IPNDV Working Group 3: Technical Challenges and Solutions
Nuclear Explosive Device (NED) in a container - Monitoring Technologies Matrix
October 10, 2017

Technology	Information detected/determined	Key Limitations (Shielding issues, possible size restraints, etc.)	Approximate Measurement Time Scales	Equip Availability (TRL)/for Simple Scenario (TRL)	IB Needed (TRL?)	Comments	Related Technology Paper
Special Nuclear Material (SNM) Detection							
Passive Gamma Detection	Detection of U235	A small amout of shielding will block any potential signal of U235	days		Yes	NOT RECOMMENDED to use this method for detecting U235	NM2 - High Resolution Gamma-ray Spectrocopy (HRGS)
	Instrument detects gamma radiation emitted that can be used to determine presence of Pu and Pu isotopics.	Vulnerable to significant external shielding. Requires homogenius isotopic composition.	30-60 minutes	Readily in use today (9) / For Dismantlement (7)	Yes	Liquid nitrogen hazard, if used	NM2 - High Resolution Gamma-ray Spectrocopy (HRGS)
Passive Gamma-ray Imaging	Detects gamma radiation and can provide information as denoted above	Vulnerable to significant external shielding. Depends on how strong the source is. Low energy photons are easily scattered by explosives but can also image where nearby materials may occur and easily attenuated by metals.	30-60 minutes	Readily in use today (9) / For Dismantlement (7)	Yes (1)	Can be done in conjunction with location and/or shape analysis	NM3 - Gamma-ray Imaging
	location of gamma-ray emitting object		several hours			takes longer to image than to do just gamma spectroscopy	NM3 - Gamma-ray Imaging
	shape of gamma-ray emitting object		several hours			Possible mass approximation	NM3 - Gamma-ray Imaging
Nuclear Resonance Fluorescence	isotopic composition of Pu and U	Can work with a large amount of shielding	Tens of minutes	Commercially available (9) / For Dismantlement (4)	Yes (1)	There will be a radiation safety concern. Relatively large physical footprint	HENM1 - Nuclear Resonance Fluorescence
Passive Neutron Counting	Detect total passive neutron emissions; presence of neutron source	Sensitive to amount of shielding. Does not tell what is the neutron source. Not likely to detect U source.	30 minutes or less	Readily in use today (9) / For Dismantlement (8)	Yes	Cannot discriminate between ^{240}Pu and other neutron sources	NM4 - Passive Neutron Counting
	Measuring neutron coincidence/ multiplicity will result in mass determination of ^{240}Pu	Dependent on the geometry of the source. However this is not a key limitation that will make the technique inapplicable especially in view of low accuracy required. Not likely to detect U source.	10-60 minutes	Readily in use today (9) / For Dismantlement (8)	Yes (7)	Used in conjunction with isotopic information to estimate total mass of Pu	NM4 - Passive Neutron Counting
	Measuring multiplicity with triplets will result in mass determination of total ^{240}Pu	Dependent on the geometry of the source. However this is not a key limitation that will make the technique unapplicable especially in view of low accuracy required. Not likely to detect U source.	few hours	Readily in use today (9) / For Dismantlement (7)	Yes (7)	Used in conjunction with isotopic information to estimate total mass of Pu	NM4 - Passive Neutron Counting

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Active Neutron Techniques	Detect delayed neutron emissions in response to bombardment with neutrons; used to determine U and Pu presence	Unable to separate parameters such as mass, density, shape, fissile isotope(s). Geometry is important. Closer distances between source and NED are better.	4 minutes (1 min irradiation + 3 min counting) to tens of minutes.	Readily in use today	Yes	Cannot determine isotopics. Can determine the ratio between U and Pu.	NM6 - Active Neutron Interrogation
	Detect prompt neutron emissions simultanuously with neutron beam excitation; used to determine U233, U235 and Pu239 presence	Unable to separate parameters such as mass, density, shape, fissile isotope(s). Geometry is important. Closer distances between source and NED are better.	few minutes	Readily in use today (9)/ For Dismantlement (6)	Yes	Technology has been proven in laboratory conditions; deployment for disarmament may introduce challenges.	NM6 - Active Neutron Interrogation
