

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 1: Nuclear Weapon removed from delivery system at the deployed site |
|----------------|----------------|---|--|--|--------------------------------------|--|--|--|
| | | | | | | | Assumptions --> | <i>High host security concerns are present. Initialization of an item could occur in Step 1 or later in Step 4. If initialization occurs in Step 1, what activities can be performed? Only very limited observation of host activities associated with removal of the item likely to be allowed by the inspectors. Note: Warhead is not containerized in Step 1.</i> |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Visual observations with managed access |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly—depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Not applicable |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly—depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Not applicable |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Not applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Not applicable |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Not applicable |

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|--------------------|---------------------------------------|---|---|--|--|--|---|--|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Not applicable |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | Applicable after item has been containerized and to establish CoC over other areas |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Not applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Not applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Not applicable |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | Not applicable |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Not applicable |

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|----------------------|---|---|--|---|---------------------------|------------------|---|--|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Not applicable |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Applicable |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable after item has been containerized. Apply unique identifier to item as soon as feasible. |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | Applicable |

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| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 2: Nuclear weapon in storage at the deployed site |
|---------------------|----------------|---|--|--|--------------------------------------|--|--|--|
| | | | | | | | Assumptions --> | <i>Storage location has ongoing host activities outside the declaration.</i> |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Applicable with managed access |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly—depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly—depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Applicable |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Applicable |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Not applicable |

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| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 2: Nuclear weapon in storage at the deployed site |
|--------------------|---------------------------------------|---|---|--|--|--|---|--|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Applicable |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | Applicable |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Not applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Applicable |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | Applicable |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Applicable |

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|----------------------|---|---|--|---|---------------------------|------------------|---|--|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Applicable |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | Not applicable |

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| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 3: Transport of nuclear weapon from deployed site to long term storage |
|----------------|----------------|---|--|--|--------------------------------------|---|--|---|
| | | | | | | | Assumptions --> | <i>All CoC applied in previous step would remain, except accelerometers. Extra seals-tags could be applied to the vehicle for extra confidence.</i> |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Applicable |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly--depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly--depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Not applicable |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Not applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Applicable |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Not applicable |

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| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 3: Transport of nuclear weapon from deployed site to long term storage |
|--------------------|---------------------------------------|---|---|--|--|--|---|--|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Applicable if S/N is appropriate |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | If already applied to container could be checked before and after movement to ensure not tampered with; could be applied to transportation vehicle |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Not applicable |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | Applicable (on vehicle door) |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Not applicable |

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| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 3: Transport of nuclear weapon from deployed site to long term storage |
|----------------------|---|---|--|---|---------------------------|------------------|---|---|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable to transport vehicle (tag remains on weapon) |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Not applicable |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable to transport vehicle (tag remains on weapon) |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | Not applicable |

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| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 4: Nuclear weapon in long term storage prior to dismantlement |
|----------------|----------------|---|--|--|--------------------------------------|--|--|--|
| | | | | | | | Assumptions --> | <i>High degree of security at site but would have a dedicated treaty monitoring storage. Long term is assumed to be on the order of years.</i> |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Applicable but possibly impractical for continuous monitoring |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly—depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly—depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Applicable |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Could be used at storage door entrance to monitor movement of radiation emitting devices into or out of the storage area |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Applicable |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Most likely not at this step |

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| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 4: Nuclear weapon in long term storage prior to dismantlement |
|--------------------|---------------------------------------|---|---|--|--|--|---|---|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Applicable in attended or unattended mode for continuous monitoring |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | Applied if not already in place; possibly applied to storage door as well as containers |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Applicable |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | Possibly applicable for monitoring equipment |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Applicable |

