Nuclear Forensic Reference Materials (RM) for Attribution of Urban Nuclear Terrorism

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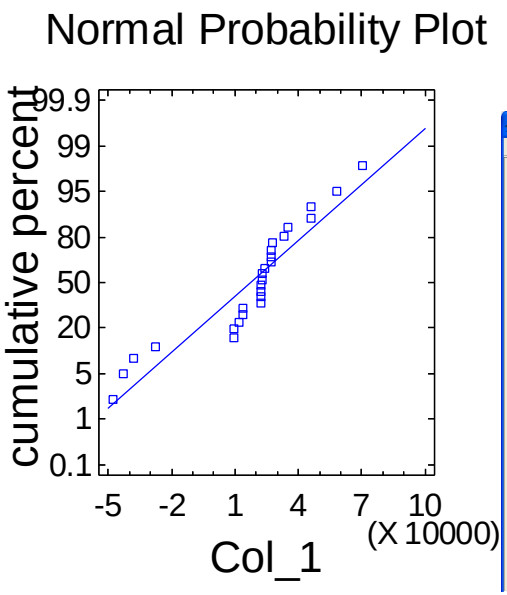
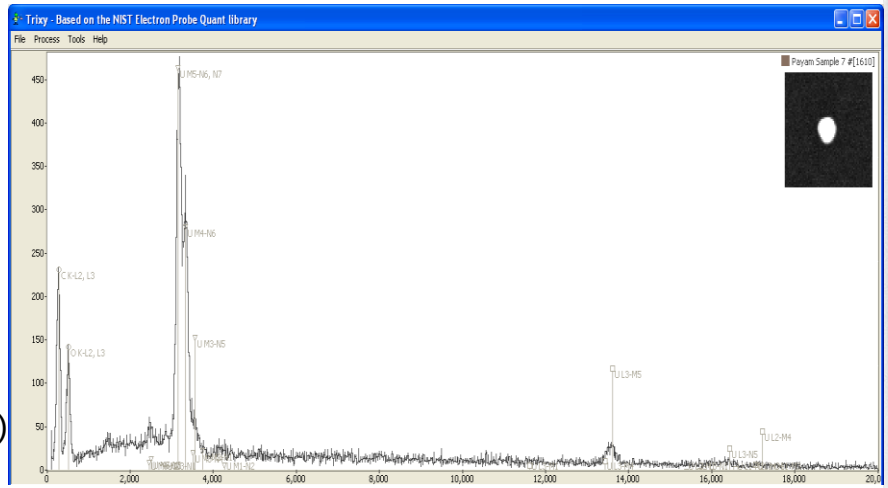




