NM Technology Name: Direction-Sensitive Neutron Detector
Physical Principle/Methodology of Technology: Direction-sensitive neutron detectors can localize static neutron sources or track the movement of mobile sources in real time. By using two direction-sensitive detector units or one mobile unit, the exact location of the neutron source can be calculated. In addition, the detector technology is capable of classifying the neutron sources into four categories: D-T, AmBe, fission, or thermal. Basically the detector is also capable of recording and identifying thermal and/or fast neutron coincidences. The detector could also turn out to be very useful in active thermal neutron interrogation studies of uranium, i.e., in the direction-sensitive detection of fast neutrons generated by the ^{235}U thermal neutron induced fissions. The detector is based on a voxel array of scintillator elements that combine different scintillator materials. This arrangement enables excellent detection efficiency for both thermal and fast neutrons (0.025 eV–14 MeV). Scintillation signals are processed using integrated digital nuclear electronics. Neutron-gamma separation is based on pulse shape analysis.
Potential Monitoring Use Cases (pre-dismantlement, dismantlement, post-dismantlement, storage stage): The direction-sensitive neutron detector or detectors can be passively used during pre- and post-dismantlement and storage stages to monitor the storage or movement of plutonium material in real time. Detector can also be used to produce rough information from the mass of plutonium before and after the dismantlement.
Physical Description of Technology (e.g., approximate size, weight): Due to the modularity of the technology, detectors can be built in various sizes and shapes. A typical detector unit is approximately 25x25x25 cm^3 and weights 10–20 kg. The detector can operate inside a sealed box that prevents unauthorized access. The recorded data can be transmitted via USB, Ethernet, or Bluetooth connection in real-time or in connection with inspector visits. Several detector units can be combined for an array of neutron detectors. Such setup could also be used for multiplicity studies.
Time Constraints (e.g., measurement times including distance from object, time to install the equipment): The detector system can be set up in fewer than five minutes. Due to its high efficiency, two detector units can show the location of a neutron source that corresponds to 10 ng of ^{252}Cf (emits approximately 20,000 n/s) in 10 s at a source to detector distance of 1.5 m. If longer measurement distances are preferred, the size of the detector units or measurement time can be increased. Notice that spontaneous fission yield of ^{239}Pu (^{240}Pu) is 2.18×10^{-2} (1.02×10^{3}) neutrons/s-g[1]. [1] Passive Nondestructive Assay of Nuclear Materials, NUREG/CR-5550, LA-UR-90-732, p. 339.

Technology Complexity (e.g., hardware, software, and ease of use by personnel):

The use of the detector is straightforward. With a single click from the control software, the systems perform an internal calibration process, check the states of health, and indicate that the detector is ready for a measurement. Once the measurement is started, the detector determines the direction of the source and points to it with an arrow in the software. Directions and corresponding time stamps are also stored to a data file. To present the source movement on a map, locations of the two detector units with respect to the reference frame must be given.

Infrastructure Requirements (e.g., electrical, liquid nitrogen, etc.):

The detector can either be connected to a main power source or operated on battery. The battery can also be used as a backup to ensure continuous operation in case of power outage.

Technology Limitations (e.g., operational temperature range, differences in materials):

The prototype detector can be operated in temperatures from -20 to +30°C. For an operational device, the temperature range can be further extended. The detector self-calibration process can correct for aging of scintillator materials by checking the detector response for cosmic muons; thus, 10 years of maintenance-free operation are expected.

Information Collected by the Technology (used to help determine if an information barrier is required for use):

The prototype detector collects information on the direction and energy of incoming neutrons. Using energy information, a rough estimate of the neutron energy spectrum can be made. Due to the detector's spatial resolution, information from the potential neutron coincidences also can be determined. If needed, the detector geometry can be modified so that information on the energy of the neutrons cannot be recorded.

Safety, Security, Deployment Concerns:

The detector does not contain toxic or flammable materials. The maximum voltage on the electric circuits inside the detector is less than 100 V.

Technology Development Stage (Technology Readiness Level, TRL):

TRL of the technology is 7. An advanced portable prototype detector has been build and tested in various environments. However, the technology has not been applied for nuclear disarmament verification.

Additional System Functionality (e.g., outside the monitoring use case):

The system can also record the precise neutron dose over a wide range of neutron energies.

Where/How the Technology Is Currently Used (e.g., international safeguards, border protection):

The technology is not in operational use, but it has applications both in nuclear security, including border protection, and in neutron dosimetry. The detector may also bring added value to safeguards.

Examples of Equipment:

https://nfacet.com/