Pacific Northwest
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MRP Microreactor Program

PNNL-38272

Final Prototype Microreactor Transportation Safety Program

September 2025

Steven J. Maheras
Shane A. Foss
Steven D. Bauman
Michael D. Steele

U.S. DEPARTMENT of ENERGY

Prepared for the U.S. Department of Energy
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Richland, Washington 99354

Summary

This report fulfills the fiscal year 2025 M2 Milestone M2AT-25PN0802042, Final Microreactor Transportation Safety Program Planning Framework.

Microreactors are compact reactors capable of producing less than 50 megawatts of electrical energy. Typically, these reactors are factory-fabricated and designed to be easily transportable by truck, rail, vessel, or air. Microreactor designs often assume that the unit can be transported containing either unirradiated or irradiated fuel. Interest in microreactors is driven by several factors, including the need to generate power at remote locations, military installations, and facilities such as data centers, and in areas recovering from natural disasters.

The U.S. Department of Defense is actively pursuing the microreactor concept to meet the increasing energy demands of military operations that require portable and dense power sources. Commercial vendors are also exploring microreactor concepts.

The report *Microreactor Transportation Emergency Planning Challenges*[1] outlined the emergency planning challenges associated with the transportation of microreactors by road, rail, and by barge/ship. The successful commercial deployment and redeployment of microreactors will also require the development of microreactor transportation safety programs. The elements in these transportation safety programs are not specific to microreactors; however, the transport of microreactors may pose unique challenges in these areas.

This report builds on the *Microreactor Transportation Emergency Planning Challenges* report and develops a prototype microreactor transportation safety program that describes the elements that should be contained in vendor-developed microreactor transportation safety programs, identifying the unique elements associated with microreactor transport. This will provide vendors and their transportation contractors with a basis for transportation planning and accelerate the commercial deployment and redeployment of microreactors by identifying issues unique to microreactor transport.

The emphasis of this report is on highway transport of microreactors. This is based on a transportation package approval strategy of crawl-walk-run, where transport by highway is

[1] Maheras S.J., S.A. Foss, R.E. Reed, C.A. Condon, and T.R. Hay. *Microreactor Transportation Emergency Planning Challenges*. PNNL-34816, Rev.1. Pacific Northwest National Laboratory, Richland, WA. September (2024).

evaluated first,[1,2,3] then other surface modes (rail and barge/ship), and finally air transport. Evaluation of maritime transport of microreactors was recently initiated.[4,5]

This report first discusses microreactors in general and planning assumptions for a microreactor transportation safety program. The report then describes the transportation safety planning process and provides an extensive discussion of the elements of transportation safety programs. Specific elements examined included transportation roles and responsibilities, transportation planning, transportation mode and route selection, carrier selection, transportation packaging, advance notification of shipments and shipment tracking, public information and communications, emergency response plans and procedures, inspections, security, safe parking, weather and road conditions, medical preparedness, training and exercises, and program evaluation.

The report then identifies the unique elements of a transportation safety program associated with microreactor transport. These unique elements were in the areas of the unusual nature of microreactor designs, compensatory measures, increased radiation dose rates in the vicinity of microreactors, transportation package approval versus 10 CFR 50.59, the use of a risk-informed approval process for transportation packages, and the prevention of criticality.

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[1] Coles, G., S. Short, S. Maheras, and H. Adkins. *Proposed Risk-Informed Regulatory Framework for Approval of Microreactor Transportation Packages*. PNNL-31867. Pacific Northwest National Laboratory, Richland, WA, August (2021).
[2] Coles G.A., T.A. Ikenberry, S.M. Short, M.S. Taylor, H.E. Adkins, Jr., P.P. Lowry, C.A. Condon, S.J. Maheras, and J.R. Phillips*. Development and Demonstration of a Risk Assessment Approach for Approval of a Transportation Package of a Transportable Nuclear Power Plant for Domestic Highway Shipment*. PNNL-36380, Rev. 1. Pacific Northwest National Laboratory, Richland, WA. August (2024).
[3] Maheras S.J., G.A. Coles, J.R. Phillips, C.A. Condon, S.M. Short, H.E. Adkins Jr., P.P. Lowry, and K. Banerjee. *Plan for Development and Application of Risk Assessment Approach for Transportation Package Approval of an MNPP for Domestic Highway Shipment*. PNNL-33524. Pacific Northwest National Laboratory, Richland, WA. December (2021).
[4] Rigato A.B., H.E. Adkins, Jr, S.M. Short, S.J. Maheras, and G.A. Coles. *Plan for the Development and Application of a Risk Assessment Approach for Transportation Package Approval of a Transportable Nuclear Power Plant for Maritime Shipment*. PNNL-34962, Rev. 1. Pacific Northwest National Laboratory, Richland, WA. January (2024).
[5] Maheras S.J., H.E. Adkins Jr, G.A. Coles, S.M. Short, V. Peoples, and A.B. Rigato. "Adaption of a Highway Risk-Informed Transportation Package Approval Process for Microreactors to Maritime Transport." In Waste Management Symposium 2025, March 9-13, 2025, Phoenix, Arizona. PNNL-SA-207374 (2025).

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Acronyms and Abbreviations

AAR	Association of American Railroads
CBFO	U.S. Department of Energy Carlsbad Field Office
CSG	Council of State Governments
CVSA	Commercial Vehicle Safety Alliance
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DUI	driving under the influence
DWI	driving while intoxicated
FRA	Federal Railroad Administration
HRCQ	highway route controlled quantity
MERRTT	Modular Emergency Response Radiological Transportation Training
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PIG	Program Implementation Guide
SCCOP	Safety Coordination and Compliance Oversight Plan
STEP	States and Tribal Education Program
TEPP	Transportation Emergency Preparedness Program
TRU	transuranic
WEP	WIPP Education Program
WIPP	Waste Isolation Pilot Plant

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1.0 Introduction

Microreactors are compact reactors capable of producing less than 50 megawatts of electrical energy. Typically, these reactors are factory-fabricated and designed to be easily transportable by truck, rail, vessel, or air. Microreactor designs often assume that the unit can be transported containing either unirradiated or irradiated fuel. Interest in microreactors is driven by several factors, including the need to generate power at remote locations, military installations, facilities such as data centers, and in areas recovering from natural disasters.

The U.S. Department of Defense (DOD) is actively pursuing the microreactor concept to meet the increasing energy demands of military operations that require portable and dense power sources. Commercial vendors are also exploring microreactor concepts.

The report *Microreactor Transportation Emergency Planning Challenges* (Maheras et al. 2024) outlines the emergency planning challenges associated with the transportation of microreactors by road, rail, and by barge/ship. The successful commercial deployment and redeployment of microreactors will also require the development of microreactor transportation safety programs. The elements in these transportation safety programs are not specific to microreactors; however, the transport of microreactors may pose unique challenges in these areas.

This report builds on the Maheras et al. (2024) report and develops the elements of a prototype microreactor transportation safety program that describes the elements that should be included in vendor-developed microreactor transportation safety programs, identifying the unique elements associated with microreactor transport. This will provide vendors and their transportation contractors with a basis for transportation planning and will accelerate the commercial deployment and redeployment of microreactors by identifying issues unique to microreactor transport.

The emphasis of this report is on highway transport of microreactors. This is based on a strategy for transportation package approval of crawl-walk-run, where transport by highway is evaluated first (Coles et al. 2021, 2024; Maheras et al. 2021), then other surface modes (rail and barge/ship), and finally air transport. Evaluation of maritime transport of microreactors was recently initiated (Rigato et al. 2024; Maheras et al. 2025).

Many of the elements described in this report are based on the Waste Isolation Pilot Plant (WIPP) Transportation Safety Program and are contained in two reports: the *WIPP Transportation Safety Program Implementation Guide*[1] (WGA 2017) and the *TRU Waste Transportation Plan* (CBFO 2022).[2] The elements in the *Planning Guide for Shipments of Radioactive Material through the Midwestern States* (CSG Midwest 2023) and the *Southern States Energy Board Transportation Planning Guide for the U.S. Department of Energy's Shipments of Transuranic Waste* (SSEB 2014) were also considered, as well as previously issued planning documents from the U.S. Department of Energy (DOE), such as the *National Transportation Plan* (OCRWM 2009), the *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions* (OCRWM 2003), and the *Program Manager's Guide to Transportation Planning* (DOE 1998).

[1] This document is colloquially known as the "WIPP PIG."

[2] The U.S. Department of Energy Carlsbad Field Office is referred to as CBFO throughout this report.

2.0 Planning Assumptions for Microreactor Transportation Safety Program

To establish a process for developing an effective microreactor transportation safety program, several key assumptions have been made:

- **Regulation.** It is expected that the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Transportation (DOT) will have regulatory oversight of the transport of microreactors (Coles et al. 2021).
- **Transportation modes**. Transportation of microreactors will occur via highway, rail, and vessel (ship or barge). Air transport of microreactors is beyond the scope of this report.
- **Commercial shipments**. Microreactor shipments will be commercial radioactive material shipments between NRC licensees and will comply with NRC regulation 10 CFR Part 71 and DOT Hazardous Materials Regulations (49 CFR Part 171-180).
- **Risk-informed regulatory framework**. Approval of transportation packages by the NRC will follow a risk-informed process. Coles et al. (2021, 2024) and Maheras et al. (2021) outline this approach.
- **Deterministic requirements**. Using a risk-informed approval process for transportation packages may result in microreactors containing unirradiated or irradiated fuel not meeting the deterministic requirements of 10 CFR Part 71. Additionally, they may not meet the dose rate limit of 10 mrem/h at 2 meters from the conveyance as specified in 49 CFR 173.441 and 10 CFR 71.47.
- **Security requirements**. The microreactor shipments will be subject to security requirements outlined in 10 CFR Part 73, including the need for physical protection of irradiated reactor fuel in transit and NRC approval of transport routes (NRC 2013).
- **Advance notification**. States and Tribes will receive advance notification of microreactor shipments, as required by 10 CFR 71.97.
- **Radionuclide inventory**. The microreactor containing its irradiated fuel would contain a highway route controlled quantity (HRCQ) of radioactive material (i.e., > 3000 A_2).
  - For truck shipments, this means that a Commercial Vehicle Safety Alliance (CVSA) Level VI inspection and safety permit would be required (see 49 CFR Part 385 and 49 CFR Part 397).
  - For rail shipments, this means that the transportation planning requirements in 49 CFR 172.820 would apply.
  - A microreactor containing its unirradiated (fresh) fuel would contain fissile material but would not contain an HRCQ of radioactive material.
- **Fuel type**. The microreactor will be fueled by low-enriched uranium or high-assay low-enriched uranium.[1]
- **Deployment and cooling**. Upon arrival at the deployment site, the microreactor will be fully utilized. It will then be stored for a period to reduce radiation dose rates and allow cooling prior to transport.

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[1] Low-enriched uranium is uranium enriched to less than five percent. High-assay low-enriched uranium has enrichments that range from 5 to 20 percent.

