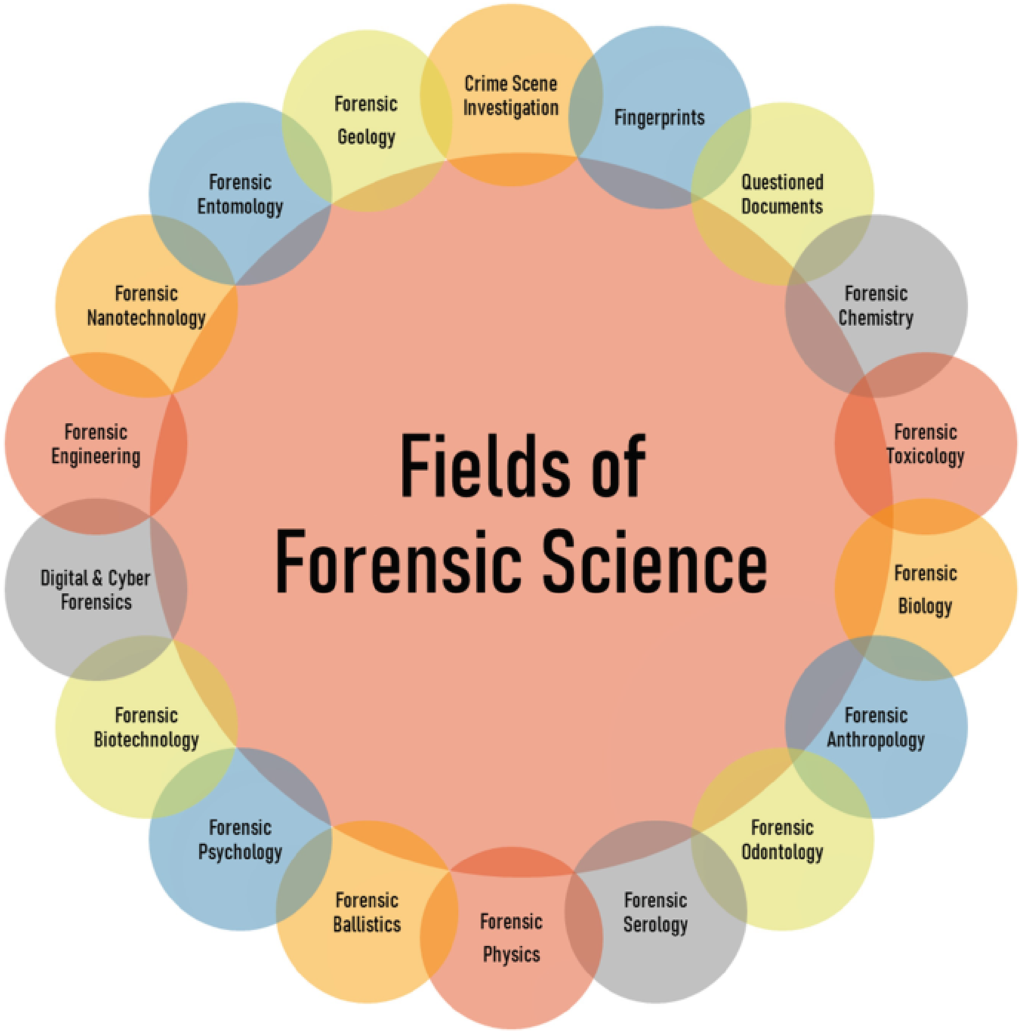
Fusion of Traditional Forensics with Nuclear Forensics

- For nuclear smuggling and interdicted RN materials, traditional forensics is often the principal crime science investigative (CSI) tool
  - Fingerprints
  - DNA
  - Fibers
  - Tool marks
  - Document analysis
  - Data/cyber
- Traditional forensics is more complicated in an RN environment



Cyanoacrylate fuming inside a glovebox of a piece of evidence collected from a radiological crime scene during an exercise with the German police

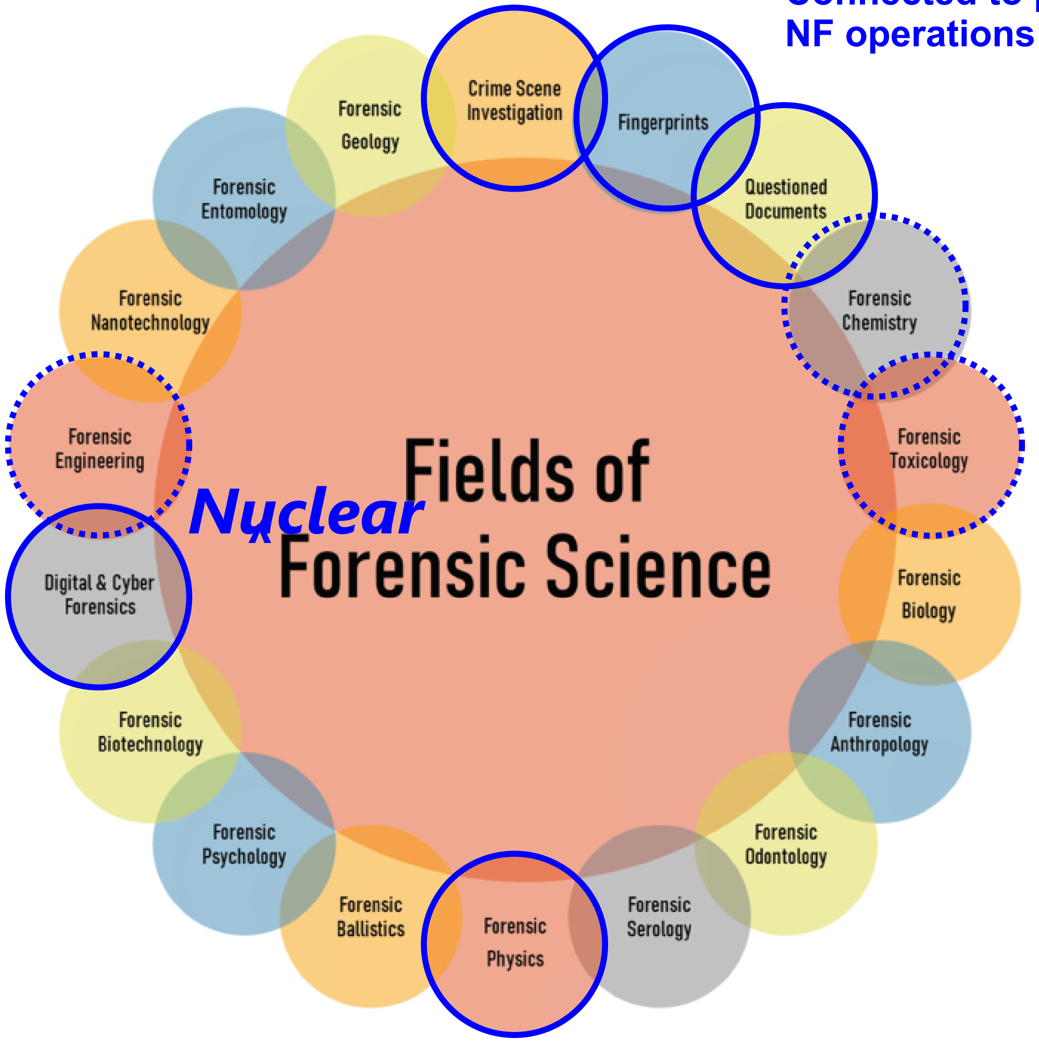
Traditional Forensic Science



"Introduction to Forensic Science", Textbook (2023)

Traditional Forensic Science

Connected to practical NF operations



May be associated with practical NF operations

"Introduction to Forensic Science", Textbook (2023)