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| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 4: Nuclear weapon in long term storage prior to dismantlement |
|----------------------|---|---|--|---|---------------------------|------------------|---|--|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable if not already applied |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Applicable |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable if not already applied |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 5: Transport of nuclear weapon to dismantlement facility |
|----------------|----------------|---|--|--|--------------------------------------|--|--|---|
| | | | | | | | Assumptions --> | <i>All CoC applied in previous step would remain, except accelerometers. Extra seals-tags could be applied to the vehicle for extra confidence.</i> |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Applicable |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly—depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly—depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Not applicable |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Not applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Applicable |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Not applicable |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 5: Transport of nuclear weapon to dismantlement facility |
|--------------------|---------------------------------------|---|---|--|--|--|---|--|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Applicable if S/N is appropriate |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | If already applied to container could be checked before and after movement to ensure not tampered with; could be applied to transportation vehicle |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Not applicable |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | Applicable (on vehicle door) |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Not applicable |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 5: Transport of nuclear weapon to dismantlement facility |
|----------------------|---|---|--|---|---------------------------|------------------|---|---|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable to transport vehicle (tag remains on weapon) |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Not applicable |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable to transport vehicle (tag remains on weapon) |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | Not applicable |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 6: Initial storage at dismantlement facility |
|---------------------|----------------|---|--|--|--------------------------------------|--|--|--|
| | | | | | | | Assumptions --> | |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Applicable but possibly impractical for continuous monitoring |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly—depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly—depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Applicable |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Could be used at storage door entrance to monitor movement of radiation-emitting devices into or out of the storage area |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Applicable |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Most likely not at this step |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 6: Initial storage at dismantlement facility |
|--------------------|---------------------------------------|---|---|--|--|--|---|---|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Applicable in attended or unattended mode for continuous monitoring |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | Applied if not already in place; possibly applied to storage door as well as containers |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Applicable |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | Possibly applicable for monitoring equipment |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Applicable |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 6: Initial storage at dismantlement facility |
|----------------------|---|---|--|---|---------------------------|------------------|---|---|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable if not already applied |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Applicable |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable if not already applied |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 7: Movement of NED within dismantlement facility |
|---------------------|----------------|---|--|--|--------------------------------------|--|--|--|
| | | | | | | | Assumptions --> | |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Applicable depending on safety and security procedures |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly—depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable, but possibly not practical due to security concerns |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly—depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Applicable when used in a curtain configuration |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Applicable for monitoring; could be used in pairs to determine direction of movement |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Applicable; could be used to determine changes in movement |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Not applicable |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 7: Movement of NED within dismantlement facility |
|--------------------|---------------------------------------|---|---|--|--|--|---|--|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Applicable in unattended mode if on the container |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | If already applied to container could be checked before and after movement to ensure not tampered with; could be applied to transportation vehicle if some sort of enclosed chamber is used; could be applied on doors along a specified path in the facility to ensure detours were not taken |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Not applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Not applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Not as applicable for containment during this step. |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | If a TIE is designed for moving the NED, this could be applicable |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Applicable if container can be interrogated before and after move |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 7: Movement of NED within dismantlement facility |
|----------------------|---|---|--|---|---------------------------|------------------|---|---|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable to verify containerized NED before and after movement |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Applicable before and after movement to verify ID and ensure containment was not breached during movement |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable to verify unique ID on containerized NED before and after movement |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 8: Warhead dismantlement |
|---------------------|----------------|---|--|--|--------------------------------------|---|--|--|
| | | | | | | | Assumptions --> | |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Not applicable for inspectors |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly--depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable but fields of view must be selected to avoid capturing images of sensitive activities, equipment, or material; could be used to monitor door access |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly--depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Could be used in a curtain configuration to monitor access control (doors, vents, etc.) |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Could be used at door entrance to monitor movement of radiation-emitting devices into or out of the dismantlement area |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Not applicable |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Could be used to do total mass balance of containerized NED and other containers before and after dismantlement |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 8: Warhead dismantlement |
|--------------------|---------------------------------------|---|---|--|--|--|---|---|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Could be used in attended mode to check room before and after to ensure absence of radiation emitting material |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | TID for containerized NED should be broken at this point; TID should be applied to containerized components post dismantlement; could be used on facility equipment that should not be used |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Could be used for facility verification before and after dismantlement |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Could be used for facility verification before and after dismantlement |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Could be used on doors |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | Could be used for monitoring equipment |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Could be used for confirming the integrity of monitoring equipment |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 8: Warhead dismantlement |