- **Rail transport**. For rail shipments, microreactors containing their irradiated fuel will be transported using Association of American Railroads (AAR) Standard S 2043 railcars (AAR 2024). The Federal Railroad Administration (FRA) would provide oversight of microreactor shipments using the *Safety Coordination and Compliance Oversight Plan for Rail Transportation of High-Level Radioactive Waste and Spent-Nuclear Fuel*[1] (FRA 2023). Microreactors containing their unirradiated fuel would not be required to use railcars that meet AAR Standard S-2043.

These planning assumptions provide a framework for the development of a prototype microreactor transportation safety program.

[1] This document is colloquially known as the "SCCOP."

3.0 Transportation Safety Planning Process

The transportation safety planning process is a structured approach that begins with stakeholder agreement and collaboration to ensure all relevant parties are involved. It ensures regulatory compliance and defines the purpose, scope, and objectives of the plan. A thorough risk assessment is conducted to identify and prioritize potential hazards, followed by the development and implementation of strategies and actions to mitigate these risks. The plan is then validated and approved by the appropriate authorities. Finally, the implemented measures are continuously monitored and evaluated to ensure their effectiveness and guide further improvements.

3.1 Stakeholder Agreement/Collaboration

The stakeholder agreement and collaboration phase is crucial for the transportation safety planning process. It involves key steps to ensure a cohesive and well-supported safety plan:

- **Establish a safety planning community of interest or working groups**. This involves bringing together relevant stakeholders, such as regulatory bodies, microreactor manufacturers, transportation and shipping entities, security and response agencies, and other pertinent parties. The goal is to create a diverse and knowledgeable group that can contribute valuable insights and expertise to the safety planning process.
- **Develop and secure agreements or endorsements from stakeholders**. The working group collaborates to develop and secure agreements on the appropriate objectives, scope, and approach of the transportation safety plan. This step ensures that all stakeholders have a shared understanding and commitment to the safety plan, which enhances its legitimacy and effectiveness. It may involve formalizing agreements through memorandums of understanding or other binding documents to confirm each party's responsibilities and contributions.
- **Define an organizational structure with clear communication channels**. An organizational structure is established to outline roles, responsibilities, and hierarchies within the working group. Clear communication channels are defined to facilitate efficient and transparent collaboration among stakeholders throughout the planning process. Regular meetings, progress reports, and communication platforms (such as project management tools) are put in place to ensure continuous information flow and decision-making.

By thoroughly addressing these steps, the stakeholder agreement and collaboration phase ensures a well-rounded and supported transportation safety plan, with all relevant parties actively contributing to and endorsing the objectives and strategies.

3.2 Regulatory Compliance

Table 1 lists potentially applicable federal transportation regulatory requirements for microreactor shipments. However, microreactor technology is advancing rapidly and it is crucial to establish a realistic, forward-thinking regulatory framework that can evolve alongside advancements in microreactor technology. Incorporating forward-thinking regulatory compliance into safety planning can ensure that standards are met to achieve robust safety measures.

Regulatory oversight should consider the following to ensure the safe design, transportation, and operation of microreactors.

- Regulations should provide a comprehensive framework for all phases of the microreactor lifecycle.
- These regulations will serve as a set of standards guiding technology development and operational planning.
- Regulations will ensure a consistent approach to risk assessment methodologies and practices, facilitating thorough evaluation of hazards and mitigation strategies.
- Regulations will define necessary qualifications and training standards for safety and critical operations.
- Regulations will enable comprehensive emergency response planning, including the integration of drills and exercises.
- These regulations will support continuous programmatic monitoring, documentation, and regulatory compliance reviews.

In the area of transportation package approvals, there are two options for demonstrating regulatory compliance:

- Demonstrating compliance with the transportation package requirements in 10 CFR Part 71 with no deviations or modifications. This is the current approach used for transportation packages containing fissile material and Type B quantities of radioactive material.

- Demonstrating compliance using a risk-informed transportation package approval process as outlined in Coles et al. (2021, 2024) and Maheras et al. (2021) for transporting a microreactor containing its unirradiated or irradiated fuel. This may involve a 10 CFR 71.12 exemption or alternate environmental and test conditions [see 10 CFR 71.41(c)]. Using this option, it is possible that many of the transportation package requirements in 10 CFR Part 71 would be met, and that an exemption or alternate environmental and test conditions would be needed in specific areas. It is also possible that as microreactor designs mature, a risk-informed process for transportation package approval may not be necessary to demonstrate compliance with 10 CFR Part 71.

Table 1. Potentially Applicable Transportation Regulatory Requirements

Document	Regulation
Title 10 Code of Federal Regulations	Part 71 – Packaging and Transportation of Radioactive Material Part 73 – Physical Protection of Plants and Materials
Title 49 Code of Federal Regulations	Part 107 – Hazardous Materials Program Procedures Part 171 – Hazardous Material Regulations, General Information, Regulations, Definitions Part 172 – Hazardous Materials Table, Special Provisions, Hazardous Materials Communications and Emergency Response Information, Training Requirements and Security Plans Part 173 – Shippers-General Requirements for Shipments and Packaging Part 174 – Carriage by Rail Part 175 – Carriage by Aircraft Part 176 – Carriage by Vessel Part 177 – Carriage by Public Highway Part 365 – Rules Governing Applications for Operating Authority Part 382 – Controlled Substances and Alcohol Use and Testing Part 383 – Commercial Driver's License Standard; Requirements and Penalties Part 385 – Safety Fitness Procedures Part 386 – Rules of Practice for Motor Carrier Intermodal Equipment Provider, Broker, Freight Forwarder and Hazardous Material Proceedings Part 387 – Minimum Levels of Financial Responsibility for Motor Carriers Part 390 – Federal Motor Carrier Safety Regulations Part 391 – Qualifications of Drivers and Longer Combination Vehicle (LCV) Driver Instructors Part 392 – Driving of Commercial Motor Vehicles Part 393 – Parts and Accessories for Safe Operation Part 395 – Hours of Service of Drivers Part 396 – Inspection, Repair, and Maintenance Part 397 – Transportation of Hazardous Materials, Driving and Parking Rules Part 399 – Employee Safety and Health Standards

Source: CBFO (2022).
Title 10 regulations available at https://www.govinfo.gov/app/collection/cfr/2025/
Title 49 regulations available at https://www.govinfo.gov/app/collection/cfr/2024/

3.3 Risk Assessment Process

The risk assessment process involves two primary methodologies: probabilistic risk assessment and traditional risk assessment. NRC uses probabilistic risk assessment, a systematic and comprehensive method that employs probabilistic techniques to estimate the likelihood and consequences of different failure scenarios associated with complex systems. In contrast, traditional risk assessment adopts a more qualitative approach, focusing on identifying hazards, evaluating likelihood and impact, and developing mitigation strategies.

Traditional risk assessment relies more heavily on expert judgment than on quantitative data. This approach is particularly useful for evaluating potential risks associated with the transportation of microreactor systems. It aims to ensure the safety of transporters, operators, and the public. The process involves several stages: hazard identification, risk analysis, risk evaluation, risk control, documentation and reporting, and review and update.

Identifying hazards is critical to ensuring the safe transportation of a microreactor. Hazard identification involves a thorough assessment of potential impacts on shipment routes, focusing on avoiding choke points, narrow bridges, tunnels with height restrictions, roads with weight restrictions, and other unsuitable conditions. Routes need to be evaluated for characteristics that minimize sharp turns and steep grades, ensuring wide and clear paths for the transport vehicle. Essential factors include identifying road conditions such as quality, traffic density, construction zones, detours, and closures, all of which can impact vehicle operations.

Routine maintenance of the transport vehicle, coupled with advanced vehicle safety monitoring, ensures vehicle integrity and optimal performance. Ensuring the microreactor remains stable and immobile during transit involves advanced securing mechanisms and anti-tamper technology to protect against sabotage or theft. Human factors also play a significant role; this includes assessing operator qualifications and ability to handle specific transportation challenges, monitoring driving behavior, adhering to laws, and assessing for fatigue, distraction, and sufficient knowledge of response procedures.

Risk analysis involves a systematic process designed to identify, evaluate, and assess potential risks using historical data and predictive models. The primary objectives of this analysis are to determine the likelihood of an occurrence and to understand the hazard's impact. The likelihood, also known as the probability or frequency, refers to the chance that a specific hazard event will occur. By analyzing historical data, it is possible to refine route selection based on particular dates or times related to traffic congestion or closures, for instance. Another crucial element of risk analysis is evaluating the hazard's impact, which describes the severity or consequences of an event. These impacts can be direct, such as physical damage to a microreactor that leads to operational malfunctions or radiation protection vulnerabilities, or indirect, such as environmental contamination, public exposure to radiation, and economic loss. This comprehensive approach ensures that all potential risks are thoroughly analyzed and assessed.

3.4 Risk Evaluation

Risk evaluation is the process of determining the significance of identified risks and prioritizing them for the development of mitigation strategies or actions. This process is influenced by factors such as organizational standards, regulatory requirements, and stakeholder input. Risk evaluation involves comparing identified risks against established criteria to make informed decisions about which risks require immediate action and which can be accepted or monitored for changes in probability.

Typically, risk evaluation uses a matrix (see Figure 1), with axes illustrating the likelihood and consequences of a hazard. This tool provides a visual understanding of the likelihood and impacts identified during the risk identification and assessment process. The matrix categorizes risks into different levels—low, moderate, high, and extreme—based on their likelihood and consequence. By classifying risks using such a matrix, hazards can be systematically prioritized. Risks with both high likelihood of occurrence and high severity of consequences are given top priority, ensuring that focused attention and resources are directed toward the most significant threats.

		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Figure 1. Risk Evaluation Matrix

3.5 Risk Control

Risk control involves developing and implementing strategies to mitigate identified and prioritized risks. These risk mitigation strategies consist of preventive measures designed to reduce the likelihood and/or impact of the identified risks, targeting aspects related to people, operations, and the environment. Such strategies may be prescriptive or flexible, depending on recommendations from experienced practitioners. Risk mitigation measures can include technical solutions, training programs, policy changes, and other methods aimed at managing risk. Once selected, these measures are implemented and subsequently monitored or evaluated to ensure their effectiveness in reducing risk and to identify areas for further improvement.

4.0 Elements of Transportation Safety Programs

This section describes the potential elements of a transportation safety program. These elements are shown in Figure 2. Not all elements shown in Figure 2 would apply to all transport modes. In addition, the elements of a microreactor transportation safety program as described in this section would be expected to have similar requirements for elements as the process used by WIPP.