General NF Techniques Used in Pre-Det Analysis

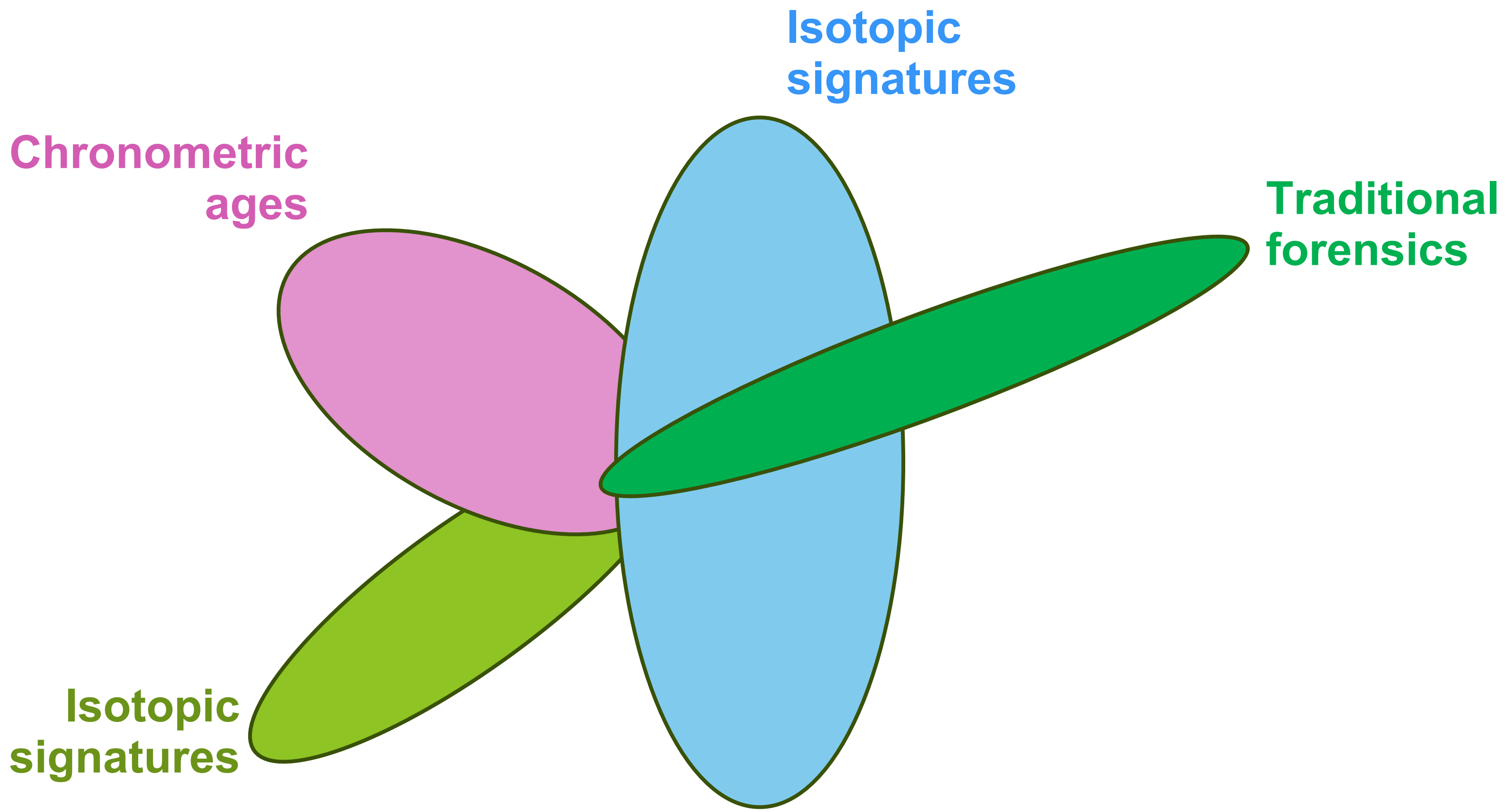
General Process	Potential Techniques	Signatures
Initial Observations	• Nuclear Sample? • Traditional Forensics	• Traditional Forensic Signatures
Non-Destructive Analyses	• Physical Analyses (mass, size, etc.) • Optical Microscopy • Scanning Electron Microscopy (SEM) • Gamma Spectrometry • X-ray Fluorescence • X-ray Diffraction • FTIR/RAMAN • Etc.	• Physical form • Size/shape • Color • Chemical Composition • Molecular Structure • Radioisotopes
Destructive Analyses	• Mass Spectrometry (TIMS, SIMS, ICP) • Alpha Spectrometry • Gas Chromatography/Mass Spectrometry	• Isotopic Composition • Elemental Composition • Material Age • Etc.

Questions

- Material Origin?
- How old is it?
- Routes of transit?
- Is there more out there?
- Etc.

Hutcheon et al. 2015. LLNL-CONF-679869

Integrating Forensic Signatures to Find an Answer



Adapted from Hutcheon et al. 2015. LLNL-CONF-679869

Basis for NF Science

NF Questions

- Where did it come from?
- How did it fall outside of regulatory control?
- What were the routes of transit?
- Who is responsible?
- Is there another one?

Physics

- Radioactive decay
- Rate laws in radioactive decay
- Nuclear reactions
- Radioactivity
- Chronometry (astrophysics & geology)
- Nuclear fission and fusion

Chemistry and Engineering

- Nuclear fuel cycle
- Uranium conversion, enrichment, deconversion
- Nuclear reactors and Pu production
- Spent nuclear fuel reprocessing
- Nuclear and radioactive material production, shielding, and transportation

Timeline for NF Analyses

Techniques/Methods	24 hour	One week	Two months
Radiological	Estimated total activity Dose rate (α, β, γ, n) Surface contamination		
Physical characterization	Visual inspection Raadiography Photography Weight Dimensions Optical microscopy Density		
Traditional forensic analysis	Fingerprints, fibers		
Isotope analysis	γ-spectroscopy α-spectroscopy	Mass spectrometry (SIMS, TIMS, ICP–MS)	Radiochemical separations
Elemental/chemical		ICP–MS XRF Assay (titration, IDMS)	GC/MS

Hutcheon et al. 2015. LLNL-CONF-679869

Example Analytical Performance

Measurement goal	Technique	Type of information	Typical detection limit	Spatial resolution
Survey	HRGS	Isotopic	ng – µg	
Elemental and Isotopic Bulk Analysis	Chemical Assay	Elemental	mg	
	Radiochemistry/Radiometric Methods	Isotopic, Elemental	fg – pg	
	TIMS	Isotopic, Elemental	pg – ng	
	ICP–MS	Isotopic Elemental	pg – ng	
	XRF	Elemental	10 µg/g	
	XRD	Molecular	~1 at.%	
	GC/MS	Molecular	µg/g	
Imaging	Visual Inspection	Macroscopic		0.1 mm
	Optical Microscopy	Microscopic Structure		1 µm
	SEM			1 nm
	TEM			0.1 nm
Microanalysis	SIMS	Elemental Isotopic	0.1 ng/g – 10 µg/g	0.1 – 1 µm
	SEM/EDS or WDS	Elemental	0.1 – 1 wt.%	1 µm
	FTIR	Molecular	0.1 – 1 wt.%	10 µm
	Raman	Molecular	~1 wt.%	1 µm

Hutcheon et al. 2015. LLNL-CONF-679869

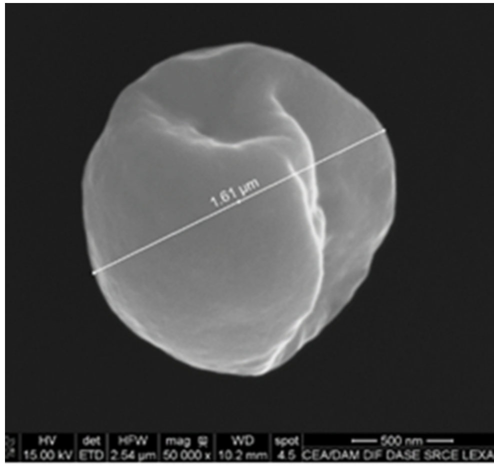
Example Analytical Performance

Measurement goal	Technique	Type of information	Typical detection limit	Spatial resolution
Survey	HRGS	Isotopic	ng – µg	
			mg	
			fg – pg	
			ng	
			ng	
			10 µg/g	
			~1 at.%	
			µg/g	
				0.1 mm
				1 µm
				1 nm
	TEM			0.1 nm
Microanalysis	SIMS	Elemental Isotopic	0.1 ng/g – 10 µg/g	0.1 – 1 µm
	SEM/EDS or WDS	Elemental	0.1 – 1 wt.%	1 µm
	FTIR	Molecular	0.1 – 1 wt.%	10 µm
	Raman	Molecular	~1 wt.%	1 µm

1 pg = 1×10^{-12} g
For ^{239}Pu, ~239 g/mol, so

For TIMS, fg (10^{-15} g) detection limits are possible

- **as low as a few million atoms!**
- **a single particle Ø ~50 nm**



A 1.61 mm UO_2 particle

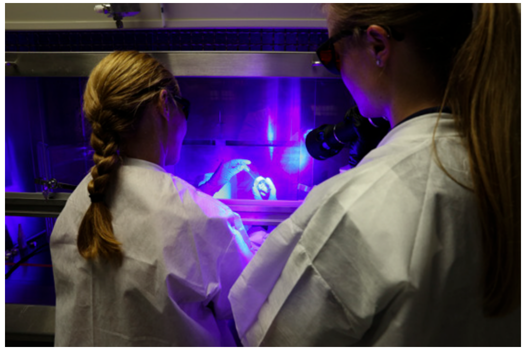
Hutcheon et al. 2015. LLNL-CONF-679869

Knott, A. (2016) Julich Dissertation

FBI Radiological Evidence Examination Facility (REEF)

Approx. 6,000 sq. ft. radiological/nuclear partner lab to conduct traditional forensics on evidence containing or suspected of containing radiological and nuclear materials

- Trace Evidence
- DNA
- Explosives
- Firearms
- Tool Marks
- Latent Print
- Questioned Documents
- Computer Analysis Response Team
- Forensic Imaging



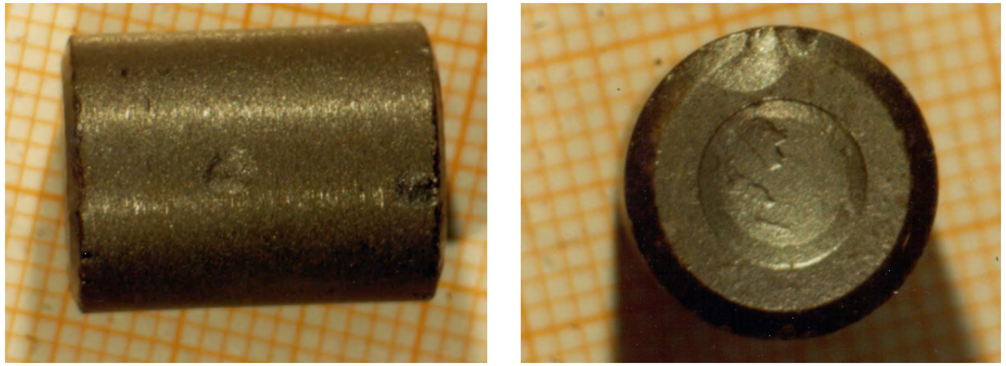
https://www.srnl.gov/fact-sheets/radiological-evidence-examination-facility-reef/