BLUF

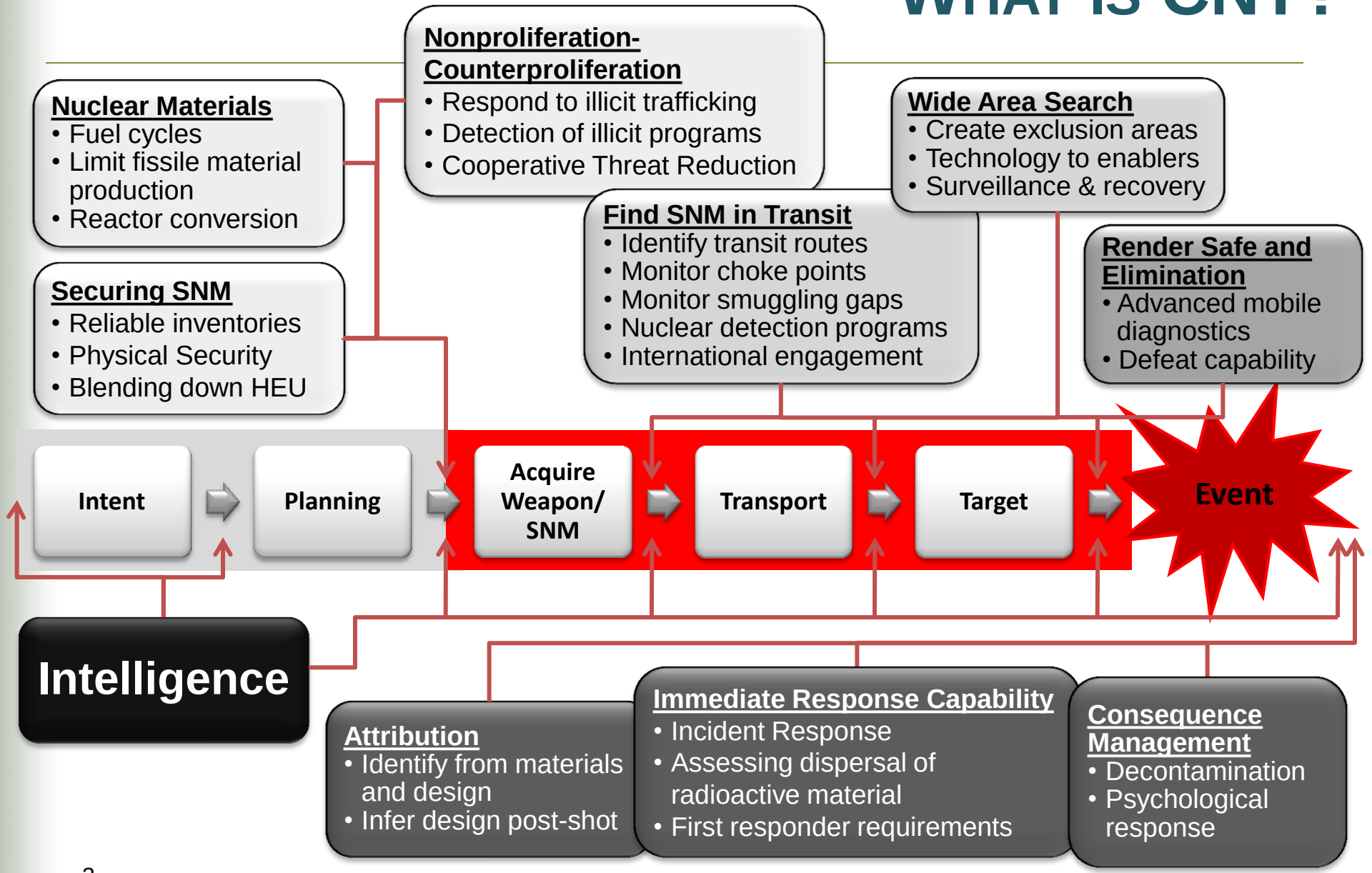
Understanding DoJ, DoD, DHS, DOE needs requires close relationships

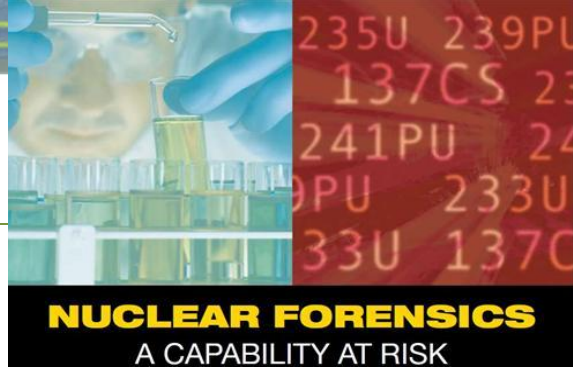
Nuclear Forensics require high-level expertise, undisputed signatures & extremely high fidelity measurement capabilities

CBRNE countermeasures must withstand legal scrutiny, and requires strong metrology backbone

Requirements for CRMs exceedingly high

WHAT IS CNT?


Nonproliferation-Counterproliferation
• Respond to illicit trafficking
• Detection of illicit programs
• Cooperative Threat Reduction
Nuclear Materials
• Fuel cycles
• Limit fissile material production
• Reactor conversion
Wide Area Search
• Create exclusion areas
• Technology to enablers
• Surveillance & recovery
Find SNM in Transit
• Identify transit routes
• Monitor choke points
• Monitor smuggling gaps
• Nuclear detection programs
• International engagement
Render Safe and Elimination
• Advanced mobile diagnostics
• Defeat capability
Securing SNM
• Reliable inventories
• Physical Security
• Blending down HEU
Intent
Planning
Acquire Weapon/ SNM
Transport
Target
Event
Intelligence
Attribution
• Identify from materials and design
• Infer design post-shot
Immediate Response Capability
• Incident Response
• Assessing dispersal of radioactive material
• First responder requirements
Consequence Management
• Decontamination
• Psychological response



Definitions

Nuclear Forensics (NF) and Attribution (A)