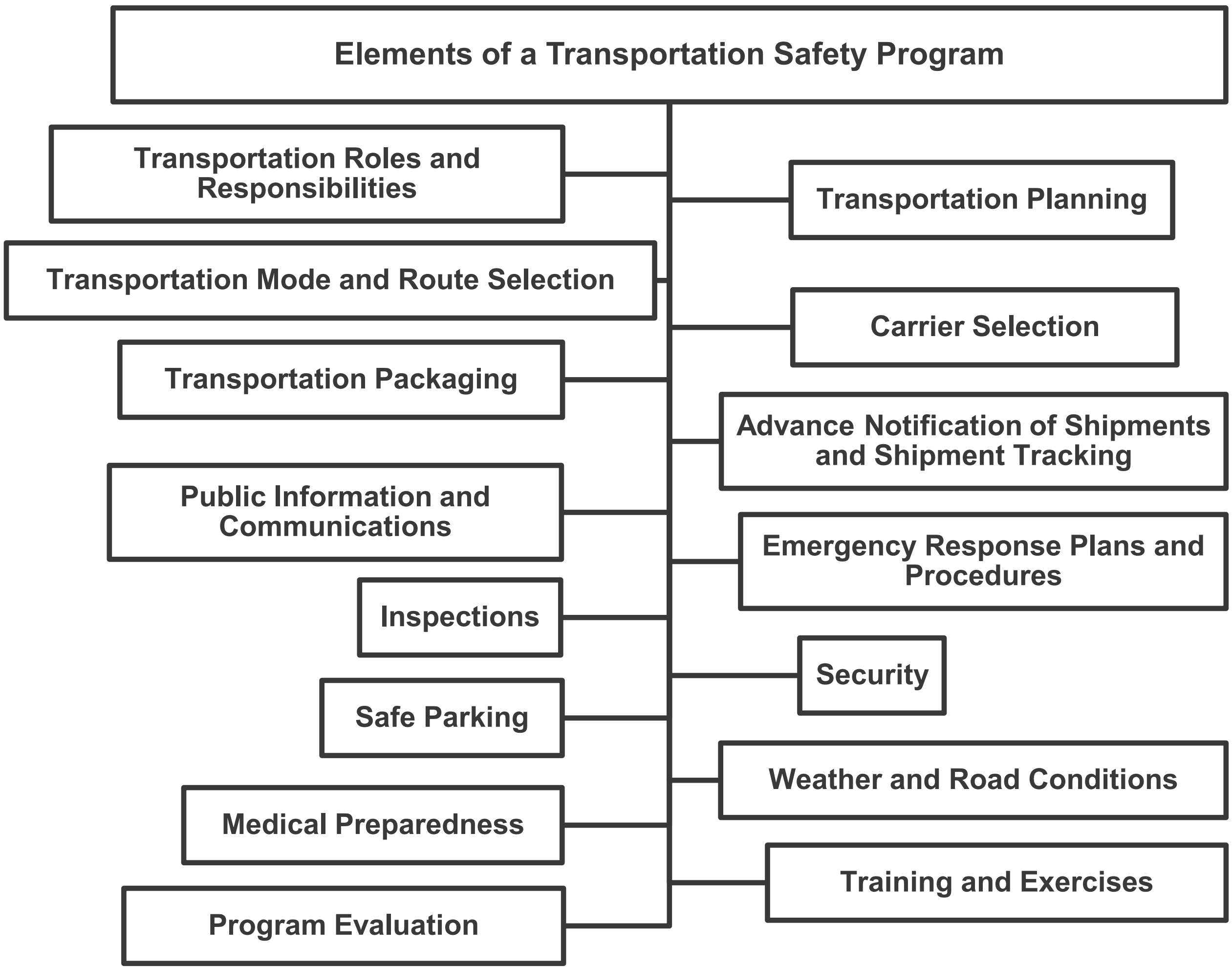

Figure 2. Elements of a Transportation Safety Program

4.1 Transportation Roles and Responsibilities

This element should define the roles and responsibilities of the entities involved in the microreactor transport safety process. Potential entities include:

- Microreactor vendors
- Utilities
- Microreactor shippers and freight forwarders/shipping agents

- Carriers
- States and Tribes
- NRC and the DOT
- U.S. Coast Guard (for shipments by barge or ship)
- Other federal agencies as applicable

Additional entities may be involved in the security process for microreactor transport.

4.2 Transportation Planning

This element should establish the timeline for the transportation planning process so that an entity acquiring a microreactor has confidence that unirradiated fuel can be shipped to the deployment site and that irradiated fuel can be shipped from the deployment site in a timely fashion.

Table 2 presents the timeline recommended by the Council of State Governments (CSG) Midwest for transportation planning. For new shipping campaigns or previously unused routes, the CSG Midwest recommends that transportation planning begin 2 years before shipments are made. Given the unique aspects of microreactor shipments, transportation planners may want to consider extending this period to 3 or more years.

Table 2. Recommended Transportation Planning Timeline

Time before Shipment	Action
2 years	For new campaigns or shipments over previously unused routes, shippers should begin the transportation planning process.
1 year	For shipping campaigns involving spent nuclear fuel, high-level radioactive waste, or transuranic (TRU) waste, the shipper should present a proposed route or routes to the affected states for their consideration.
6 months	For shipments of spent nuclear fuel and high-level radioactive waste, a final transportation plan should be in place.
8 weeks	For TRU waste, DOE will ensure that a rolling projection of shipments is sent via e-mail to the affected states and CSG Midwest.
45 days	For long shipping campaigns (i.e., longer than 1 year), the shipper should provide the carrier's draft management plan to the corridor states for their review and comment.
2 weeks	For all shipping campaigns, a final transportation plan, reviewed by the corridor states, should be in place.
2 weeks	Shippers will achieve all objectives in NRC regulation 10 CFR 73.37 or 10 CFR 37.75, as applicable.

Source: CSG Midwest (2023)

4.3 Transportation Mode and Route Selection

This element should establish the process used to select transportation modes and routes. The choice of transportation mode would largely be driven by accessibility and the dimensions and weight of the microreactor shipment. The choice of transportation route would largely be driven by regulations (e.g., 49 CFR 397.101 and 49 CFR 397.103 or 49 CFR 172.820), the dimensions and weight of the microreactor shipment, and the capacity of the transportation infrastructure.

In the U.S., microreactor shipments would typically be made by highway or rail, although barge/vessel may be useful for some destinations, and air transport may be useful for shipments to remote locations or when transporting a microreactor overseas. Air transport would probably be limited to microreactors containing their unirradiated or slightly irradiated fuel.

DOT regulation 49 CFR 397 Subpart D contains routing requirements for Class 7 shipments of radioactive material. This regulation would cover both unirradiated and slightly irradiated microreactor shipments and microreactor shipments containing an HRCQ of radioactive materials that would be representative of a microreactor after being operated.

In general, microreactor shipments containing an HRCQ of radioactive materials would be transported on preferred routes, which typically consist of interstate highways and bypasses and beltways around cities. States can also designate preferred routes. If a microreactor shipment is overweight or overdimension, additional state permitting requirements would apply.

Routing requirements for transporting highway-route-controlled quantities of radioactive material by rail are contained in 49 CFR 172.820 (colloquially known as the Rail Routing Rule).

4.4 Carrier Selection

This element should establish the processes used to select and evaluate carriers. Carrier contractors are required to comply with applicable federal, state, Tribal, and local laws and regulations, including obtaining, maintaining, and payment of applicable licenses, permits, fees, and standards necessary to transport microreactor shipments over the selected routes. The subsections below describe the carrier selection process used at the WIPP from CBFO (2022). The elements of a microreactor transportation safety program would be expected to have similar requirements for carrier selection as the process used by WIPP.

4.4.1 WIPP Carrier Selection

CBFO (2022) requires that the WIPP carrier contractor comply with the following:

- Carriers must comply with the TRU Waste Transportation Plan (CBFO 2022).
- Motor carriers, including the carrier contractor, shall possess the required operational authority per 49 CFR Part 365, registered in the name of the carrier contractor.
- All tractors must be registered to the carrier contractor.
- Each commercial motor vehicle operator must be employed by the carrier contractor.
- Motor carriers must possess and maintain minimum levels of financial responsibility as required by 49 CFR Part 387[1]

4.4.2 WIPP Equipment Specifications

For equipment specifications, CBFO (2022) requires the following:

[1] Available at https://www.govinfo.gov/app/collection/cfr/2024/

- The overall length, width, height, and weight of tractor and trailer shall meet state dimensional requirements.
- The tractor shall have sufficient horsepower to maintain the speed limit on a 3 percent upgrade with a maximum load.
- The tractor shall be governed to a maximum speed limit of 65 miles per hour.
- All tractors shall be equipped with safety equipment (including fire extinguishers, first aid kit, triangles, etc.), tire chains/cables, and any other equipment required by federal or state law.
- All tractors shall be equipped with the following communications equipment:
  - A cellular telephone
  - A 40-channel, 2-way citizens band radio
  - TRANSCOM tracking[1] and communications equipment
  - Panic button
- All tractors shall be equipped with a current technology, five-range, digital or analog survey meter equipped with two detectors (a Geiger-Mueller open and closed window detector for beta-gamma radiation from 0.001 millisieverts per hour [0.1 mrem/h] to 2 millisieverts per hour [200 mrem/h], and an open window pancake detector to detect alpha-beta-gamma radiation at a level of 0 to 5,000 counts per minute).
- Each tractor shall be equipped with a mounted onboard video system to record and monitor events in front of the tractor.
- All tractors shall be equipped with anti-lock brakes, power steering, sleeper, air-ride suspension, parking brakes on both rear axles, mud-flaps with spray guards on both front and rear wheels, auxiliary braking system (“Jake brakes”), and a low- profile, heavy-duty sliding fifth wheel.
- All tractors shall be equipped with a go/no-go gauge for use on the contact-handled TRU waste packaging tie-downs.

4.4.3 WIPP Equipment Maintenance

For equipment maintenance, CBFO (2022) requires the following:

- Carrier contractor shall provide all required tractor and trailer maintenance in accordance with the manufacturer's recommended maintenance and the CVSA Enhanced North American Standard Inspection requirements. Carrier contractor management plans shall address the following maintenance areas:
  - Pre- and post-trip inspections to the CVSA Enhanced North American Standard Level VI Inspection criteria.
  - A specific maintenance procedure and schedule for each trailer type and each tractor model.
  - Verifiable maintenance and inspection records on each tractor and trailer.

[1] TRANSCOM tracking is available for DOE shipments. Commercial shipments would likely use an alternative system.

- Replacing tractors within 8 hours while en route with a loaded shipment. Replacement tractors shall meet the carrier contract's requirements of no defects after a Level VI inspection before being placed in service.

4.4.4 WIPP Carrier Inspections and Out-of-Service Criteria

For inspections and out-of-service criteria, CBFO (2022) requires the following:

- State agencies shall perform point-of-origin inspections using the CVSA Enhanced North American Standard Level VI Inspection criteria; Tribes may also participate. State agencies may also perform inspections at the point of entry into their state. State agencies may perform additional inspections en route.
- Vehicle, drivers, and cargo must be "defect free" by the CVSA Enhanced North American Standard Inspection criteria before they leave the point of origin. While en route, the vehicle, drivers, and cargo remain subject to these same criteria.
- The CVSA developed a special nuclear symbol decal for vehicles meeting the enhanced inspection criteria. The decal is affixed at the successful completion of a Level VI inspection and removed at the destination. It is valid for only one trip, as long as the tractor and trailer have not been disconnected.