NF International Technical Working Group (ITWG)

- Coordinated under the G7 Nuclear Safety and Security Group (NSSG)
- Open to all states interested in nuclear forensics
- Objective: To advance the scientific discipline of nuclear forensics and to provide a common approach and effective technical solutions to competent national or international authorities that request assistance
- Focused on nuclear forensic best practice through the development of techniques and methods for forensic analysis of nuclear, other radioactive, and radiologically contaminated materials

- Regularly holds internal Collaborative Materials Exercise (CMX) events for all ITWG members to participate

ITWG Nuclear Forensics
International Technical Working Group



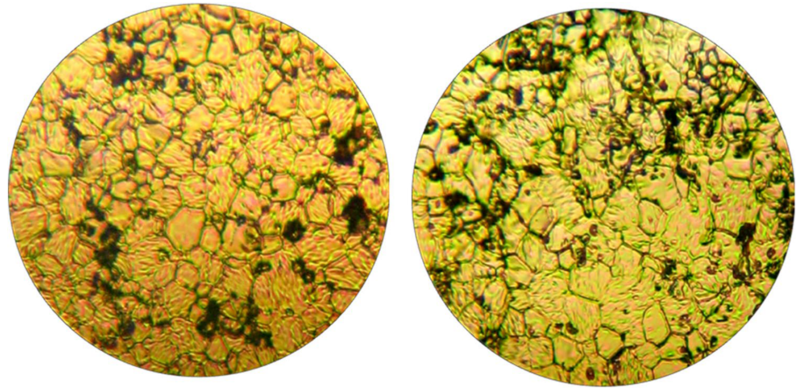
Pellets from the first nuclear forensics analysis at the JRC in 1992.

ITWG CMX-5

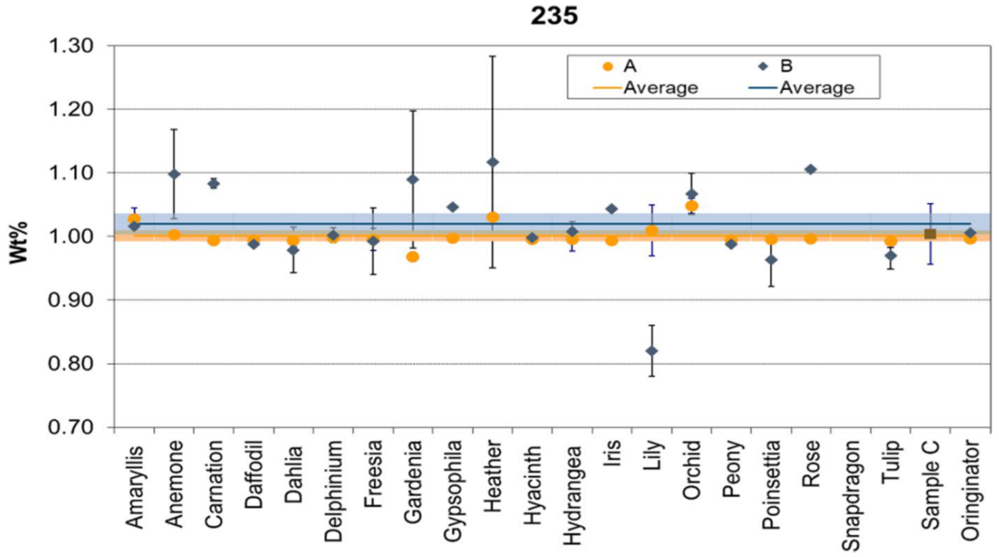
- Forensic laboratories from 19 countries and one multinational organization
- Goals span both legal and broader national security interests
  - Legal: NF supports law enforcement determinations in a criminal investigation and decisions regarding hazard management to first responders, law enforcement and the public
  - National security: NF can help authorities attribute material origins, aid in determining the ‘when’ and ‘where’ materials have escaped regulatory control and locate security vulnerabilities within nuclear facilities.
- 30 analytical techniques
- Scenario: Two materials (A and B) were provided by the French CEA both of which consisted of high fired, low enriched, uranium oxide (UO_2) pellets. The pellets were manufactured specifically for the CMX-5 exercise in May 2014 in two batches from the same source materials, prepared using two different physical processes. The source materials were enriched UO_2, depleted UO_2, and alumina Al_2O_3.

ITWG CMX-5 (2)

- Isotopic techniques were not able to render conclusive evidence for group inclusion/ exclusion evaluations of the samples due to the material isotopic similarity.
  - This is contrary to previous sample investigations, demonstrating that the characteristics useful for inclusion/exclusion assessments are case specific, and directly tied to the materials and questions being asked by investigators and the sample type under investigation.
  - This strengthens the case to continue CMX events.
- Physical characterization and elemental impurities were able to distinguish between the processing histories of the two samples to allow for determination of the production facility in a hypothetical scenario.



Optical microphotography 320× Sample A left, Sample B right



^{235}U isotopic abundance determined by the participants of the exercise

Pre-Detonation NF Case Study

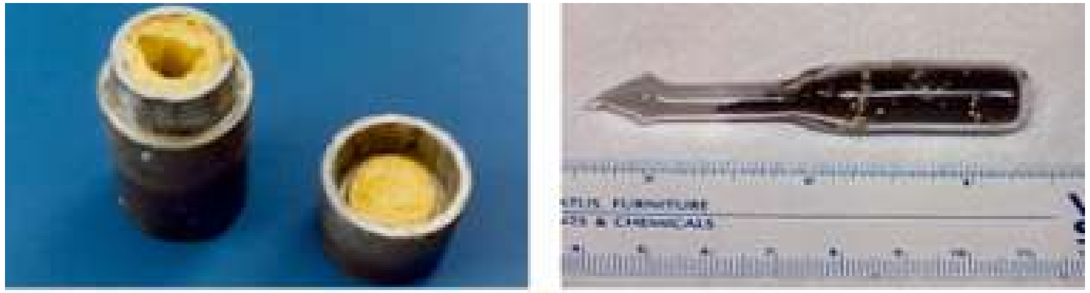
May 29, 1999
Bulgaria-Turkey Border Crossing

https://www.naharnet.com/stories/en/158807

Moldova, 2011

The arrest of Teodor Chetrus in Moldova in 2011. Moldovan Police Directorate

https://publicintegrity.org/national-security/the-fuel-for-a-nuclear-bomb-is-in-the-hands-of-an-unknown-black-marketeer-from-russia-u-s-officials-say/



TOP: A container and uranium sample seized by Moldovan law enforcement in 2011.

MIDDLE: The container and uranium sample seized by French law enforcement in Paris in 2001.

BOTTOM: A lead cylinder and HEU inside a hand-blown glass bulb, or ampoule, seized in 1999 from a Moldovan smuggler by border guards in Bulgaria.

TOP: The Ministry of Internal Affairs of Moldova.

MIDDLE: "Illicit Nuclear Trafficking: Collective Experience and the Way Forward," Proceedings of an International Conference in Ediinburgh, 19-22 November 2007.

BOTTOM: Undated paper "Nonproliferation Nuclear Forensics" by Ian D. Hutcheon, Michael J. Kristo and Kim B. Knight, Glenn Seaborg Institute, Lawrence Livermore National Laboratory.

https://publicintegrity.org/national-security/the-fuel-for-a-nuclear-bomb-is-in-the-hands-of-an-unknown-black-marketeer-from-russia-u-s-officials-say/

Forensic Analyses

1999 Bulgaria 73% HEU Example

Non-nuclear forensics

- Wax type
- Wax colorant
- Paper origin
- Pb metallurgy
- Pb isotopics
- Ampoule material

Nuclear material forensics

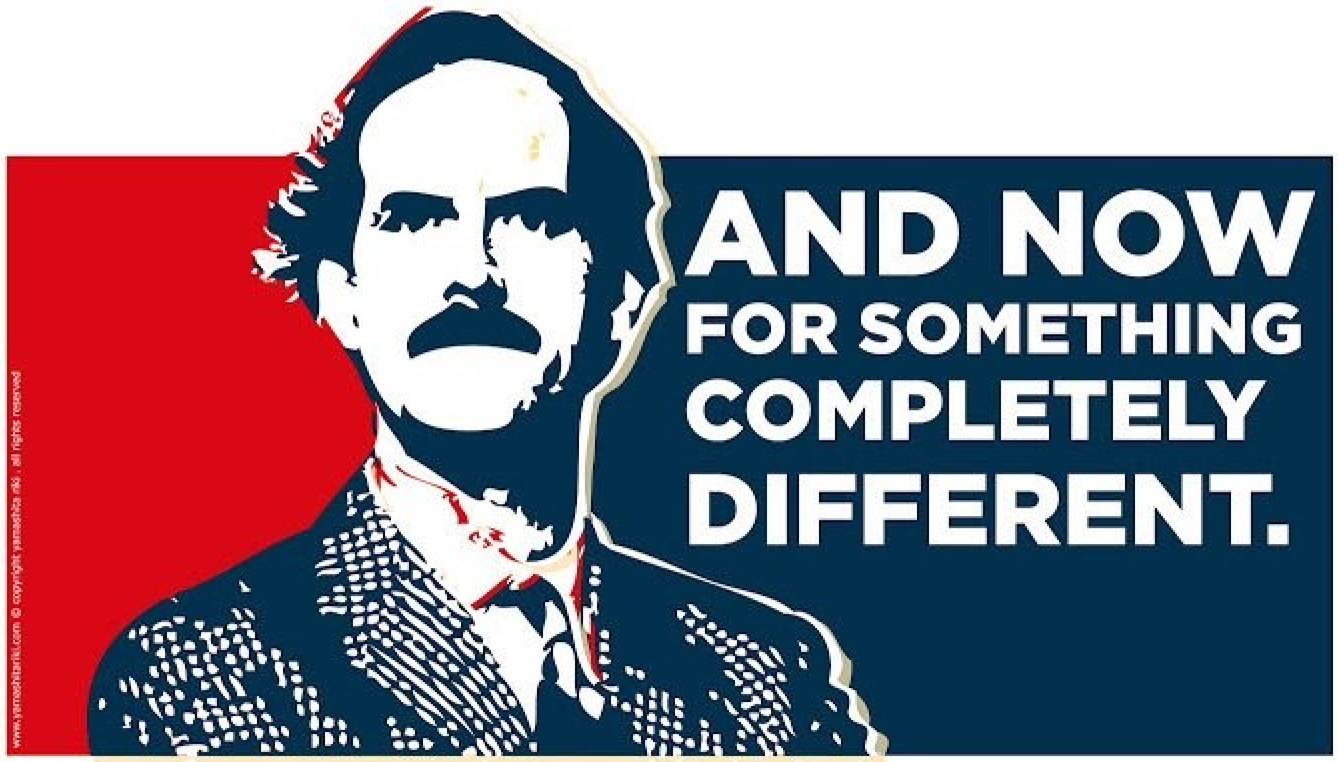
- Particle characterization
- Stoichiometry
- Impurity elements
- Residual radionuclides
- Age-dating
- U & Pu isotopics