|----------------------|---|---|--|---|---------------------------|------------------|---|---|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable to verify containerized NED just prior to dismantlement; could be applied to containerized components post-dismantlement |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Applicable to verify containerized NED just prior to dismantlement; could be applied to containerized components post-dismantlement |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable to verify containerized NED just prior to dismantlement; could be applied to containerized components post-dismantlement |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 9: Movement of components within dismantlement facility |
|---------------------|----------------|---|--|--|--------------------------------------|---|--|---|
| | | | | | | | Assumptions --> | |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Applicable depending on safety and security procedures (likely more restrictions with HE) |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly--depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable, but possibly not practical due to security concerns |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly--depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Applicable when used in a curtain configuration |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Applicable for monitoring presence or absence of SNM; could be used in pairs to determine direction of movement |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Applicable; could be used to determine changes in movement |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Not applicable |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 9: Movement of components within dismantlement facility |
|--------------------|---------------------------------------|---|---|--|--|--|---|--|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Applicable in unattended mode if on the SNM container |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | If already applied to container could be checked before and after movement to ensure not tampered with; could be applied to transportation vehicle if some sort of enclosed chamber is used; could be applied on doors along a specified path in the facility to ensure detours were not taken |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Not applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Not applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Not as applicable for containment during this step |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | If a TIE is designed for moving the containers, this could be applicable |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Applicable if container can be interrogated before and after move |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 9: Movement of components within dismantlement facility |
|----------------------|---|---|--|---|---------------------------|------------------|---|---|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable to verify containerized components before and after movement |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Applicable before and after movement to verify ID and ensure containment was not breached during movement |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable to verify unique ID on containerized components before and after movement |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 10: Storage of components (SNM and HE) at dismantlement facility |
|----------------|----------------|---|--|--|--------------------------------------|--|--|--|
| | | | | | | | Assumptions --> | <i>Is HE important to remain under CoC (per Phase I summary report it suggests in Step 10 that it is still needed)?</i> |
| Surveillance | Personnel | N/A | Inspector observing in person | Depends on the abilities of the person | Readily in use | N/A | Consider security implications (e.g., knowledge of route could be sensitive) | Applicable but possibly impractical for continuous monitoring |
| | Video | N/A | Video surveillance to capture all optical images | High effort (human/technology) required for the video review. Change detection algorithms are affected by ambient light and authorized movement. | Readily in use | Possibly—depends on the content of the image | Challenge to screen through surveillance; best when paired with a trigger system. Consider security implications. | Applicable |
| | 3D | CoC3: 3D Surveillance | Realtime 3D camera that provides distance measurements complementary to video system | The resolution is lower than static 3D scanner or video imagery | Readily in use | Possibly—depends on the content of the image | Possible to use as a trigger for surveillance system. Consider security implications. | Applicable |
| | Portal Monitor | CoC5: Radiation Detection | Non-spectroscopic radiation portal monitor used to detect movement of radiation emitting device into or out of an area | Shielding will affect the measurement; susceptible to background levels | Readily in use | No (as long as no information is retained) | Could be used to confirm presence of radiation emitting device and can act as a trigger for other surveillance systems. No IB is needed for system with limited functionality. Consider security and practical implications. | Could be used at SNM storage door for entrance to monitor movement of radiation emitting devices into or out of the storage area |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of container; if it cannot be applied to a container it could be applied to mechanical structures. Consider security implications (e.g., knowledge of route could be considered sensitive). | Applicable |
| | Scale | N/A | Can be used for total material balance to detect diversion of material | Should not be used to determine mass of NED or SNM or containers themselves | Readily available (9) | Yes? | May also be used to identify a container type based on gross weight | Most likely not at this step |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 10: Storage of components (SNM and HE) at dismantlement facility |
|----------------|---------------------------------------|---|---|--|--|--|---|---|
| | Radiation Detection | CoC5: Radiation Detection | Monitoring system (attended or unattended) that performs qualitative measurements of gamma and neutron counting to indicate movement or presence of a radiation emitting device | Shielding and room configuration will affect the measurement; susceptible to background levels; sensitive to peak drifts over time/temperature | Yes | No | Primarily for storage area(s) in close proximity to item(s). Consider security and practical implications. | Applicable in attended or unattended mode for continuous monitoring in SNM storage room |
| Containment | Tamper Indicating Devices (TID)/Seals | CoC6: Tamper-indicating Seals and Enclosures | Various devices that can be used to indicate if a container or room has been opened or tampered with | Containers need to be conducive to application of a seal or tamper indicating device | Yes (9) | No | Examples include adhesive and loop seals/TIDs | Possibly applied to storage door as well as containers |
| | 3D Laser Change Detection System | CoC1: 3D Facility Verification and Change Detection | 3D laser system used to measure a room that enables inspector to identify changes between two inspections in the 3D geometry of a facility and the installed equipment | The detection limit is approximately 1mm | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection. Consider security implications. | Applicable |
| | Optical Change Detection Systems | CoC8: Optical Change Detection | Optical system used to detect changes in configuration between two inspections | Changes in lighting may trigger a configuration change determination; detection limit is variable depending on camera characteristics and lighting, typically less accurate than the 3D laser system | Readily available (9) | Possibly—depends on the content of the image | Can be used to verify design information, verify the absence of undeclared changes, detect movement of containers, and for containment verification; could be a fixed system that remains installed or portable system that is brought in for each inspection | Applicable |
| | Accelerometers | CoC4: Accelerometers | Sensors that can indicate whether or not an object of interest has moved; can provide continuous monitoring and triggering | Battery lifetime (can run for years but not indefinitely) | Readily in use in other applications | No | Could be applied to the outside of the container to monitor movement of a container; if it cannot be applied to a container it could be applied to mechanical structures | Applicable |
| | Tamper Indicating Enclosure (TIE) | CoC6: Tamper-indicating Seals and Enclosures | TIE can be used if sealing a container isn't possible or is not considered to be sufficient enough. Few systems exist, but specific TIEs could be developed. | Needs to be designed to the specific requirements | Requires specific development for possible application (7–8) | No | Potential technologies are laser verification of enclosure, active electrical mesh, under pressure monitored enclosure, special coating, etc. | Possibly applicable for monitoring equipment |
| | Container Integrity Assessment | CoC7: Container Integrity Assessment | Technologies to establish and to maintain confidence in the integrity of containers; categories include acoustic, electromagnetic, and optical | Considered active as they need to interact with the container as part of a measurement. May need to come into contact with the container. | In use for other applications, may require adaptations (7–9) | No | Can be used to monitor warhead and warhead component containers as well as monitoring equipment enclosures | Applicable |