	Detect prompt/ or delayed gamma emissions simultanuously with/or following neutron activation; can be used to determine presence of U and U isotopics	Sensitive to amount of shielding. Depends on neutron flux and spectrum	few minutes uo to 30 minutes	Readily in use today (9)/ For Dismantlement (6)	Yes	Technology has been proven in laboratory conditions; deployment for disarmament may introduce challenges. Detection of gamma emissions may be used to indicate presence of explosives (low TRL).	NM6 - Active Neutron Interrogation
	Detect prompt/or delayed gamma emissions simultanuously with/or following neutron activation; can be used to determine presence of Pu and Pu isotopics	Sensitive to amount of shielding. Depends on neutron flux and spectrum	few minutes uo to 30 minutes	Readily in use today (9)/ For Dismantlement (6)	Yes	Technology has been proven in laboratory conditions; deployment for disarmament may introduce challenges. Detection of gamma emissions may be used to indicate presence of explosives (low TRL).	NM6 - Active Neutron Interrogation
	PULSED NEUTRON: Detects time sequence of prompt fission neutrons in response to pulsed neutrons; used to determine presence of fissile U and Pu including differentiation between the two. The differentiation between U and Pu may not be very sensitive, and requires a different measurement regime.	Unable to separate parameters such as mass, density, shape, fissile isotope(s). The inability to separate parameters is a strong point of the method and not a limitation. Large neutron shield is not a problem, but will only slow-down the source neutrons further towards thermal energy.	The proposed measurment time is 600-1000 seconds	Laboratory measurements (4)	Yes (2)	Technology has been proven in near ideal laboratory conditions and modeling; deployment on complete NED in container may introduce challenges	NM5 - Pulsed Neutron Interrogation
Fast Neutron Imaging	Fast neutron emission imaging: images neutron emitters; possible location and shape of Pu	This technique is only practical for plutonium assay.	One to several hours.	Laboratory maintained systems (6) / For dismantlement (3)	Yes (2)	Images are much less detailed than those produced by transmission imaging. Intended for imaging distributed sources or an array of sources from a distance.	NM7 - Fast Neutron Imaging
	Fast neutron transmission imaging: active imaging technique from bombaring with fast neutrons; imaging of material without compositional detail	Although all materials can be imaged with this technique, it cannot identify specific materials, elements, or isotopes. Image contrast can be degraded when neutrons must penetrate a significant amount of low-Z material.	Ten minutes to several hours.	Laboratory maintained systems (6) / For dismantlement (3)	Yes (2)	Measurement times are strongly dependent upon the size of the imaged object and desired feature(s) to measure. May be used to verify that an item's internal geometry has changed when appropriate.	NM7 - Fast Neutron Imaging
	Stimulated emission imaging: imaging of induced neutron emissions of an item by bombarding with neutrons; location and shape of SNM	This technique can be used to assay uranium in the presence of plutonium or other neutron emitter, but the characterization may be more challenging. Low-Z materials significantly degrade the image quality.	Ten minutes to several hours.	Laboratory maintained systems (6) / For dismantlement (3)	Yes (2)	Particularly useful for U. Measurement times are strongly dependent upon the size of the imaged object.	NM7 - Fast Neutron Imaging

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Muon Tomography	Imaging of muons, which are preferentially scattered by heavier elements	Muon tomography does not have the sensitivity to identify the exact mass. Depleted U cannot be distinguished from HEU or Pu.	20 minutes to several hours	Commercial systems available (9) / Laboratory measurements (4)	Yes (1), if measurements provide high resolution image	Useful for relative density imaging; possible verification of presence of high denisty material in container. Does not require an additional source.	NM8 - Muon Tomography