LLNL-Led Effort: Excellent demonstration of what could be done!

Los Alamos NATIONAL LABORATORY

8

R. Steiner, et al., LA-UR-22-31673, https://www.osti.gov/biblio/1897399



https://www.linkedin.com/pulse/now-something-completely-different-bob-zent/

Post-Detonation Nuclear Forensics

- The collection, analysis, and evaluation of exploded radiological or nuclear materials, devices, and debris, as well as the immediate effects created by a nuclear detonation
- Prompt Signatures
  - Explores signals that may enable accurate knowledge of the specifics of a nuclear device after a detonation
  - Understanding unique identifiers of, measurements of these identifiers
  - Those which can be measured instantaneously to within a few days after the event
- Radiochemical Signatures
  - Collect samples of material, analyze radioactive debris, and identify signatures from debris analysis
  - Starts with targeted airborne and ground collection
  - Methods for rapid dissolution, pre-concentration of debris, and sample analysis that rapidly identifies and quantifies elemental and isotopic constituents

https://www.dhs.gov/nuclear-forensics-technical-mission-areas

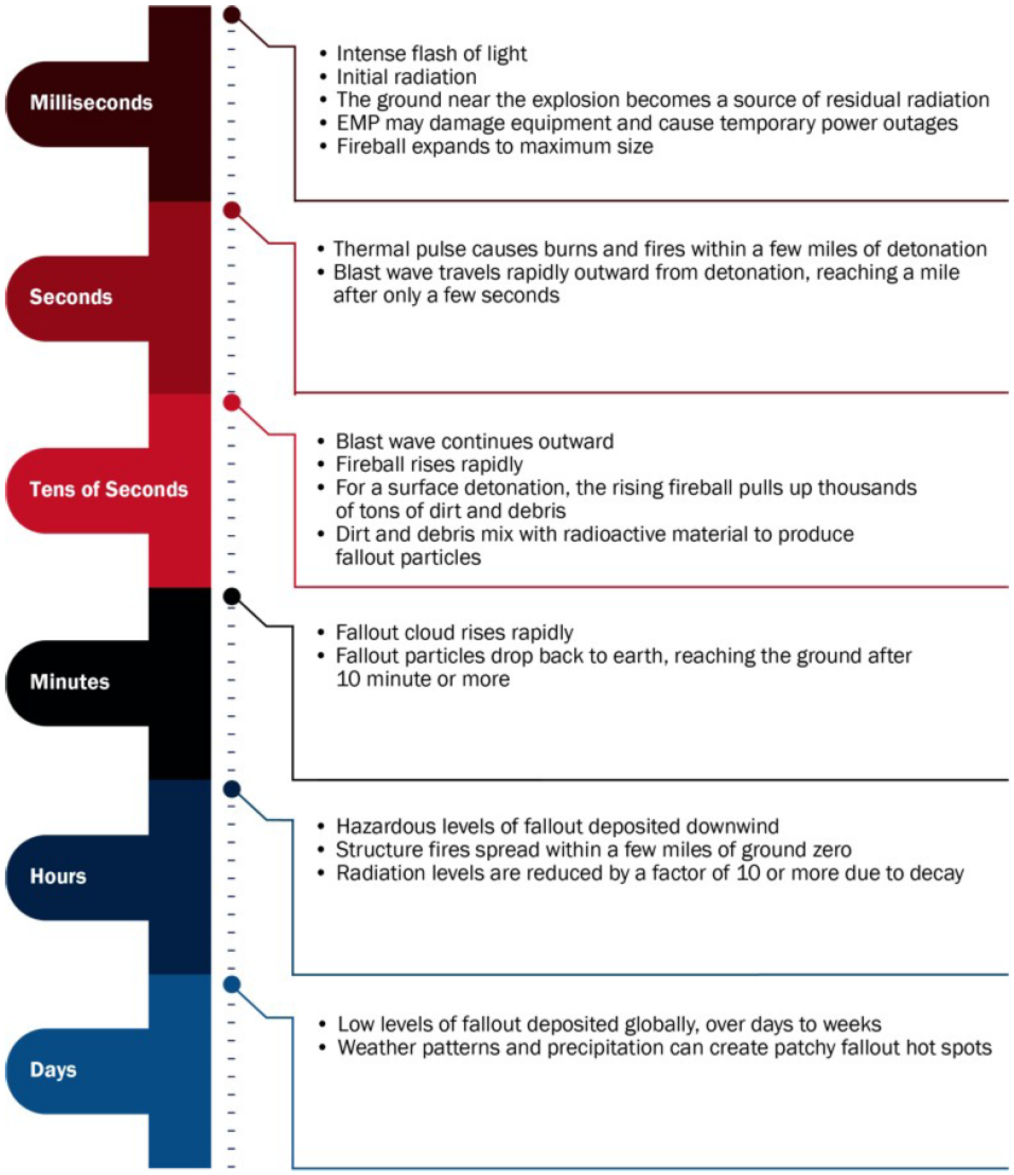
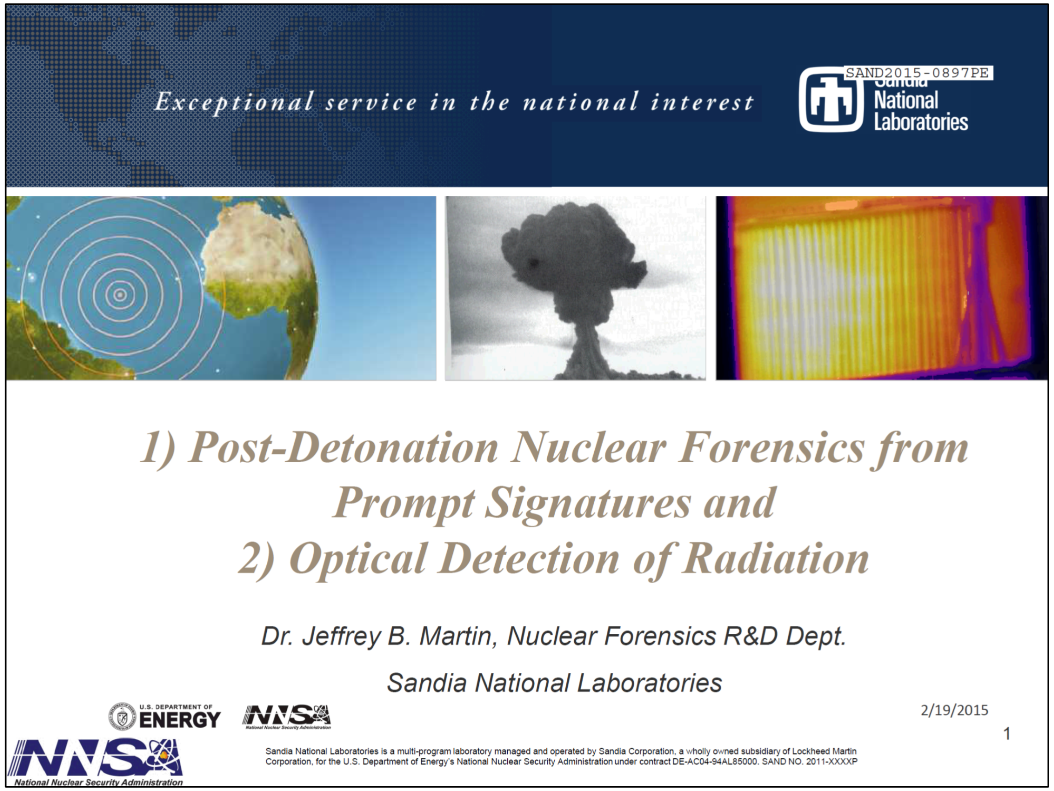


Figure 2: Timeline of key effects for a 10 kT surface detonation. (Topics defined and/or described in this figure are described in more depth in the following text.)