4.4.5 WIPP Driver Qualifications

CBFO (2022) specifies the following driver qualifications:

- The carrier contractor shall provide drivers who meet the DOT licensing, training, and physical qualification requirements. Drivers must also meet the following criteria:
  - Drivers shall have logged a minimum of 325,000 miles in the last 5 years or 100,000 miles per year in 2 of the last 5 years in commercial semi-tractor combination over-the-road operation.
  - Drivers shall not have received a chargeable accident or have been convicted of a moving violation in a commercial motor vehicle within the last 5 years. The carrier contractor shall consider the driving history of potential drivers for the past 5 years in their private vehicles. Drivers shall not have repeated chargeable incidents, repeated convictions of moving violations, or a single violation for driving while intoxicated (DWI) or driving under the influence (DUI).
  - Drivers shall not have been convicted of a felony.
- The contractor shall maintain a strict driver penalty system for moving violations and deviations from routes. A driver shall be prohibited from transporting TRU waste after any of the following occur:
  - Conviction of a moving violation in a commercial motor vehicle
  - Unauthorized second deviation from route
  - Third failure to make mandatory DOE/Central Monitoring Room shipment notifications
  - Chargeable accident in a commercial vehicle
  - Second constant surveillance violation
  - Maintaining repeated inadequate or deliberately fraudulent driver logs/records

  - Conviction of a felony
  - Drug/alcohol screening violation
  - Conviction of a DWI or DUI in a commercial or private motor vehicle
  - Repetitive or serious moving violations in a personal vehicle
- The carrier contractor shall establish written policies to ensure that drivers maintain a professional appearance at all times while performing under the contract. The carrier contractor shall provide drivers with a standard uniform. Uniforms shall be worn while drivers are acting as representatives of DOE.

4.4.6 WIPP Driver Training Requirements

CBFO (2022) specifies the following driver training requirements:

- The carrier contractor shall maintain a driver training program. Each driver, before performing transportation services under the carrier contract, must successfully complete all DOT-required training plus the training listed below and other training DOE determines necessary to maintain a safe and secure transportation program:
  - Operation of packaging tie-downs
  - Use of radiation detection instruments
  - WIPP general employee training
  - Adverse weather and safe parking protocols
  - Public affairs training
  - WIPP first-responder and incident command training
  - Radiation worker training
  - Use of TRANSCOM tracking systems[1]
  - Generator/storage site-specific training
  - Security
- CBFO shall annually, or as required, approve the carrier contractor's training program for the following:
  - Shipping container recovery procedures
  - CVSA Enhanced Vehicle Inspector Training, Level VI
  - Decision driver training
  - Use of hand-held radios
  - Quality assurance
  - Integrated safety management
  - Electronic log book
  - GPS route designation equipment

[1] TRANSCOM tracking is available for DOE shipments. Commercial shipments would likely use an alternative system.

- HRCQ per 49 CFR 397.101(e)
- Hazardous materials

4.5 Transportation Packaging

This element should establish the process used to obtain NRC approval for transportation packages so that an entity acquiring a microreactor has some amount of confidence that unirradiated fuel can be shipped to the deployment site and that irradiated fuel can be shipped from the deployment site. As discussed in Section 3.2, there are two options for transportation package approval:

- Transportation package approval using 10 CFR Part 71 with no deviations or modifications. This is the current approach used for transportation packages containing fissile material and Type B quantities of radioactive material. This option could be used for transporting unirradiated or irradiated fuel separately from the microreactor. This option could also be used for transporting a microreactor containing its unirradiated or irradiated fuel. For example, Nemec (2025) describes a deployment strategy for the eVinci microreactor where a Type B, fissile material transportation package would be developed for transporting the eVinci microreactor containing its irradiated fuel.

- Transportation package approval using a risk-informed transportation package approval process as outlined in Coles et al. (2021, 2024) and Maheras et al. (2021) for transporting a microreactor containing its unirradiated or irradiated fuel. This may involve a 10 CFR 71.12 exemption or alternate environmental and test conditions [see 10 CFR 71.41(c)]. Using this option, it is possible that many of the transportation package requirements in 10 CFR Part 71 would be met, and that an exemption or alternate environmental and test conditions would be needed in specific areas. It is also probable that compensatory measures will be required as part of this risk-informed process. Depending on the details of the risk-informed process, an NRC environmental assessment or a DOT special permit may be required. It is also possible that as microreactor designs mature, a risk-informed process for transportation package approval may not be necessary to demonstrate compliance with 10 CFR Part 71.

4.6 Advance Notification of Shipments and Shipment Tracking

This element should establish the processes used for advance notification of shipments and shipment tracking.

NRC regulation 10 CFR 71.97 requires advance notification of states and participating Tribes along transportation routes for spent nuclear fuel and radioactive waste shipments. Typically, these advance notifications are performed by freight forwarders/shipping agents.

Shipment tracking is typically performed by a movement control center that is maintained by the freight forwarder/shipping agent.

4.7 Public Information and Communications

This element should establish the processes used to communicate information to address concerns and questions about transporting microreactors safely and uneventfully. This will often involve identifying and establishing partnerships, activities, and messages that will be most effective in addressing these concerns and questions. The following subsection describes the

WIPP approach to public information and communications (CBFO 2022). The elements of a microreactor transportation safety program would be expected to have similar requirements for public information and communications as the process used by WIPP.

4.7.1 WIPP Public Information and Communications

For shipments of TRU waste to the WIPP, CBFO believes that without proper information, the mix of the media, special interest groups, and an uninformed public may impede the safety of WIPP shipments. A strong, coordinated effort must be made to educate the public about the TRU waste transportation process and the comprehensive safety precautions in place. Accordingly, CBFO (2022) has established the following communications guidelines:

- Address public concern about the transport of TRU waste by providing accurate and unbiased information about the TRU waste transportation safety program and the risks involved with this activity.
- Respond in a timely manner to inquiries from the media, elected and appointed officials, and others about the TRU waste transportation activities.
- Coordinate public information efforts among corridor states and Tribes, state regional groups, generator/storage sites, CBFO, and DOE Headquarters.
- Ensure all parties provide a consistent message.
- Identify and provide opportunities for public involvement.

Audiences along the transportation routes will vary from state to state, but include:

- Citizens
- Public safety officials
- Elected and appointed officials
- News media
- Public interest groups

Messages include:

- Safety is the first priority.
- The TRU Waste Transportation System is a cooperative effort among states, Tribes, local officials, and DOE.
- The TRU Waste Transportation System goes beyond legal requirements.
- The program is proven.
- No shipment on the road has undergone as much scrutiny by state, Tribal, and local transportation safety specialists as the WIPP shipments.

Potential public information activities outlined in CBFO (2022) include:

- Keep the fact sheet on the TRU Waste Transportation System current for distribution.
- Make presentations to schools, civic and special interest groups, and others.
- Display the TRU waste transportation packages, truck, and WIPP exhibit in communities.

- Arrange and participate in public meetings along the transportation routes.
- Develop guidance for public information activities with WIPP Transportation Emergency Exercises.
- Distribute informational materials on the TRU Waste Transportation System.

For the news media, activities include (CBFO 2022):

- Work with news media, including meetings with editorial boards, in submitting articles and news releases.
- Conduct risk communication training for state and local spokespersons.

For public officials, activities include (CBFO 2022):

- Arrange meetings with state and local officials along the transportation route.
- Identify public officials along the transportation route who may wish to visit the WIPP site and offer an escorted tour.

4.8 Emergency Response Plans and Procedures

This element should establish the emergency response plans and procedures associated with microreactor transport. The following subsection describes the WIPP approach to emergency response plans and procedures (WGA 2017); however, note that this approach is for a large number of shipments, and it may be appropriate to scale back the program evaluation approach for microreactor transport based on the number of potential shipments. The elements of a microreactor transportation safety program would be expected to have similar requirements for emergency response plans and procedures as the process used by WIPP; however, microreactors may pose unique emergency planning challenges as discussed in Maheras et al. (2024).

4.8.1 WIPP Approach to Emergency Response Plans and Procedures

As described in WGA (2017), state emergency response plans and procedures help ensure coordinated, timely, and effective incident response, and the objective is to develop effective emergency response plans and procedures for responding to a WIPP transportation incident along the entire shipping corridor.

The approach outlined in WGA (2017) acknowledges that state, local, and federal agencies have varied responsibilities for responding to an incident involving a WIPP or inter-site shipment. Each response organization must know what other organizations are involved and who is responsible for each task. Advance planning and exercises of those plans help ensure all key response actions and responsibilities are covered. In case of an incident involving either an inter-site or WIPP shipment, CBFO and carriers should also be familiar with the specific plans and procedures in the state where the incident occurred.

Emergency response plans describe the organizations involved and their responsibilities, and include emergency response procedures that describe how the planned activities will be implemented. Each state's emergency response plan and procedures are to include a section describing a response to a WIPP incident. State plans or procedures specific to a WIPP incident are to be consistent with other state and local emergency plans, particularly those for radiological emergencies and hazardous materials incidents.

Each state along the shipping corridor takes its own individual approach to transportation emergency response planning. This is especially true for division of responsibilities among state agencies. Several states developed emergency response plans for radiological transportation incidents. These plans are available for use as a model for other states who want to develop their own plans. There are many other guidance documents that can be used to determine the key components of an emergency response plan.

Oregon developed model field procedures for response to a radiological transportation incident. Other states have used the generic model to develop their own procedures.

The states also reviewed DOE's plans and procedures for responding to a WIPP incident. The review was to ensure consistency of federal actions with state and local actions.

Each state is responsible for reviewing and updating its own emergency response plans and procedures on a biennial basis. This is done to keep the plans and procedures current and to include lessons learned from exercises and shipments. Exercises are used to test these plans and to train responders. Comments from exercise participants and evaluators are used to identify ways to improve the plan and procedures. States that conduct exercises will provide a summary report on findings and lessons learned at an appropriate meeting of the WIPP Technical Advisory Group. If a written report on the exercise has been prepared, the state that conducts the exercises will make the report available to WGA for distribution to other states.

DOE's plans and procedures will also be tested during exercises. Lead states will prepare suggested changes or improvements to correct any problems identified in these plans and procedures. These suggested changes will be provided to the other states and DOE.

4.9 Inspections

This element should establish how inspections are included in the program. The following subsections describe CVSA inspections (CVSA 2024), the WIPP approach to inspections (WGA 2017), and inspections conducted by the NRC (NRC 2020). The elements of a microreactor transportation safety program would be expected to have similar requirements for inspections as the process used by WIPP; however, note that this approach is for a large number of shipments, and it may be appropriate to scale back the training and exercise approach for microreactor transport based on the number of potential shipments.

4.9.1 Commercial Vehicle Safety Alliance Inspections

The CVSA is a nonprofit association composed of local, state, provincial, territorial, and federal commercial motor vehicle safety officials and industry representatives.

The CVSA created the North American Standard Inspection Program as the roadside inspection process for commercial motor vehicles and drivers throughout North America. The objective is to improve the safe operation of commercial motor vehicles by establishing a uniform and reciprocal process for roadside inspection and enforcement. The program outlines minimum inspection procedures, standards, and requirements, and ensures consistency in compliance, inspections, and enforcement, while minimizing duplication of efforts and unnecessary operating delays for the motor carrier industry. The North American Standard Inspection Program identifies critical inspection items and unsafe conditions that place vehicles and/or drivers out of service through a uniform inspection process.

