## SNM in a Container Monitoring Technologies

| 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?) | Applicable Dismantlement Steps (1-14) | Comments | Related Technology Paper |
|---|---|---|---|---|---|---|---|---|
| **Passive Gamma Detection** | Instrument detects gamma radiation emitted that can be used to determine presence of HEU, Pu, and Pu isotopics. | Vulnerable to significant external shielding. Requires homogenous isotopic composition. | 30–60 minutes, days for HEU | Readily in use today (9) / for dismantlement (7) | Yes | 1–14 | Severe constraints likely for any use in Step 8; not applicable for actual dismantlement operation (physical separation of components). In many scenarios, passive gamma detection would be unnecessary during the transport steps because chain of custody techniques would be sufficient. A small amount of shielding will block any potential signal of U235, so this method is not recommended for detecting U235. | 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) | Storage steps | Can be done in conjunction with location and/or shape analysis | NM3: Gamma-ray Imaging |
| | Location of gamma-ray emitting object | | Several hours | | | Storage steps | Takes longer to image than to do just gamma spectroscopy. Imaging is only practical for the storage steps because of the longer time required. | |
| | Shape of gamma-ray emitting object | | Several hours | | | Storage steps | Possible mass approximation | |
| **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) | 10, 12, 14 | There will be a radiation safety concern. Relatively large physical footprint. It is assumed that no active methods will be permitted with an assembled NED due to safety/security concerns. | HENM1: Nuclear Resonance Fluorescence |
| **Passive Neutron Counting** | Detects total passive neutron emissions; presence of neutron source; could be used as a Pu or Pu/U absence measurement. | 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 | 1–14 | Severe constraints likely for any use in Step 8; not applicable for actual dismantlement operation (physical separation of components). Cannot discriminate between 240Pu and other neutron sources. | NM4: Passive Neutron Counting |
| | Measuring neutron coincidence/ multiplicity will result in mass determination of $^{240}$Pu. | Depends 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, few hours for triplets | Readily in use today (9) / for dismantlement (8) | Yes (7) | 1–14 | Severe constraints likely for any use in Step 8; not applicable for actual dismantlement operation (physical separation of components). Used in conjunction with isotopic information or declared Pu239/Pu240 ratio to estimate total mass of Pu. In many scenarios, passive neutron detection would be unnecessary during the transport steps because chain of custody techniques would be sufficient. | |

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| **Active Neutron Techniques** | Detects 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 minute irradiation + 3 minutes counting) to tens of minutes | Readily in use today | Yes | 10, 12, 14 | Cannot determine isotopics. Can determine the ratio between U and Pu. It is assumed that no active methods will be permitted with an assembled NED due to safety/security concerns. | NM6: Active Neutron Interrogation |
| | Detects 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 | 10, 12, 14 | Technology has been proven in laboratory conditions; deployment for disarmament may introduce challenges. It is assumed that no active methods will be permitted with an assembled NED due to safety/security concerns. | |
| | Detects 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 | 10, 12, 14 | 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). It is assumed that no active methods will be permitted with an assembled NED due to safety/security concerns. | |
| | Detects 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 | 10, 12, 14 | 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). It is assumed that no active methods will be permitted with an assembled NED due to safety/security concerns. | |
| | 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 toward thermal energy. | The proposed measurment time is 600–1000 seconds | Laboratory measurements (4) | Yes (2) | 10, 12, 14 | Technology has been proven in near ideal laboratory conditions and modeling; deployment on complete NED in container may introduce challenges. It is assumed that no active methods will be permitted with an assembled NED due to safety/security concerns. | NM5: Pulsed Neutron Interrogation |

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| **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) | Storage steps | Images are much less detailed than those produced by transmission imaging. Intended for imaging distributed sources or an array of sources from a distance. Imaging is only practical for the storage steps because of the longer time required. | NM7: Fast Neutron Imaging |
| | Fast neutron transmission imaging; active imaging technique from bombarding 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) | 10, 12, 14 | Measurement times strongly depend on 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. It is assumed that no active methods will be permitted with an assembled NED due to safety/security concerns. | |
| | 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 U in the presence of Pu 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) | 10, 12, 14 | Particularly useful for U. Measurement times strongly depend on the size of the imaged object. It is assumed that no active methods will be permitted with an assembled NED due to safety/security concerns. | |
| **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 | Storage steps | Useful for relative density imaging; possible verification of presence of high denisty material in container. Does not require an additional source. Will require significant time, so only applicable to storage steps. | 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) | 1–14 | Not necessarily a measurement instrument but used in conjunction with a measurement instrument to enable comparision of a measurement with a known signature(s). This method is part way between full imaging and simple counting. Available but probably not required in may transport scenarios, since chain of custody technologies should be sufficient there. Severe constraints likely for any use in Step 8; not applicable for actual dismantlement operation (physical separation of components). | 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. | Hours | Readily in use today (9) / for dismantlement (1) | No | 10, 12, 14 | Will require significant time, so only applicable to storage steps. | NM1: Calorimetry |