FEMA Planning Guidance for Response to Nuc Det, 3rd Ed (2023)

Prompt Signatures

- A nuclear detonation creates and releases many types of energy which result in “nuclear weapons effects” (overpressure, ground shock, and radiation)
- At longer ranges these effects can become measurable signatures and signals which can be used to characterize the detonation
- The CTBTO already senses many of these in its *International Monitoring System*
- Speed of light
  - Thermal □ visual light
  - Electromagnetic
  - Ionizing radiaion
- Speed of sound
  - Seismic □ acoustic waves in the earth
  - Atmospheric overpressure □ acoustic waves in the air



J. Martin, Sandia (2016), SAND2015-0897PE 565615, https://www.osti.gov/biblio/1504341

CTBTO and the International Monitoring System (IMS)

- The IMS is a unique global network that, when complete, will consist of 321 monitoring stations and 16 laboratories hosted by 89 countries around the globe
- Four complementary verification methods
  - 50 primary and 120 auxiliary seismic stations to monitor for an underground test by measuring shockwaves through the ground
  - 11 hydroacoustic stations to detect soundwaves through the ocean from an underwater explosion
  - 60 infrasound stations to listen for ultra-low-frequency sound waves moving through the atmosphere at levels inaudible to the human ear
  - 80 radionuclide stations to detect radioactive particles or gases from atmospheric explosions, or vented by underground or underwater nuclear explosions

CTBTO
PREPARATORY COMMISSION

https://www.ctbto.org/our-work/monitoring-technologies

International Monitoring System

CTBTO PREPARATORY COMMISSION | COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION

50	Primary Seismological Stations
120	Auxiliary Seismological Stations
11	Hydroacoustic Stations
60	Infrasound Stations
80	Radionuclide Stations
16	Radionuclide Laboratories
337	Total Number of Facilities

- Seismic Primary Array (PS)
- Seismic Primary 3-Component Station (PS)
- Seismic Auxiliary Array (AS)
- Seismic Auxiliary 3-Component Station (AS)
- Radionuclide Station (RN)
- Radionuclide Station with Noble Gas Monitoring Capabilities (RN)
- Radionuclide Laboratory (RL)
- Hydroacoustic (Hydrophone) Station (HA)
- Hydroacoustic (T-Phase) Station (HA)
- Infrasound Station (IS)
- International Data Centre - CTBTO - Vienna

The boundaries and presentation of material on this map do not imply the expression of any opinion on the part of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) Preparatory Commission concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

Revised August 2021 | CTBTO.ORG

https://www.ctbto.org/our-work/monitoring-technologies

CTBTO - Seismic

https://www.ctbto.org/our-work/monitoring-technologies

Seismic

- Seismic technology is an efficient means of detecting a suspected nuclear explosion
- Seismic waves travel so fast that an event creating these waves can be registered by seismic stations distributed worldwide in a time span ranging from a few seconds to about ten minutes

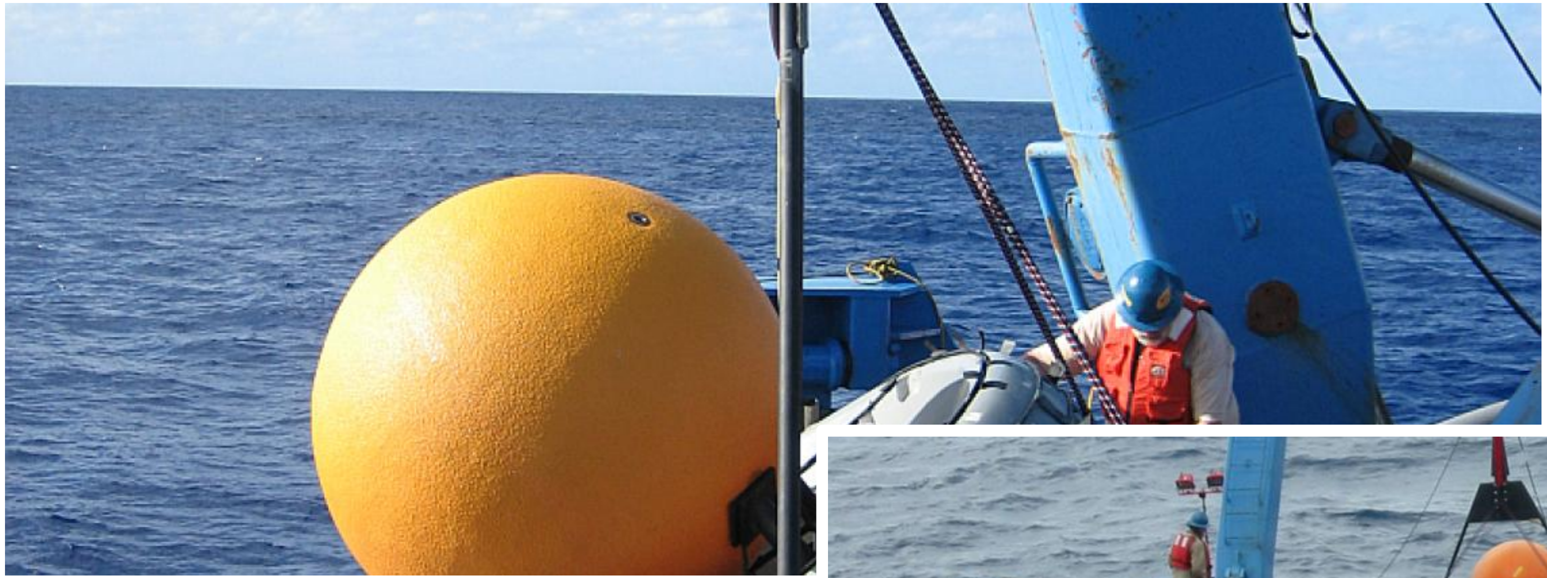
Checking seismometers at PS48, Pinedale, Wyoming, USA.

Primary seismic station PS15, Dimbroko, Cote d'Ivoire.

- Body waves and surface waves: faster body waves travel through the interior of the Earth while slower surface waves travel along its surface
- Two types of body, P-waves and S-waves
  - P-waves are primary or compressional waves that alternately compress and expand the ground in the direction of the wave's propagation. These waves can move through any material.
  - S-waves are secondary or shear waves in the ground that move perpendicular to the direction of the wave's propagation. S-waves can only move through solids.

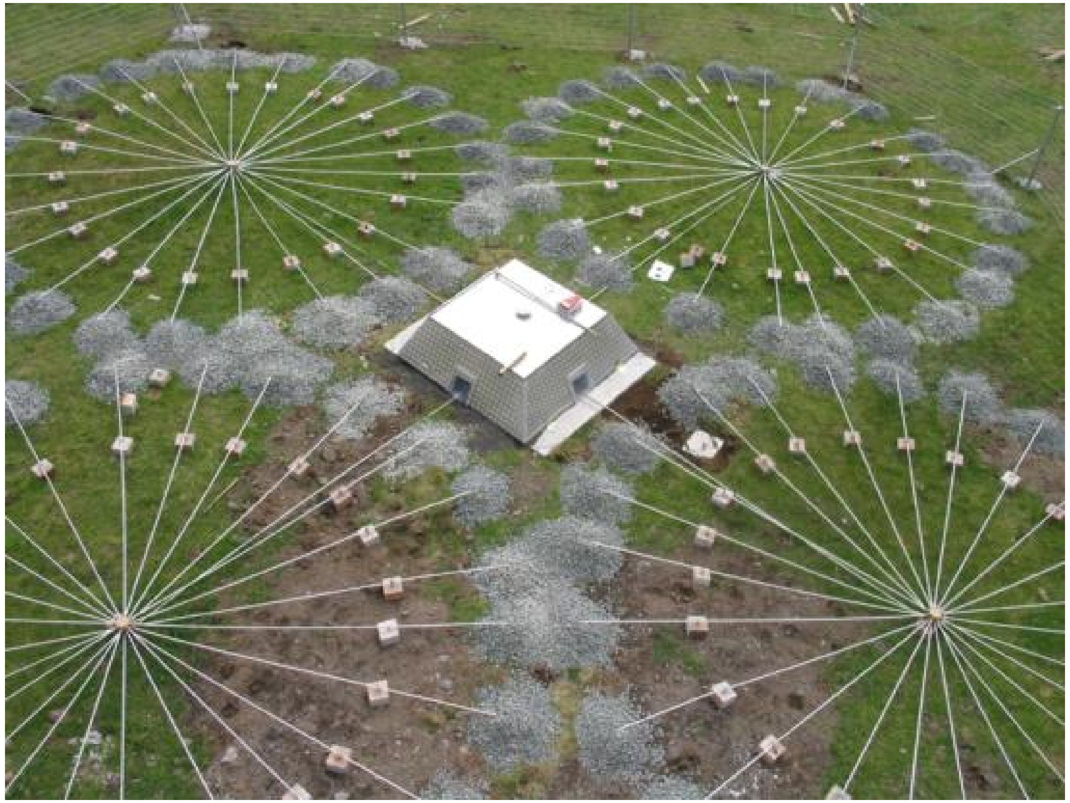
https://www.ctbto.org/our-work/monitoring-technologies

CTBTO - Hydroacoustic



https://www.ctbto.org/our-work/monitoring-technologies

CTBTO - Infrasound



https://www.ctbto.org/our-work/monitoring-technologies

CTBTO - Radionuclide

https://www.ctbto.org/our-work/monitoring-technologies

Radionuclide Monitoring

- Stations must have a denser presence near the equator than in higher latitudes because global wind fields in the equatorial region are virtually vertical.
- A disadvantage is that it is passive, relying on air currents to move the particles or gases to the radionuclide detection site.