There are eight levels of inspection under the North American Standard Inspection Program:

- Level I is a 37-step procedure that involves examining the motor carrier's and driver's credentials, record of duty status, the mechanical condition of the vehicle, and any hazardous materials/dangerous goods present.
- Level II is a driver and walk-around vehicle inspection for items that can be checked without physically getting under the vehicle.
- Level III is a driver-only inspection that includes examination of the driver's credentials and documents.
- Level IV special inspections are a one-time examination of a particular item. These examinations are normally made in support of a study or to verify or refute a suspected trend.
- Level V is a vehicle-only inspection that may be performed without a driver present, at any location.
- Level VI is a specialized inspection of TRU waste and HRCQ of radioactive material.
- Level VII is a jurisdictionally mandated inspection.
- Level VIII is an inspection conducted electronically or wirelessly while the vehicle is in motion, without direct interaction with an inspector.

Table 3 lists the CVSA inspection levels and items. As shown, the difference between CVSA Level I and Level VI inspections is the addition of a radiological survey of the vehicle and the load prior to performing the 37-step inspection. In addition, Level I and Level VI inspections have different out-of-service criteria. As a result, the Level VI inspection is referred to as an enhanced inspection. Table 4 lists the inspection items for which the out-of-service criteria are different between Level I and Level VI inspections.

Table 3. CVSA Inspection Levels and Items

		Inspection Level					
Step	Item	I	II	III	V	VI	VIII
1	Choose the Inspection Site	X	X	X		X	
2	Approach the Vehicle	X	X	X		X	
3	Greet and Prepare Drive	X	X	X		X	
4	Interview Driver	X	X	X		X	
5	Collect Driver's Documents	X	X	X		X	X
6	Check for the Presence of Hazardous Materials/Dangerous Goods	X	X	X		X	X
7	Identify the Carrier	X	X	X		X	X
8	Examine Driver's License	X	X	X		X	X
9	Check Medical Examiner's Certificate and Skill	X	X	X		X	X
10	Performance Evaluation Certificate (if applicable)	X	X	X		X	X
11	Check Record of Duty Status	X	X	X		X	X
12	Review Driver's Daily Inspection Report (if applicable)	X	X	X	X	X	X
13	Review Periodic Inspection Report(s)	X	X		X	X	
14	Prepare Driver for Vehicle Inspection	X	X		X	X	
15	Inspect Front of Tractor	X	X		X	X	
16	Inspect Left Front Side of Tractor	X	X		X	X	

Step	Item	Inspection Level I	II	III	V	VI	VIII
17	Inspect Left Saddle Tank Area	X	X		X	X	
18	Inspect Trailer Front	X	X		X	X	
19	Inspect Left Rear Tractor Area	X	X		X	X	
20	Inspect Left Side of Trailer	X	X		X	X	
21	Inspect Rear of Trailer	X	X		X	X	
22	Inspect Double, Triple and Full Trailers	X	X		X	X	
23	Inspect Right Rear Trailer Wheels	X	X		X	X	
24	Inspect Right Side of Trailer	X	X		X	X	
25	Inspect Right Rear Tractor Area	X	X		X	X	
26	Inspect Right Saddle Tank Area	X	X		X	X	
27	Inspect Right Front Side of Tractor	X	X		X	X	
28	Inspect Steering Axle(s)	X			X	X	
29	Inspect Axle(s) 2 and/or 3 (under carriage of vehicle)	X			X	X	
30	Inspect Axle(s) 4 and/or 5	X			X	X	
31	Check Brake Adjustment	X			X	X	
32	Inspect Tractor Protection System (which tests the tractor protection system and emergency brakes)	X			X	X	
33	Inspect Low Air Pressure Warning Device and Brake Pedal	X	X		X	X	
34	Test Air Loss Rate	X	X		X	X	
35	Check Steering Wheel Lash	X	X		X	X	
36	Check Fifth Wheel Movement	X	X		X	X	
37	Complete the Inspection	X	X	X	X	X	X

The Level VI inspection involves a radiological survey of the vehicle and load prior to completing the 37-step inspection procedure.

The Level IV special inspection and Level VII jurisdictionally mandated inspection could have any or all steps included; therefore, those two inspection levels are not included in this table.

Based on https://cvsa.org/wp-content/uploads/NASI-Program-Brochure.pdf.

Table 4. Inspection Items for which Out-of-Service Criteria Differ between CVSA Level I and Level VI Inspections

Number	Inspection Item
Part I – Driver Inspection Standards	
1.	Driver’s age
8.c	Intoxicating beverages, out-of-service order violation
12.	Certificate of training (HRCQ only)
13.	Personal dosimetry
Part II – Vehicle Inspection Standards	
1.a, 1.a.(1), 1.a.(4), 1.a.(5), 1.a.(5)(c), 1.a.(6), 1.a.(7), 1.a.(8), 1.b.(3)	Brake systems, defective brakes
1.e	Parking brake
1.h.(3), 1.h.(6)	Air brake/hosing
1.m	Air reservoir (tank)
1.n.(4)	Air compressor
1.r	Anti-lock braking system lights

Number	Inspection Item
2.d	Aggregate working load limit
3.a.(1).(c), 3.a.(1).(d), 3.a.(1).(e), 3.a.(1).(f), 3.a.(2).(a), 3.a.(2).(b), 3.a.(2).(c), 3.a.(2).(d) 3.a.(2).(f), 3.a.(3).(a), 3.a.(5).(a), 3.a.(5).(b)	Coupling devices, fifth wheels (lower coupler assembly)
3.b.(5), 3.b.(6), 3.b.(7)	Coupling devices, fifth wheels (upper coupler assembly)
6.a, 6.e, 6.f	Exhaust systems
7.a.(1), 7.a.(3), 7.a.(5)	Frames
8.c	Fuel systems
9, 9.a, 9.a.(2), 9.a.(3), 9.b.(1), 9.b.(2)	Lighting devices
11.a.(2), 11.b.(1), 11.b.(3), 11.c.(2)	Suspensions
11.e.(1), 11.e.(1)(a), 11.e.(1)(b), 11.e.(1)(c), 11.e.(2),	Suspensions, adjustable axles/sliding trailer suspension system
12.a.(1), 12.a.(5), 12.a.(9), 12.a.(11), 12.b.(3), 12.b.(5), 12.b.(7), 12.b.(8), 12.b.(9), 12.b.(10), 12.b.(12)	Tires
14.c.(1), 14.c.(2), 14.c.(3), 14.e.(1), 14.e.(2), 14.f.(1), 14.f.(2), 14.g,	Wheels, rims, and hubs
15.	Windshield wipers
17.	Seatbelts
18.	Horn
19.	Windshield/windshield glazing
20.	Defroster
21.	Rear vision mirrors
22.	Floor, firewall, and wiring systems
23.	Headlight beam selector switch
24.	Trailer reflective tape
25.	Sleeper berth
26.a, 26.b	Emergency equipment
27.	Hood securement and hinges
28.	Battery
29.	Rear-end protection
30.	Car and body components
31.	TRUPACT II package tiedown assemblies
32.	RH-72B cask tiedown
33.	RH-72B cask accessories
34.	TRUPACT II tiedown
35.	Level VI decal/inspection
36.	Proof of periodic (annual) inspection
Part III – Hazardous Materials/Dangerous Goods Inspection Standards	
1.a.	Shipping papers
2.a.(1)	Placarding
3.f	Bulk packages/large means of containment
4.a.(1)	Transport vehicle markings
9.b, 9.c	Radiation levels

Number	Inspection Item
11.	Emergency response information
12.	Route plan (HRCQ only)
13.	Labeling
14.	Package Marking
15.	Federal Motor Carrier Safety Administration hazardous materials safety permit
16.	Security seal
17.	General packaging
Source: CVSA (2024)	

4.9.2 WIPP Inspections

As stated in WGA (2017), a quality, independent inspection program assures that drivers and vehicles perform at optimum levels and that radiation levels are within allowable limits. The objective of the inspections is to reduce the chance of incidents from mechanical failure or human error by identifying and correcting defects before they pose a threat to shipment safety.

In the approach outlined in WGA (2017), federal and state agencies share inspection and enforcement activities for radioactive material transportation. Implementation of the inspection program by state personnel will provide independent verification of regulatory compliance, enhancing public confidence in the safety of the WIPP shipping campaign. DOE selected the CVSA, an organization of state motor carrier officials responsible for the administration and enforcement of motor carrier safety laws, to develop an inspection and enforcement program. The CVSA inspections are discussed in Section 4.9.1.

The inspection procedures were developed with the assistance of the Conference of Radiation Control Program Directors. The procedures provide uniform standards for radiation surveys and inspection of drivers, shipping papers, vehicles, and packages. The standards also provide for vehicle inspections at points of origin and destination, and for en route inspections. The enhanced inspection Level VI procedures also require a higher level of out-of-service criteria than the North American Inspection Standards (i.e., a Level I inspection).

The CVSA Level VI inspections provide a comprehensive interstate program that enables consistent training, procedures, and application from state-to-state, and DOE has agreed that vehicles carrying TRU waste to the WIPP will comply with the CVSA Level VI out-of-service criteria.

CVSA Level VI inspections for shipments to WIPP are performed at the point of origin and require that shipments be defect-free before departure. Before departure, a CVSA Level VI decal is affixed to the tractor, certifying the shipment has met inspection criteria and is defect free. During transit to WIPP, each state may inspect the shipment to verify that the CVSA Level VI inspection was performed and that the sticker verifying such is attached. Individual states may choose to perform en route inspections of shipments according to law or policy. Any reinspection en route should be performed in accordance with CVSA guidelines. In addition, a CVSA Level VI inspection should be conducted if the tractor and trailer have been separated or an accident or other off-normal event has occurred.

4.9.3 NRC Inspections

NRC uses Inspection Procedure 86740, *Inspection of Transportation Activities* (NRC 2020) to determine whether its licensees have established and are maintaining an effective management-controlled transportation program, to ensure radiological and nuclear safety in the receipt, packaging, delivery to a carrier and, as applicable, the private carriage of licensed radioactive materials; and to determine whether transportation activities are in compliance with the applicable NRC and DOT transportation regulations. The elements inspected by NRC are shown in Figure 3.

Other relevant NRC inspection procedures may also include:

- Inspection Procedure 86001, *Design, Fabrication, Testing, and Maintenance of Transportation Packagings* (NRC 2025)
- Inspection Procedure 86730, *Transportation of Radioactive Materials* (NRC 2000).

4.10 Security

This element should establish the interface between the Microreactor Transportation Safety Program and the Microreactor Transportation Security Program. The effective integration of the Transportation Safety Program and the Transportation Security Program is crucial for ensuring the safe and secure shipment of microreactors. This interface, as outlined by the International Atomic Energy Agency (IAEA 2021), ensures that regulatory compliance and best practices are met. Because microreactor shipments are assumed to be regulated by the NRC and the DOT, the Transportation Security Plan would meet the requirements of 10 CFR Part 73 and the DOT requirements in 49 CFR Part 172, Subpart I, *Safety and Security Plans* (49 CFR 172.800-172.822). For microreactor shipments containing irradiated fuel, detailed guidance is provided in NUREG-0561, Revision 2, *Physical Protection of Shipments of Irradiated Reactor Fuel* (NRC 2013).

By establishing a comprehensive interface between the Transportation Safety Program and the Transportation Security Program, microreactor shipments can be conducted safely and securely, ensuring compliance with NRC and DOT regulations and addressing both current and emerging threats. This carefully coordinated approach helps to protect these critical materials throughout the transportation process. In addition, a robust and all hazards security exercise plan should be established that evaluates and verifies the effectiveness of transportation security plans and identifies shortfalls within the program. These exercises should include both safety and security entities to ensure an effective integration of response functions.