Radiation Templates	Reference data set of radiation signatures of a NED(s) or NED components; provides unique set of signatures used to provide confirmatory verification of an inspectable item against a "trusted" item's reference data set	Template matching needs to account for time difference between initial template and next measurement. Method is geometry and background dependent.	several minutes	Demonstration completed (7)	Yes (7)	Not necessarily a measurement instrument but used in conjunction with a measurement instrument to enable comparision of a measurement with a known signature(s)	NM9 - Radiation Templates
Calorimetry	Measure of thermal power output of heat-producing materials;	Cannot be used on assembled NED as there are likely more heat sources than just the SNM.				Cannot be used on assembled NED as there are likely more heat sources than just the SNM. NOT RECOMMENDED	NM1 - Calorimetry

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High Explosive (HE) Detection							
Raman Explosive Identification System	Spectroscopic technique to observe vibrational, rotational and other low frequency modes of a molecular system; when compared to known spectra can be used to confirm presence and identification of HE	Dependent on HE stored in a semi-transparent container; would not likely work with a sturdy wooden container				The sealed nature of the NED limit applicability of this technique on a NED in a container. NOT RECOMMENDED	HE4 - Raman Explosive Indentification System
NQR-explosive Identification System	Spectroscopic technique where select nuclei are excited using radio waves, where the response is observed; when compared to known spectra can be used to confirm presence and identification of HE	Likely works with a variety of containers but not metal				The sealed nature of the NED limit applicability of this technique on a NED in a container. NOT RECOMMENDED	HE3 - NQR explosive identification system
Fast Neutron Interrogation System	Measures gamma emissions in response to excitation by neutron bombardment; resulting spectra observed can be used to confirm presence and identification of HE; also can be used to image material	need compositional information ahead of time; container composition dependent	10 minutes	Readily in use today (9) / For Dismantlement (5)	Yes (1)	Operator needs to be shielded from the neutron source.	HE2 - Fast neutron interrogation system for HE identification
Active Neutron Techniques	Detect gamma emissions in response to bombardment with thermal neutrons	neutron source usually needs to be 10-30m away from personnel	2-10 minutes	Readily in use today (9)	Yes	Detection of gamma emissions may be used to indicate presence of explosives (N, H) [example PINS]	HE2 - Fast neutron interrogation system for HE identification
Compton Backscattering Cameras	Active x-ray technique to determine shape and number of components	Battery operated; can't be used with thick metal containers.	Quick measurements	Commercially available (9) / For Dismantlement (7)	Yes (1)	Minor health and safety issues (x-ray source) NOT RECOMMENDED	HE5 - X-ray backscattering imaging
Nuclear Resonance Fluorescence	Gamma-ray spectrum, isotope information, C/N and C/O ratios for explosives determination, potential for SNM mass determination.	Hydrogen is the only element that can't be detected. In the transmission configuration, the measurement is aided by a 'witness or detection' foil that consists of the isotope of interest.	10 minutes	Commercially available (9) / For Dismantlement (7)	Yes (1)	There will be a radiation safety concern. Relatively large physical footprint	HE/NM1 - Nuclear Resonance Fluorescence
X-ray Computed Tomography	3D volumetric information, shape, location, effective atomic number, density, mass, material type. The technology can identify objects that are surrounded (hidden) by other objects.	will not penetrate through materials with a high density thickness	seconds to 10 minutes	Commercially available (9) / For Dismantlement (7)	Yes (1)	designed to the used within a concrete bunker and do pose a radiation hazard if used outside of these conditions NOT RECOMMENDED	HE1 - X-ray Computed Tomography
Passive Gamma Detection	Detect C, N, O, H that could be indicative of HE.	only applicable to Pu device		Not readily used for this application today		Not a direct indication of HE but only of C, N, O, H	NM2 - High Resolution Gamma-ray Spectrocopy (HRGS)
Swipe Sampling	Detects trace amounts of explosive	Dismantlement facilities will have trace amounts of HE all over the facility and in empty containers		Commercially available (9)		NOT RECOMMENDED	N/A