Radionuclide station 73, Palmer station, Antarctica

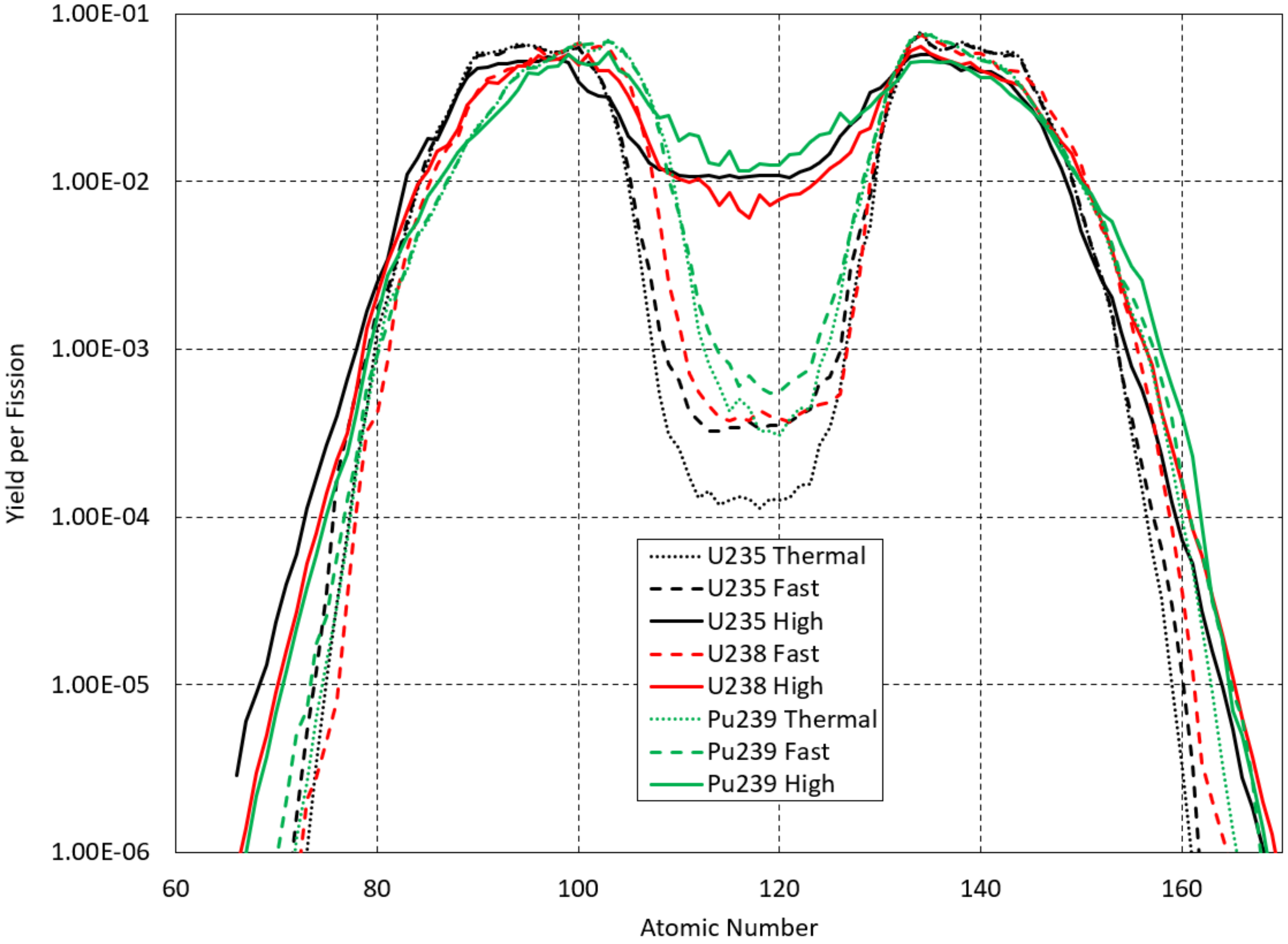
Radionuclide station RN74, Ashland, Kansas, USA.

- A radionuclide particulate monitoring station contains an air sampler, detection equipment, computers and a communication setup. Air is forced through a filter, which retains more than 85% of all particles that reach it. Filters are replaced daily.
- In noble gas monitoring systems, air is pumped into a charcoal-containing purification device where xenon is isolated. The resulting air contains higher concentrations of xenon, both in its stable and radioactive forms. The radioactivity of the isolated and concentrated xenon is measured and the resulting spectrum is sent to the IDC for further analysis.

https://www.ctbto.org/our-work/monitoring-technologies

Radionuclide Analysis

- A key aspect of understanding radionuclides is the analysis of fission products
- The "wing" and "valley" FPs differ depending upon the fuel and the spectrum of neutrons causing fission
- Analysis of FPs in theses regions provides key insights



Near Surface Burst and Mixing

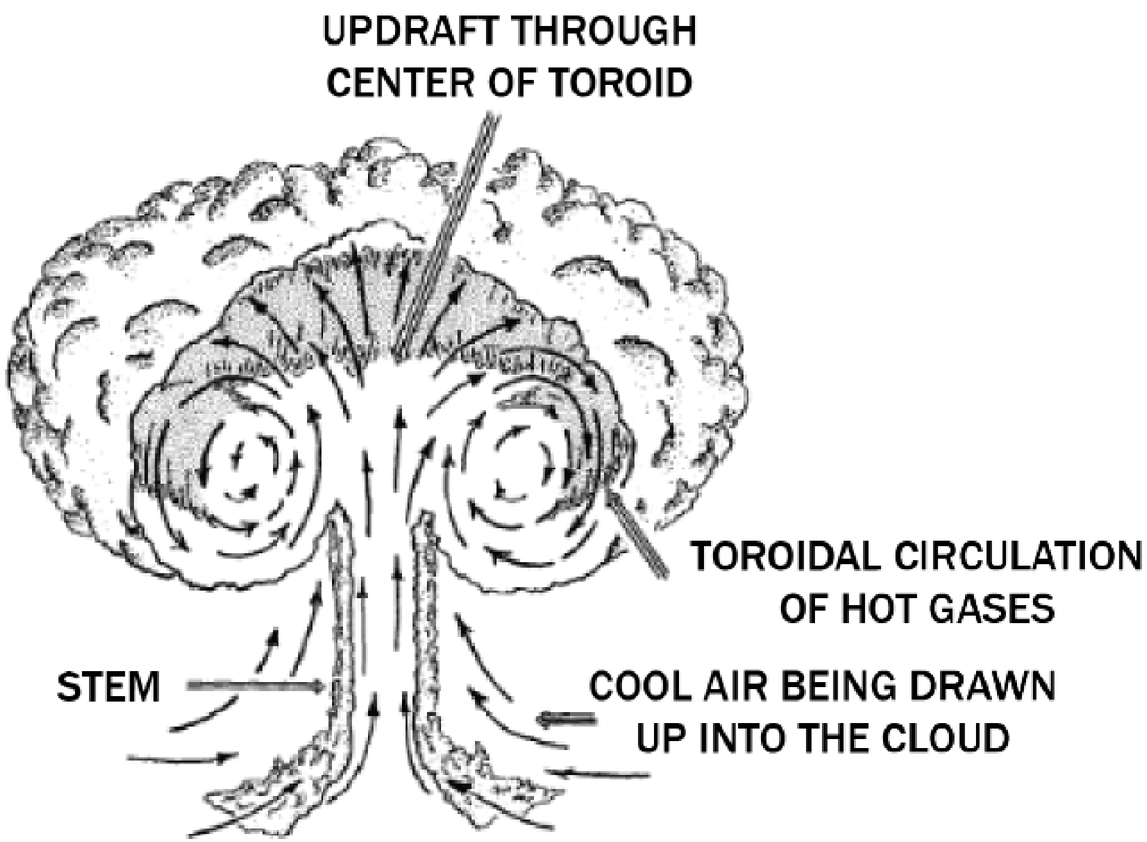


Figure 11: Example Mushroom-Shaped Cloud from a Near-Surface Nuclear Detonation (derived from Glasstone & Dolan, 1977)[12]

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Fallout Collection and Analysis