Additional vulnerability assessments may be required to address various microreactor and transport vehicle designs to hedge against current and emerging threats. A cookie-cutter, one size fits all approach to threat mitigation may not be appropriate due to the uniqueness of microreactor designs. As such, it is highly recommended that microreactor security planners work closely with intelligence offices to adequately capture the threats within their specific area(s) of operation.

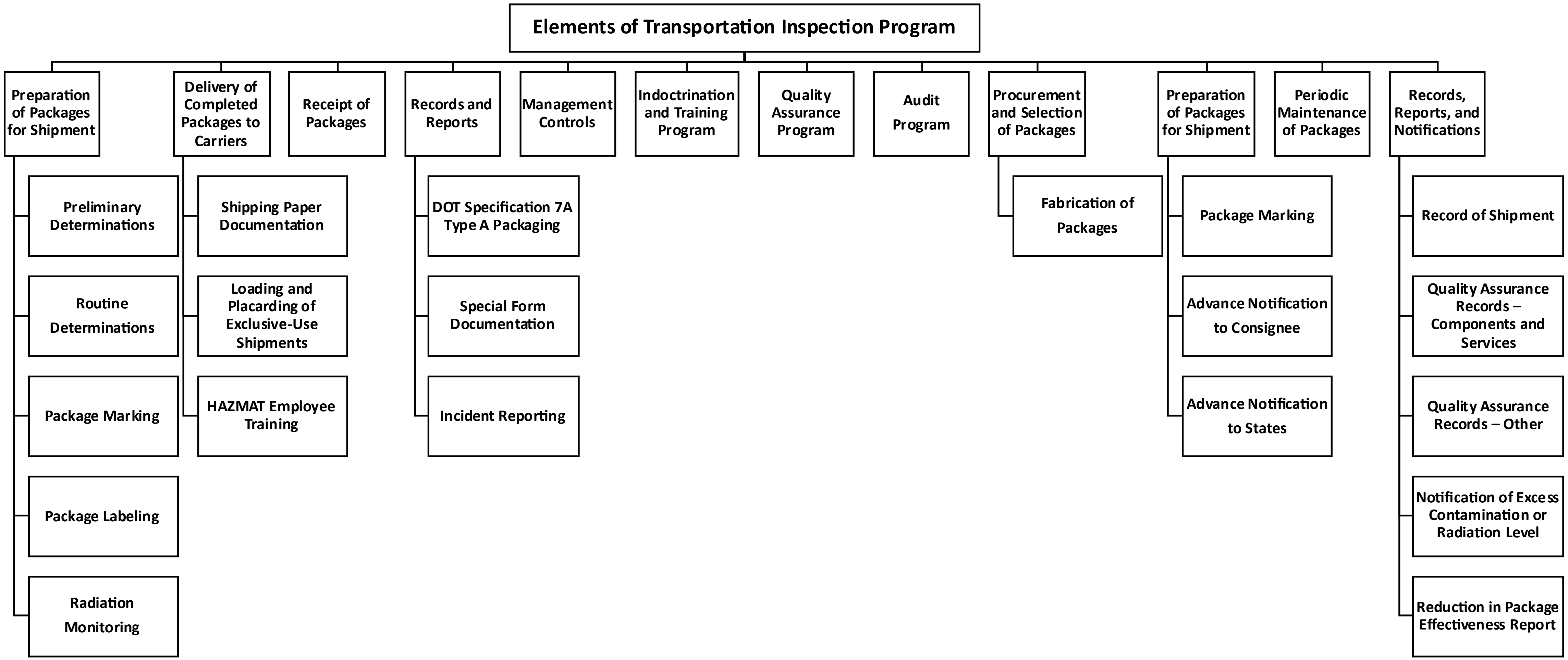

Figure 3. Elements of a Transportation Inspection Program

4.11 Safe Parking

This element should establish provisions for safe parking when a shipment is delayed en route due to mechanical problems, bad weather, hazardous road conditions, or other unanticipated problems. For these reasons, safe parking locations are typically identified or designated, and criteria are developed for selecting safe parking locations if a predesignated location cannot be safely reached. For shipments of TRU waste to WIPP, the following criteria were established (WGA 2017):

- **First Choice:** DOE and DOD facilities are the most desirable parking areas for WIPP shipments. However, it may not be possible for the driver to safely reach a DOE or DOD facility. The driver should then proceed down the hierarchy to select a parking area.
- **Second Choice:** Specific types of facilities (e.g., ports of entry) are likely to be more common than DOE or DOD facilities. State-specific information on the types of facilities that are acceptable has been identified and provided to CBFO and the drivers. If the driver cannot reach one of these facilities, the driver should use the third choice criteria.
- **Third Choice:** If facilities listed in the first or second tier cannot be reached safely, a series of avoidance factors are applied to select a parking area. No priorities have been assigned to these factors. It may not be possible to select a parking site that meets all of the criteria listed in the third tier, and the driver, in consultation with the affected state and the WIPP Central Monitoring Room operator, will select the most suitable location.

For shipments of radioactive material through the Midwestern states, CSG Midwest (2023) made the following safe parking recommendations:

- The selection of safe parking areas should be coordinated with the stakeholders through whose jurisdictions the shipments would pass.
- Security plans for the shipping campaigns should identify safe parking areas, additional security requirements for shipments in safe parking, and avoidance criteria for selecting other safe parking locations in the event the driver/crew cannot reach the pre-designated locations.
- Safe parking areas should be selected based on the desirability of a particular type of parking area and the ability of the driver/crew to reach the parking area.
- Safe parking areas should achieve the following objectives:
  - Provide adequate separation from vehicles carrying hazardous material
  - Facilitate required security (e.g., lighting)
  - Provide adequate driver/crew services
- The following avoidance factors should be applied in selecting a suitable safe parking location:
  - Highly populated areas
  - Heavily industrialized areas (e.g., refineries)
  - Hospitals and schools
  - Areas with difficult access (e.g., no room for fire equipment)
  - Crowded parking areas (e.g., shopping malls and rest areas)

- Residential areas
- Highway shoulders (for truck shipments)
- Areas with numerous pedestrians.

The elements of a microreactor transportation safety program would be expected to have similar requirements for safe parking as those used by WIPP and proposed by the CSG Midwest.

4.12 Weather and Road Conditions

This element should establish provisions for responding to bad weather and road conditions that create hazardous travel conditions. Microreactor shipments should avoid bad weather and hazardous roads by carefully monitoring road and weather conditions and restricting travel when adverse conditions pose a threat to shipment safety. CSG Midwest (2023) identified the following types of severe weather warnings that could make travel hazardous:

- Winter storm warning
- Heavy snow warning
- Blizzard warning
- Blowing and drifting snow
- Freezing rain/drizzle
- Ice storm warning
- Sleet warning
- Dense fog advisory
- Tornado warning
- Severe thunderstorm warning
- Flash flood warning
- River flood warning
- High wind warning

CSG Midwest (2023) also makes the following recommendations regarding pre-departure and en route adverse weather conditions:

- Pre-Departure – The shipper and drivers should agree that weather and road conditions are acceptable prior to dispatching a shipment. Before dispatching a shipment, the shipper should consider current weather conditions, weather forecasts, and projected road conditions at the point of origin and along the entire route. A shipment should not be dispatched if severe weather conditions are forecasted anywhere along the route at the time the shipment is expected to be in that area.

- En Route – The shipper and/or the carrier should monitor weather conditions while the shipment is in transit. Shipments should not travel when adverse weather or road conditions along routes make travel hazardous. When severe weather conditions or adverse road conditions occur unexpectedly, law enforcement may divert the shipment to safe parking or may contact the shipper to suggest that the shipment use an alternate route. If a state deems it necessary to divert a shipment to an alternate route, the state must coordinate with any other states that will be affected by the route deviation.

The potential for severe weather conditions resulting in shipment delays could lead to implementing travel restrictions for specific months in specific regions.

If the shipment is traveling under an oversize/overweight permit and there are additional restrictions regarding weather and road conditions, the driver must comply with both the microreactor shipment protocols and the permit conditions.

4.13 Medical Preparedness

This element should establish how medical preparedness is included in the program. Effective medical response to a microreactor transportation incident requires radiological-specific emergency plans, procedures, supplies, and equipment. Emergency medical responders and medical facilities need to develop unique capabilities for emergency radiological response to prepare for and maintain preparedness for microreactor shipments. Key elements and activities for emergency medical preparedness include assessments of hospital readiness and medical facilities; development and refinement of radiological response plans and procedures; training, drills, and exercises; and the identification and purchase of appropriate radiological and non-radiological supplies and equipment. The following subsection describes the WIPP approach to medical preparedness (WGA 2017). The elements of a microreactor transportation safety program would be expected to have similar requirements for medical preparedness as the process used by WIPP; however, note that this approach is for a large number of shipments, and it may be appropriate to scale back the program evaluation approach for microreactor transport based on the number of potential shipments.

4.13.1 WIPP Medical Preparedness

The approach to medical preparedness outlined in WGA (2017) is based on emergency medical responders and medical facilities developing unique capabilities for radiological emergency response to prepare for and maintain preparedness for WIPP shipments. The WIPP Technical Advisory Group developed the *Regional Medical Preparedness Action Guidance* (Action Guidance) to help state and local organizations prepare. The Action Guidance identifies key elements and activities for emergency medical preparedness for a WIPP transportation incident. These include assessments of hospital readiness and medical facilities; development and refinement of radiological response plans and procedures; training, drills, and exercises; and the identification and purchase of appropriate radiological and non-radiological supplies and equipment.

States may use the Action Guidance as the basis for developing an emergency medical preparedness program that best meets their individual needs. States should strive for consistency among state programs as possible. Planning and response guidance is also provided by such organizations as the American Medical Association, American College of Emergency Physicians, the Joint Council on the Accreditation of Hospital Organizations, Radiation Emergency Assistance Center/Training Site,[1] and the Occupational Safety and Health Administration (OSHA).

Training and exercises for all first responders, pre-hospital personnel, and hospital emergency medical personnel is an important element of the WIPP Medical Preparedness Program. In addition, states are working to ensure emergency medical personnel are properly equipped to handle a TRU waste transportation incident. The Action Guidance lists recommended supplies and equipment for hospitals, and states should include equipment needs in their medical assessments.

[1] https://orise.orau.gov/reacts/index.html

4.14 Training and Exercises

This element should establish the training and exercises needed to mitigate the risks associated with microreactor shipments and to build public confidence in the transport of microreactors. The following subsections describe the WIPP approach to training and exercises (WGA 2017). The elements of a microreactor transportation safety program would be expected to have similar requirements for training and exercises as the process used by WIPP; however, note that this approach is for a large number of shipments, and it may be appropriate to scale back the training and exercise approach for microreactor transport based on the number of potential shipments.