IPNDV WG6 Chain of Custody Technologies Mapping Table

| Technical Area | Technology | Related Technology Paper | Description | Key Limitations | Equip Availability (TRL?) | IB Needed (TRL?) | Comments | Step 10: Storage of components (SNM and HE) at dismantlement facility |
|----------------------|---|---|--|---|---------------------------|------------------|---|---|
| Identification | Radiation-hardened Radiofrequency Identification (RFID) | CoC9: Radio Frequency Identification | Devices that can be used to assign a unique ID to a container using radiofrequencies; RFID-based devices range from very simple, passive systems to complex, active systems integrating other sensor information | Active systems are battery powered and have a limited lifetime. Active systems would have to meet safety and security requirements. Information security/authentication is an issue for simple systems. | 9 | No | If combined with other sensors, it can also be used for tamper indication (e.g., ARG-US RFID) | Applicable |
| | 3D Container Identification | CoC2: 3D Identification and Containment | Laser system that performs a high-accuracy 3D measurement of the unique surface structure of a container to fingerprint and identify the item | The item requires a unique surface geometry (e.g., a weld surface) with variations on the micrometer scale | 7-8 | No | Depending on the scenario, can be used for identification, authentication, and tamper indication. Each use case requires specific development. TRL needs to be evaluated according to the specific application. | Applicable |
| | Tagging (Unique Identifier) | CoC10: Unique Identifiers | Any visual identifier (e.g., bar code, QR code, ID number, reflective particle tag) that can be read visually or by an electronic reader | Should not be used on its own for authentication | 9 | No | Tags are simple and fast to apply and read. They can be complemented with another technology (e.g., weld identification, TID) for authentication. | Applicable |
| Absence Measurements | Radiation Detection | | Sweeping to establish CoC | Sensitivity of the detector must be checked and adequate for the CoC requirements | 9 | No | | |