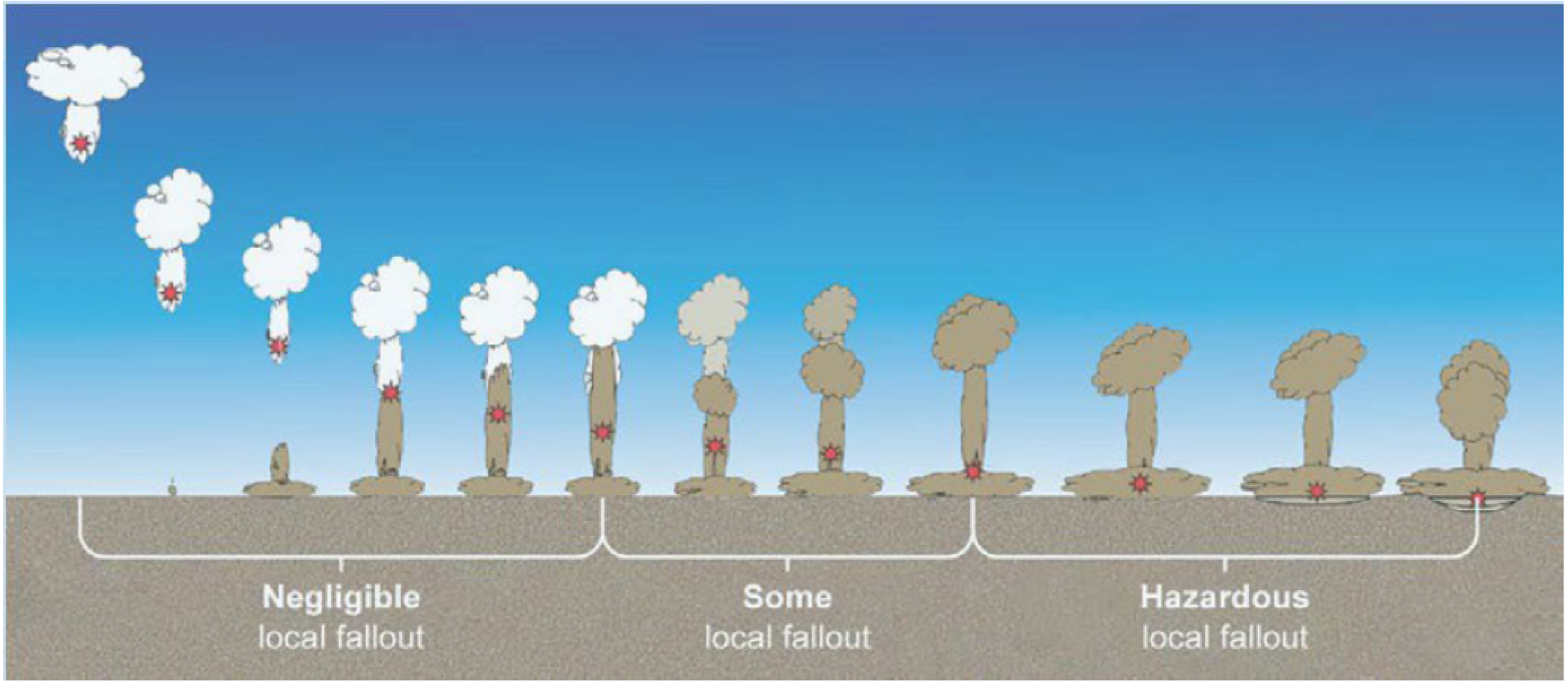

Figure 12: Examples of cloud shapes and shading for various heights of burst. Color of cloud indicates the amount of environmental materials, like dirt, in the cloud; brown clouds have the most materials and white clouds have the least (derived from Spriggs et al., 2020).

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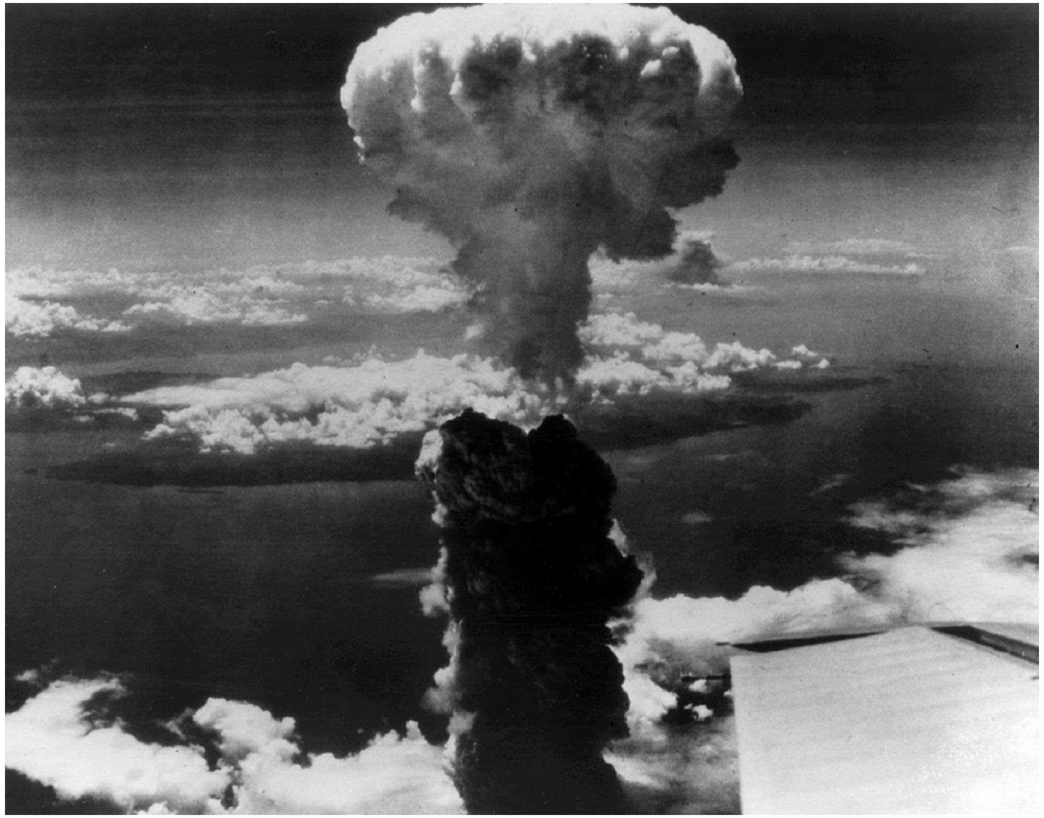
Hiroshima and Nagasaki

Hiroshima, August 6, 1945. NATIONAL ARCHIVES



Atomic bomb cloud over Nagasaki

https://www.nps.gov/articles/000/the-atomic-bombings-of-hiroshima-and-nagasaki.htm
https://www.atomicarchive.com/history/atomic-bombing/nagasaki/page-4.html

Hiroshima and Nagasaki

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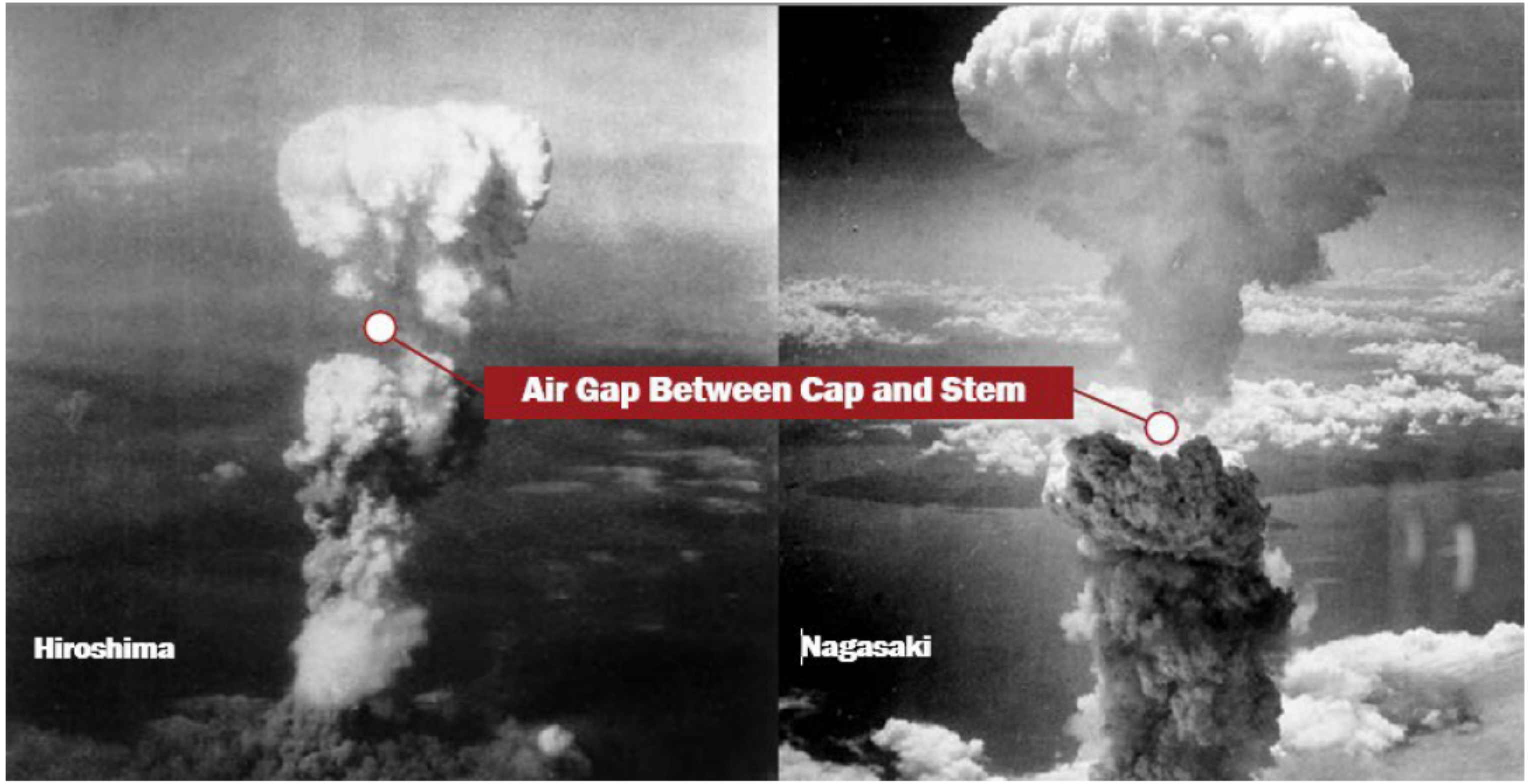

Figure 13: Air Gap Between the White Mushroom Cap Containing Fission Products and the Dark Stem of Dirt and Debris for Hiroshima and Nagasaki