4.14.1 WIPP Training Responsibility

Employers are responsible for providing training required by OSHA 29 CFR 1910.120 to emergency responders. Specifically, it is the employer's responsibility to determine the appropriate level of training required, provide the required training, and certify that the employee demonstrates the competencies following initial training and annual refresher training. To help emergency response organizations meet their responsibility, the WIPP Land Withdrawal Act[1] requires CBFO to provide training for emergency responders, emergency care providers, and other public officials who might be required to respond to a WIPP transportation incident. The Technical Advisory Group shares the responsibility with CBFO to ensure training is appropriate, adequate, and effective.

4.14.2 WIPP Target Audiences

Preparedness is a vital link to response. There are scores of key individuals and agencies, at both the local and state level, who are involved in preparedness activities in anticipation of response to a radiological incident. Some of the disciplines that are considered audiences for training include but are not limited to fire safety, law enforcement, emergency medical services, environmental and public health, emergency management, medical, public works, dispatch, medical examiners, coroners, crime scene investigators, government officials, public and elected officials, public safety officers, and radiological protection workers.

4.14.3 WIPP Education Program

CBFO created the States and Tribal Education Program (STEP) in 1988 to fulfill its training responsibilities. The states have worked with CBFO since the beginning to review, update and improve the training. The states also work with CBFO to promote and coordinate training with state and local responders, government officials, and the public. Some states also participate in delivering training by providing state-specific information to attendees. This cooperation between CBFO and the Technical Advisory Group ensured the creation of a model training program for radiological emergencies. The STEP course offerings have expanded and now include dispatcher, hospital, and incident command courses. In 2013, CBFO changed the name of the training program from STEP to WIPP Education Program (WEP).

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[1] The Waste Isolation Pilot Plant Land Withdrawal Act. Public Law 102-579 as amended by Public Law 104-201

4.14.4 Modular Emergency Response Radiological Transportation Training Program

The Modular Emergency Response Radiological Transportation Training (MERRTT)[1] program was developed by DOE as a nationwide program to ensure consistent training for responding to transportation incidents involving radioactive material. MERRTT exclusively covers Hazard Class 7 radioactive material and builds on information taught in other hazardous material courses. MERRTT is designed to provide emergency responders with the fundamental knowledge and skills required to respond with confidence to incidents involving radioactive material.

MERRTT emergency response program topics include the following:

- Tools for conducting a readiness needs assessment at the State, Local, Tribal, and Territorial (SLTT) levels.
- Awareness of Radiological Material Shipping Packages
- Hazard recognition and Incident Response Actions
- Transportation of Safeguards Material

4.14.5 WIPP Training Plans

Each state has specific training needs that must be addressed. An assessment should be the first step in any training program. The assessment will determine the current versus necessary radiological response capabilities in affected areas. The assessment should evaluate elements such as personnel training, personnel experience, response equipment, and available resources.

A long-range training plan should be developed based on the assessment results. The planning process should begin early, at least 3 years in advance of shipments.

Training plans should address the following:

- Location, type, and number of classes and exercises required
- Suggested background or prerequisite training
- Duration of shipping campaign and training program
- Administration and funding requirements
- Certification requirements
- Quality control and review methods
- Instructor qualifications

The DOE Transportation Emergency Preparedness Program (TEPP)[2] provides additional training resources that supplement WEP resources. Model response procedures, needs

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[1] https://teppinfo.com/merrtt/modules
[2] https://teppinfo.com/

assessments, exercise planning resources, and program contacts are available on the TEPP website. Instructors from both the TEPP and WEP programs often teach courses together.

4.14.6 WIPP Training Content

Training should meet regulatory requirements as a minimum. Many federal agencies have specific training requirements for personnel responding to radiological accidents or personnel providing care for accident victims. State and local jurisdictions may have additional regulations that apply to training requirements. The WIPP Land Withdrawal Act requires that DOE emergency response training programs provided by CBFO be reviewed with the affected states and for compliance with OSHA and National Institute for Occupational Safety and Health requirements. This review does not alter the responsibility of each employer to ensure their employees are trained according to these regulations.

Many professionals are required to complete continuing education to maintain their certifications or licenses. Emergency responders and emergency care providers are less inclined to attend non-certified courses where they do not receive credits. CBFO should maintain accreditations for all of their courses to assure training course quality and encourage participation by various disciplines.

4.14.7 WIPP Training Resources

There are multiple federal agencies that provide radiological training at little or no cost. Many of these, though not oriented to transportation, may enhance state and local response capability. Each has advantages and disadvantages that should be evaluated against the local responder's needs.

4.14.8 WIPP Training Delivery

Methods and capabilities for delivering training vary widely from state to state and even among local jurisdictions. Training programs developed to support WIPP program shipments need to be flexible enough to support this diversity. Training should be tailored to the individual needs of each jurisdiction.

Many emergency responders are volunteers with limited time to meet a variety of training requirements. Training time can be used more efficiently by incorporating the CBFO material into existing hazmat and radiological training curricula. State and local instructors will need train-the-trainer courses to facilitate this.

Instructional material should be supplied to instructors in a format (electronic, video) that is easy to incorporate into existing courses.

CBFO's cadre of trainers has been essential to the WEP training program's success to date. These trainers conduct ongoing train-the-trainer programs to help build state and local training capabilities. This helps to ensure consistency among the different states' training programs. Additionally, the CBFO-supplied instructors provide an invaluable pool of qualified instructors to supplement state or local instructors.

The CBFO-supplied instructors are also vital to the success of the exercise program. They provide invaluable advice and assistance to local jurisdictions that may have little or no experience planning major exercises.

4.14.9 WIPP Exercises

Exercise programs are an integral part of a training program. Exercises can enhance learning, test systems, increase awareness, and evaluate training. Exercises should begin small and build to full scale. Exercise programs, like training programs, should be multi-year efforts.

Small tabletop or functional exercises are easy, low cost, and brief. More small exercises are possible with limited resources, allowing all affected communities to participate. The majority of exercises conducted should be in this category.

Full-scale exercises are useful and should be run. Because of the large expense of resources, it may not be possible to conduct one for every community. A full-scale exercise will be the most challenging and comprehensive exercise.

4.14.10 WIPP Training Evaluations

The truest evaluation of any training program is how the trainee performs following course completion. Since transportation accidents are rare, other methods of evaluation must suffice. Periodic radiological emergency assessments of affected communities can be useful in evaluating a training program. A standard assessment form would make data compilation and analysis easier.

Each state should routinely evaluate whether it is providing sufficient training and exercise opportunities to its emergency responders. States may wish to set goals to train a certain percentage of state and local emergency responders annually. Each state should also ensure that responders all along its portion of the route have been trained and eliminate “gaps” where no or few emergency response personnel have received training. States should also continue to evaluate whether responders are receiving refresher training on a regular basis.

States should share important lessons learned from their individual evaluations with the lead states. The lead states will summarize this information as appropriate and provide it to the other states and CBFO.

Training and exercise requirements change due to changes in regulations, procedures, policies, and other factors. Courses may need to be changed to ensure they are accurate, current, and appropriate. The training and exercise programs should have provisions for regular evaluations, reviews, updates, and revisions. Review and evaluation should be a joint effort between CBFO, states, and other relevant agencies.

4.15 Program Evaluation

This element should establish how the program is evaluated to determine its effectiveness. The following subsection describes the WIPP approach to program evaluation (WGA 2017). The elements of a microreactor transportation safety program would be expected to have similar requirements for program evaluation as the process used by WIPP; however, note that this approach is for a large number of shipments, and it may be appropriate to scale back the program evaluation approach for microreactor transport based on the number of potential shipments.

4.15.1 WIPP Program Evaluation Approach

As stated in WGA (2017), the WIPP Transportation Safety Program and its individual elements must be regularly and rigorously evaluated to determine their effectiveness. The objective is to measure the effectiveness of the program, identify areas needing improvement, and ensure open issues are resolved.

Western states have worked with CBFO to develop a comprehensive transportation safety program for WIPP shipments. This safety program is designed to reduce the risk of a WIPP transportation incident, ensure effective emergency response capabilities, and increase public confidence in the safety of the shipments and nuclear waste transportation in general. The program is also intended to serve as a model for use or adaptation on other radiological shipments.

The evaluation process involves (1) reviews of procedures and policies specific to each element and (2) evaluation of the WIPP Transportation Safety Program as a whole. For each task, the lead states develop the criteria for evaluating each element of the program. Criteria to evaluate the overall program are developed by all the states. Data collection and analysis should not be unnecessarily burdensome. Quantitative, qualitative, and anecdotal information will be used.

The evaluation of each element will include both the procedures and policy decisions specific to that element. For example, evaluation of safe parking could include looking at specific procedures, such as whether directions to designated safe parking locations are easy to understand. It could also include a review of the policy issues, such as whether the avoidance criteria agreed to by the states results in the selection of appropriate safe parking locations. This evaluation will be conducted by the lead states for each task.

The overall program evaluation will occur biennially and involve all the states. The lead states for program evaluation will coordinate this activity and develop recommended suggestions for the program.

Program elements related to remote-handled TRU waste shipments should be evaluated within a year after the beginning of remote-handled shipments.

5.0 Unique Elements Associated with Microreactor Transport

Many of the Microreactor Transportation Safety Program elements for microreactor shipments would be the same as for other radioactive material shipments. This section identifies unique Transportation Safety Program elements associated with microreactor transport in the areas of:

- The unusual nature of microreactor designs
- Compensatory measures
- Increased radiation dose rates in the vicinity of microreactors
- Transportation package approval versus 10 CFR 50.59
- Use of a risk-informed transportation package approval process
- Prevention of criticality

5.1 Unusual Nature of Microreactor Designs

The unusual nature of microreactor designs could impact several Transportation Safety Program elements:

- Increased time may be required for transportation planning.
- Increased coordination with states and Tribes along transportation routes may be required.
- Due to the unusual nature of the microreactor designs, there may be a desire to perform more en route inspections.
- Due to the unusual nature of microreactor designs, there may be a need to include features in the transport vehicles that minimize the effect of vibrations and shocks.
- There may be a need to implement a system of employing escort vehicles and real-time monitoring to expedite response to incidents.
- Due to the unusual nature of the microreactor designs, there may be an increased need for public information and communications regarding microreactor transport.
- There may be calls for increased microreactor-specific training, and additional microreactor-specific training modules may be required. These training modules may be design-specific.
- Microreactor designs that contain other hazardous materials such as beryllium or sodium could affect the content of emergency response plans and procedures.

5.2 Compensatory Measures

In the traditional non-risk-informed 10 CFR Part 71 transportation package approval process, compensatory measures are not typically required as a condition of approval. However, when implementing a risk-informed transportation package approval process, compensatory measures may be required. These compensatory measures would have to be accounted for in the Microreactor Transportation Safety Program.

5.3 Increased Radiation Dose Rates in the Vicinity of Microreactors

It is likely that microreactors shipped containing their irradiated fuel will not meet the radiation dose rate limits specified in DOT and NRC regulations. This could have several impacts:

- A large exclusion area, on the order of 60 meters in diameter, around the microreactor shipment may be required. This larger exclusion area would need to be factored into the Microreactor Transportation Safety Program.
- Workers performing CVSA Level VI inspections could be exposed to much higher dose rates, which would need to be factored into the Microreactor Transportation Safety Program.