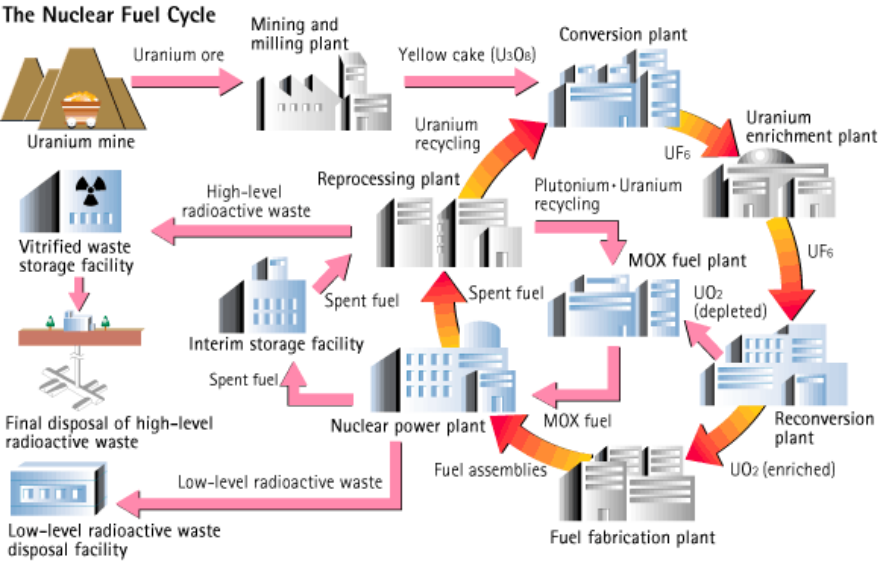
- (NF) - Nuclear forensics is the use of physical and chemical properties to help determine the age, origin, and history of nuclear materials and the design of nuclear devices. Identifying these "nuclear signatures" can help investigators track nuclear materials back to their origin

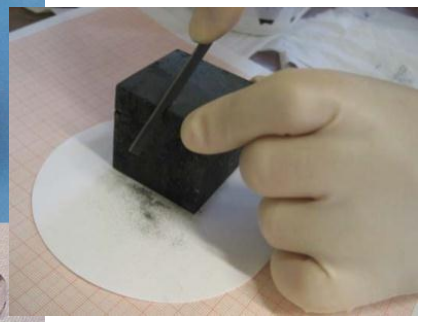
- (A) Attribution is the integration of all information, including nuclear forensic data, law enforcement and intelligence data, to suggest or exclude the origin of nuclear materials and devices, routes of transit, and responsible groups or individuals

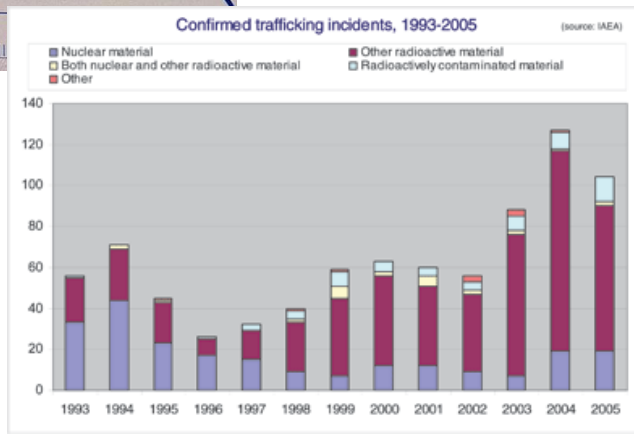
Physical –Chemical –Radiological and Isotopic Characterization

Increasing Uncertainty

What is it?
How was it constructed?
When?
Where, Who, Why?







Signatures are created and erased throughout the life cycle of nuclear materials

Some of these signatures are maintained in Interdicted & Post Detonation Materials

Nuclear Forensic Goals & Applications

Goals

- **Identify those responsible for nuclear theft or nuclear terrorism**
- **Deter the theft of nuclear materials or acts of nuclear terrorism**
- **Enhance protection, control, and accounting for nuclear materials and weapons**
- **Prevent additional thefts or terrorist acts by plugging leaks and tracking down other missing materials or devices**

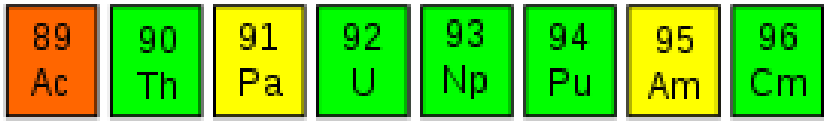
Applications

- **Intercepted nuclear materials or devices**
- **Debris from a nuclear explosion**
- **Debris from a radiological dispersal device**

Some of these signatures are maintained in Interdicted & Post Detonation Materials

Fetter, S. (2007) U.S.-Russia Dialogue on Strategic Cooperation & Joint Crisis Management

What Information does Nuclear Forensics Provide?