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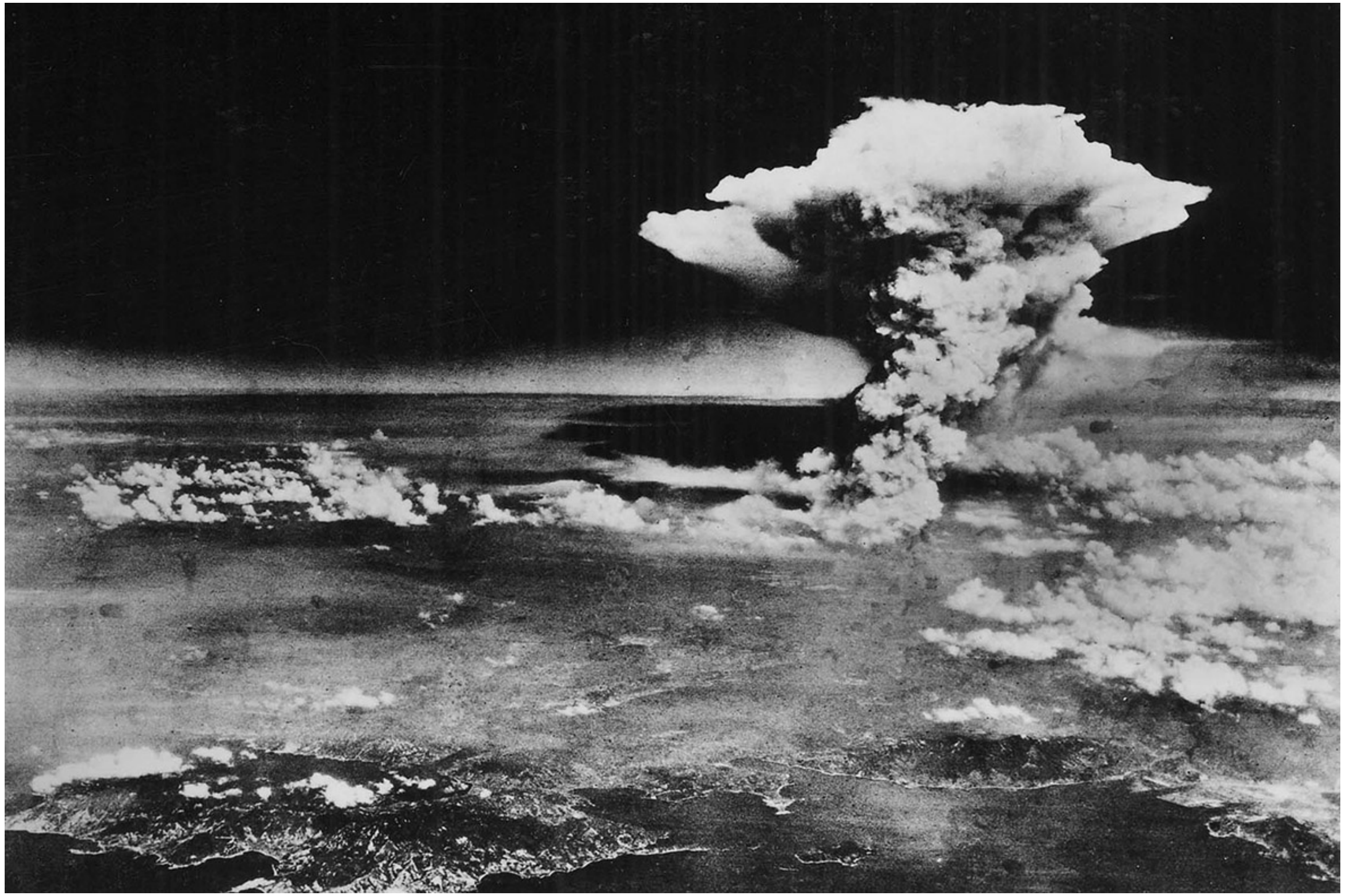
Rainout - Black Rain

- For decades this image was misidentified as the mushroom cloud of the bomb at Hiroshima. However, due to the clouds much greater height and time of day, it was identified in March 2016 as the cloud created by the firestorm that engulfed the city, a fire that reached its peak intensity some 3 hrs after the bomb.

- During the birthing of this cloud, 20 mins after detonation soot filled black rain began to fall on survivors.



https://commons.wikimedia.org/wiki/File:Firestorm_cloud_over_Hiroshima.jpg

Rainout - Black Rain

- A shirt donated by Toyoko Matsumiya in 2012 to the Hiroshima Peace Memorial Museum still shows stains from black rain, containing radioactive fallout that fell on Aug. 6, 1945.
- Scientific tests on this shirt detect slight amounts of cesium-137 more than 70 years after the attack.
- The girl washed the shirt for physical education classes a number of times on a washboard but could not remove the dark stains left after her exposure to the rain.

CHUGOKU SHIMBUN
https://www.japantimes.co.jp/news/2018/08/06/national/history/black-rain-radiation-1945-hiroshima-bombing-can-still-detected-survivors-shirt-study/

US Post-Detonation NF Collection - GCTF

- Ground Collections Task Force, an interagency group capable of deploying to a post-detonation environment to rapidly collect ground-deposited fallout debris
- DOE Forensics Operations (DFO) Team - technical experts from across the National Laboratory complex who are trained and equipped to perform nuclear forensics analysis following a nuclear detonation in support of the interagency effort to identify the perpetrator of the attack. DFO supports ground collection and processing of post-detonation debris to provide the highest quality samples for forensic analysis.

"We exercise our capabilities in a very public way to deter our enemies and protect the United States and our friends against terrorist nuclear attacks."

- Grant Ford, Director of the CTCP Office of Nuclear Forensics

"In this scenario, getting the right samples to the national laboratories is crucial to a solid nuclear forensics analysis."

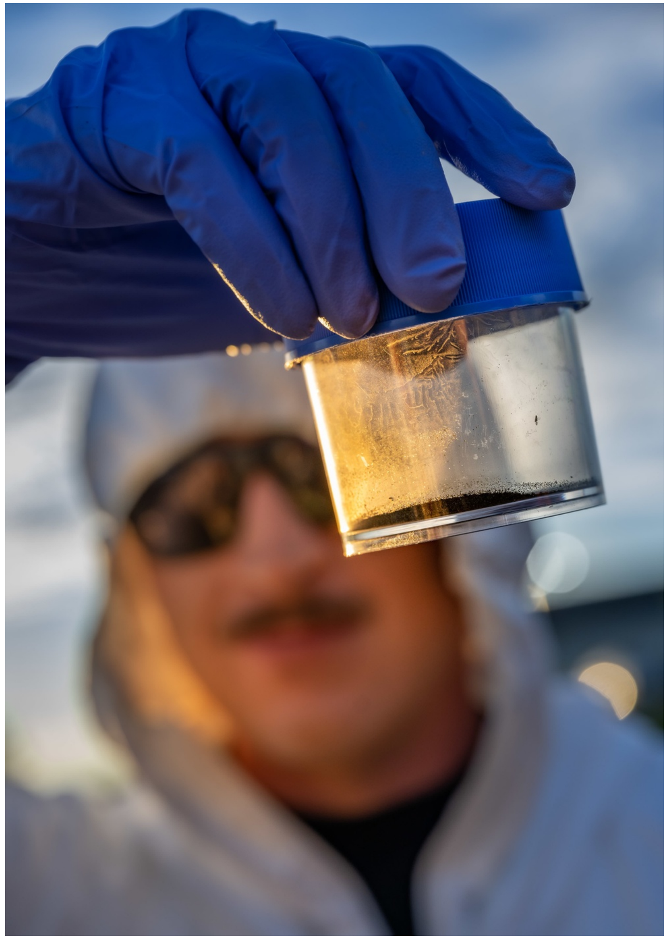
- Patrick Ragen, DFO Program Manager

https://www.energy.gov/nnsa/articles/nnsa-joins-fbi-and-department-defense-nuclear-forensics-exercise-Texas
https://inl.gov/national-homeland-security/nuclear-forensics-team-braves-winds-to-learn-fallout-collection-techniques/

GCTF

A soldier collecting simulated nuclear fallout in an exercise in Colorado, 2018

A soldier and a DOE scientist in nuclear fallout collection in Florida, 2021



A sample of surrogate nuclear fallout

https://www.dvidshub.net/news/295072/20th-cbrne-soldiers-participate-prominent-hunt-nuclear-forensics-exercise
https://www.dvidshub.net/image/6915137/20th-cbrne-command-units-train-nuclear-forensics-mission-during-exercise-prominent-hunt
https://www.energy.gov/nnsa/articles/nnsa-joins-fbi-and-department-defense-nuclear-forensics-exercise-texas

DFO & NEST

DFO scientists analyzing a surrogate fallout sample in an exercise at INL

Practice transferring a hot fallout sample

A model of a fallout deposition map

A NEST aerial measurement system aircraft

"The point of the training is deterrence. We want our adversaries to know we can figure out who was responsible – and hold them accountable."
- C.J. Johnson DFO Program Manager

National Atmospheric Release Advisory Center

https://inl.gov/national-homeland-security/nuclear-forensics-team-braves-winds-to-learn-fallout-collection-techniques/
https://www.energy.gov/nnsa/nuclear-emergency-support-team-nest

Final Remarks

"A credible nuclear forensics enterprise is essential for deterring nuclear trafficking and attacks and supporting attribution after an attack. Nuclear forensics capabilities, along with engaging international partners and a robust and credible monitoring, detection, and verification enterprise, can help empower leaders to make informed decisions about nuclear threats on short timelines.

"Restoring and Improving Nuclear Forensics to Support Attribution and Deterrence: Public Summary," (2021), National Academies Press