5.4 Transportation Package Approval Versus 10 CFR 50.59

In the traditional non-risk-informed 10 CFR Part 71 transportation package approval process, NRC must approve changes to the design of a transportation package. However, NRC regulation 10 CFR 50.59 allows minor changes to be made to reactor designs. If this practice continues with microreactor designs, then microreactor designs may have to be resubmitted to the NRC for transportation package approval. This could increase the time and costs required for transportation planning.

5.5 Use of a Risk-Informed Transportation Package Approval Process

In the traditional non-risk-informed 10 CFR Part 71 transportation package approval process, NRC activities are subject to a categorical exclusion and a National Environmental Policy Act (NEPA) analysis of the transportation package approval process is not required. However, if a risk-informed transportation package approval process is used, then a NEPA analysis may be required, and a DOT special permit may also be required. The time required for these activities would need to be factored into the transportation planning process.

5.6 Prevention of Criticality

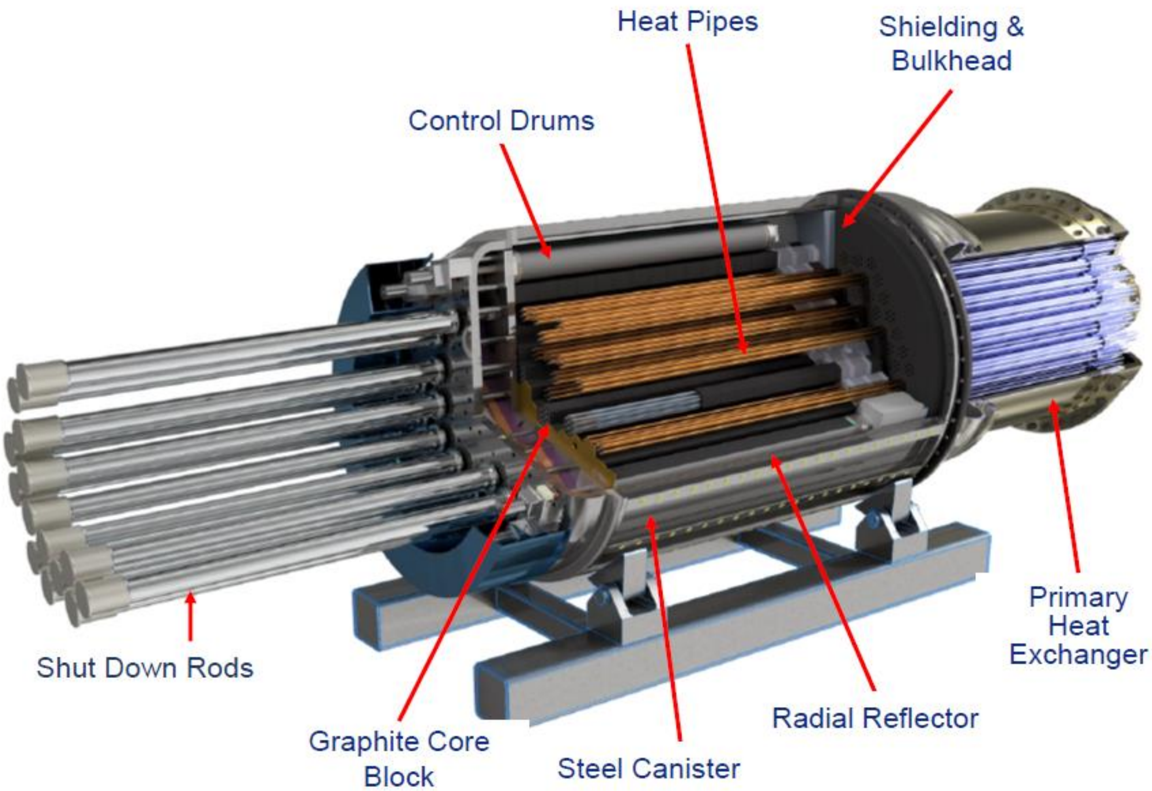
Proposed Rule 10 CFR Part 53, *Risk-Informed, Technology-Inclusive Regulatory Framework for Commercial Nuclear Plants*[1] states that a manufacturing license may include authorizing the loading of fresh (unirradiated) fuel into a manufactured reactor under 10 CFR Part 70. The proposed rule also specifies required systems to prevent criticality:

- At least two independent physical mechanisms in place, each of which is sufficient to prevent criticality assuming optimum neutron moderation and neutron reflection conditions

This requirement could be met by using structures, systems, and components such as control drums, shutdown rods, or poison wires. Figure 4 shows an example of this for the eVinci microreactor, where control drums and shutdown rods are used to control criticality.

Implementation of this requirement could also influence the transportation package approval process for a microreactor containing its unirradiated or irradiated fuel.

[1] 89 FR 86918-87126, October 31, 2024.



Source: Nemec (2025)

Figure 4. Cutaway View of eVinci Microreactor Showing Control Drums and Shutdown Rods

6.0 References

10 CFR Part 37. "Physical Protection of Category 1 And Category 2 Quantities of Radioactive Material." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2025/ (2025)

10 CFR Part 50. "Domestic Licensing of Production and Utilization Facilities." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2025/ (2025)

10 CFR Part 70. "Domestic Licensing of Special Nuclear Material." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2025/ (2025)

10 CFR Part 71. "Packaging and Transportation of Radioactive Material." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2025/ (2025)

10 CFR Part 73. "Physical Protection of Plants and Materials." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2025/ (2025)

29 CFR Part 1910. "Occupational Safety and Health Standards." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2024/ (2024)

49 CFR Part 365. "Rules Governing Applications for Operating Authority." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2024/ (2024)

49 CFR Part 385. "Safety Fitness Procedures." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2024/ (2024)

49 CFR Part 397. "Transportation of Hazardous Materials; Driving and Parking Rules." Available at https://www.govinfo.gov/app/collection/cfr/2024/ (2024)

49 CFR Part 171–180. "Pipeline and Hazardous Materials Safety Administration Hazardous Materials Regulations." Code of Federal Regulations. Available at https://www.govinfo.gov/app/collection/cfr/2024/ (2024)

AAR (Association of American Railroads). "Performance Specification for Trains Used to Carry High-Level Radioactive Material." Standard S-2043, AAR Manual of Standards and Recommended Practices, Section C, Car Construction Fundamentals and Details. AAR Circular Letter C-14336, April 12, 2024. Washington, DC (2024).

CBFO (Carlsbad Field Office). *TRU Waste Transportation Plan*. Report No. DOE/CBFO-98-3103, Revision 5. U.S. Department of Energy, Carlsbad, New Mexico. October (2022).

Coles, G., S. Short, S. Maheras, and H. Adkins. *Proposed Risk-Informed Regulatory Framework for Approval of Microreactor Transportation Packages*. PNNL-31867. Pacific Northwest National Laboratory, Richland, WA, August (2021).

Coles G.A., T.A. Ikenberry, S.M. Short, M.S. Taylor, H.E. Adkins, Jr., P.P. Lowry, C.A. Condon, S.J. Maheras, and J.R. Phillips. *Development and Demonstration of a Risk Assessment Approach for Approval of a Transportation Package of a Transportable Nuclear Power Plant for Domestic Highway Shipment*. PNNL-36380, Rev. Pacific Northwest National Laboratory, Richland, WA. August (2024).

CSG Midwest (Council of State Governments Midwest). *Planning Guide for Shipments of Radioactive Material through the Midwestern States*. The Council of State Governments Midwestern Office and the Midwestern Radioactive Materials Transportation Committee, Lombard, IL (2023).

CVSA (Commercial Vehicle Safety Alliance). *North American Standard Out-of-Service Criteria and Level VI Inspection Procedures and Out-of-Service Criteria for Commercial Highway Vehicles Transporting Transuranics and Highway Route Controlled Quantities of Radioactive Materials as Defined in 49 CFR 173.403*. Washington, DC. April (2024).

DOE (U.S. Department of Energy). *Program Manager's Guide to Transportation Planning. U.S. Department of Energy National Transportation Program*. Washington, D.C. December (1998).

FRA (Federal Railroad Administration). *Safety Coordination and Compliance Oversight Plan for Rail Transportation of High-Level Radioactive Waste and Spent-Nuclear Fuel*. Washington, DC. June (2023).

IAEA (International Atomic Energy Agency). *Managing the Interface Between Safety and Security for Normal Commercial Shipments of Radioactive Material*. Technical Reports Series No. 1001, Vienna, Austria. September (2021).

Maheras S.J., G.A. Coles, J.R. Phillips, C.A. Condon, S.M. Short, H.E. Adkins Jr., P.P. Lowry, and K. Banerjee. *Plan for Development and Application of Risk Assessment Approach for Transportation Package Approval of an MNPP for Domestic Highway Shipment*. PNNL-33524. Pacific Northwest National Laboratory, Richland, WA. December (2021).

Maheras S.J., S.A. Foss, R.E. Reed, C.A. Condon, and T.R. Hay. *Microreactor Transportation Emergency Planning Challenges*. PNNL-34816, Rev. 1. Pacific Northwest National Laboratory, Richland, WA. September (2024).

Maheras S.J., H.E. Adkins Jr, G.A. Coles, S.M. Short, V. Peoples, and A.B. Rigato. "Adaption of a Highway Risk-Informed Transportation Package Approval Process for Microreactors to Maritime Transport." In Waste Management Symposium 2025, March 9-13, 2025, Phoenix, AZ. PNNL-SA-207374 (2025).

Nemec R. "eVinci Microreactor Deployment Strategy." In Proceedings of the 21st International Symposium on the Packaging and Transportation of Radioactive Materials (PATRAM 2025), July 27-August 1, 2025, San Antonio, TX (2025).

NRC (U.S. Nuclear Regulatory Commission). Transportation of Radioactive Materials. NRC Inspection Procedure 86730 (2000).

NRC (U.S. Nuclear Regulatory Commission). *Physical Protection of Shipments of Irradiated Reactor Fuel*. NUREG-0561, Rev. 2. Washington, DC. April (2013).

NRC (U.S. Nuclear Regulatory Commission). *Inspection of Transportation Activities*. NRC Inspection Procedure 86740 (2020).

NRC (U.S. Nuclear Regulatory Commission). Design, Fabrication, Testing, and Maintenance of Transportation Packagings. NRC Inspection Procedure 86001 (2025).

OCRWM (Office of Civilian Radioactive Waste Management). *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions*. U.S. Department of Energy, Washington, D.C. November (2003).

OCRWM (Office of Civilian Radioactive Waste Management). *National Transportation Plan*. DOE/RW-0603. U.S. Department of Energy, Washington, DC. January (2009).

Rigato A.B., H.E. Adkins, Jr, S.M. Short, S.J. Maheras, and G.A. Coles. *Plan for the Development and Application of a Risk Assessment Approach for Transportation Package Approval of a Transportable Nuclear Power Plant for Maritime Shipment*. PNNL-34962, Rev. 1. Pacific Northwest National Laboratory, Richland, WA. January (2024).

SSEB (Southern States Energy Board). *Southern States Energy Board Transportation Planning Guide for the U.S. Department of Energy's Shipments of Transuranic Waste*. Peachtree Corners, GA (2014).

WGA (Western Governors Association). WIPP Transportation Safety Program Implementation Guide. (2017).