Nuclear Forensics – Weapons Fuel Processing

Parameter	Signature	Analytical Technique
Appearance	Material type (e.g. powder, pellet)	Optical Microscopy
Dimensions (Pellet)	Reactor Type	Database
U, Pu, Content	Chemical Concentration, nuclear fuel type, weapon type, and device type	Titration, Hybrid K-Edge Dosimetry, Isotope Dilution Mass Spectrometry
Isotopic Composition	Enrichment--intended use/reactor type, nuclear fuel type, weapon type, and device type	Gamma Spectrometry, TIMS, ICP-MS, SIMS
Impurities	Production Process, geolocation, device type, and weapon type	ICP-MS
Age	Production Date	Alpha Spectrometry, TIMS, ICP-MS
Surface Roughness	Production Plant	Profilometry
Microstructure	Production Process	SEM, TEM

Nuclear Forensics – Weapon Design

Parameter	Signature	Analytical Technique
Fission Fuel	Pu, U Ratio	Radiochemistry, actinide mass spectrometry
Reactor Power and Irradiation time	Fission Product Isotopic Ratios	Radiochemistry, beta/gamma counting
Fuel Sophistication	Enriched U and Pu Isotopic Ratios	Radiochemistry, actinide mass spectrometry
Initiator	^{210}PoBe	Chemical analysis, Radiochemistry, alpha-counting
Boosting	^{6}Li	Mass Spectrometry
Fission neutron energy	Fission Yield Curve	Radiochemistry, alpha/beta/gamma counting

Evidence Legal Standards

Daubert v. Merrell Dow Pharmaceuticals (1993)

- Has the technique been validated?
- Were the conditions controlling the technique's operation maintained?
- Were the results peer reviewed?
- Does, and at what frequency, the method lead to any erroneous results? (false positives and/or negatives)
- Has the technique been generally accepted in the scientific community?

US Federal Rules of Evidence 702

- evidence is based upon sufficient facts or data,
- evidence is the product of reliable principles and methods, and
- the principles and methods have been applied reliably to the facts of the case

What is missing? **Urgent CRMs to support State-of-the-Art Measurement Capabilities and Metrology Infrastructure**

Non-Existent
Not Good Enough for High Fidelity Attribution
in Short Supply
Exceedingly Rare
Long Development Time
Very Expensive

Problem?

Required CRMs are needed NOW
5 years to develop one CRM
Few have the capability to develop state-of-the-art CRMs
CRM production require specialized non-existent facilities
Process is labor intensive and costly

How to Close the Gap?

Enlist increased numbers of capable metrologists
Focus their attention on this mission (affect their priority list)
Establish specialized facilities

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Forensic science problem: No fresh fission product urban RM to test nuclear forensics capabilities for attribution

Objective(s):

- Micro-homogeneity Evaluation of UVC material using micro-XRF
- Microwave digestion/fusion dissolution
- Elemental/actinide concentration by ID-HR-ICP-MS
- Stable isotopic “fingerprint” by HR-ICP-MS
- Documentation/Publications
- Elemental/isotopic mass certification of UVC

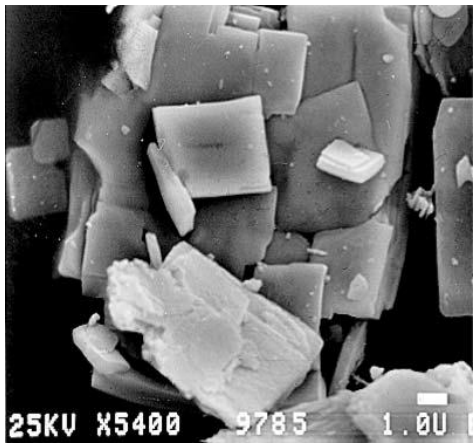
Nuclear Forensic Reference Materials (RM) for Attribution of Urban Nuclear Terrorism

End of project outcomes: **Characterization of HEU doped UVC to test the U.S. nuclear attribution capabilities**

- **Documentation/Publications**
- **UVC RM certified for Elemental/isotopic mass**

Anticipated impact on forensic science: **RM for high fidelity attribution capabilities of an urban nuclear terrorist event**

- **Method development/validation/testing/preparedness**
- **High fidelity attribution/legal defensibility (Daubert v. Merrell Dow)**



Nuclear Forensics Challenge

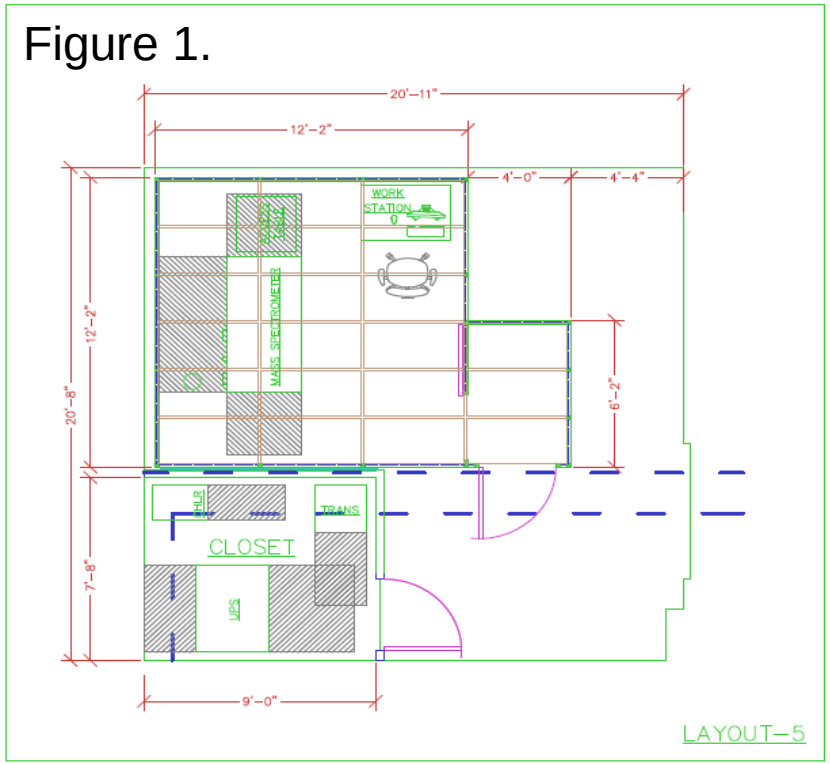


Figure 1. Approved layout for the lab retrofit.

Lab Retrofit

Goal: Lab space with controlled humidity and temperature for optimal operation of new ELEMENT2 mass spectrometer.

Figure 2. Exterior Hard wall clean lab space for new mass spectrometer

Figure 3. Interior clean lab space with continuous flooring

Nuclear Forensics Challenge

Mass Spectrometer Purchase

Element2 HR-ICP-MS high-resolution (single-collector) sector field inductively-coupled plasma mass spectrometer

Goal: Establish NIST atom-counting capability for required high-precision/accuracy assay/isotopic trace and major radio-element nuclear forensics certified reference materials

Nuclear Forensics Challenge

UVC Characterization/Certification Plan

- Assess UVC micro-homogeneity with micro-XRF
- Develop dissolution protocols
- Determine elemental/actinide massic concentrations
- Determine Stable Isotopic "Signature"
- Document/Certify UVC elemental/isotopic massic concentrations

Work Done

UVC Dissolution

Procedure: 4 samples (2 of 0.100 g and 2 of 0.200 g):
Step 1 – Digest Al with H_3PO_4 + HCl
Step 2 – Digest Si with HBF_4 + HNO_3

Microwave held at 200 bar, 300° C

Results: Success with 0.100g samples
particles observed with 0.200g samples

Future: Will attempt with pure HF and then
H_3BO_3 replacing HBF_4

UVC Composition

Element	ppm	Element	ppm	Element	ppm
Si	186000	As	14	Cl	37
Al	7900	B	3	Sr	130
Fe	230000	C	470	Cr	850
Ca	220000	Co	37	Zn	47
Mg	4800	Cu	220	F	260
S	3700	Mo	190	Zr	15
Na	700	Nb	55	*(N*	*2)*
K	1900	Ni	450	U	100
Ti	550	Sn	36	W	10
P	200	Ta	25	Th	10
Mn	1200	V	150	*(O*	*Balance)*

Conclusions

- **Understanding DoJ [FBI], DoD [COCOMs, JRO], DHS [DNDO/NTNFC], DOE [NNSA] needs requires close relationships**
- **Nuclear Forensics require high-level expertise, undisputed signatures & extremely high fidelity measurement capabilities**
- **CBRNE countermeasures must withstand legal scrutiny, and requires strong metrology backbone**
- **Uncertainty Requirements for CRMs exceedingly high**

Concentration [ppm]	Uncertainty [k = 2, %]
High [500-1000]	1 - 5
Medium [100-500]	1 - 5
Low [1-100]	5 - 30

Thank You

Future Plans

Micro-homogeneity of UVC material using micro-XRF

Microwave digestion/fusion dissolution

Elemental/actinide concentration by ID-HR-ICP-MS

Stable isotopic “fingerprint” by HR-ICP-MS

Documentation/Publications

Elemental/isotopic mass certification of UVC