



FY2026 Microreactor Transportation Activities

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**DOE-NE Microreactor Program Winter
Review Meeting
March 3-5, 2026**

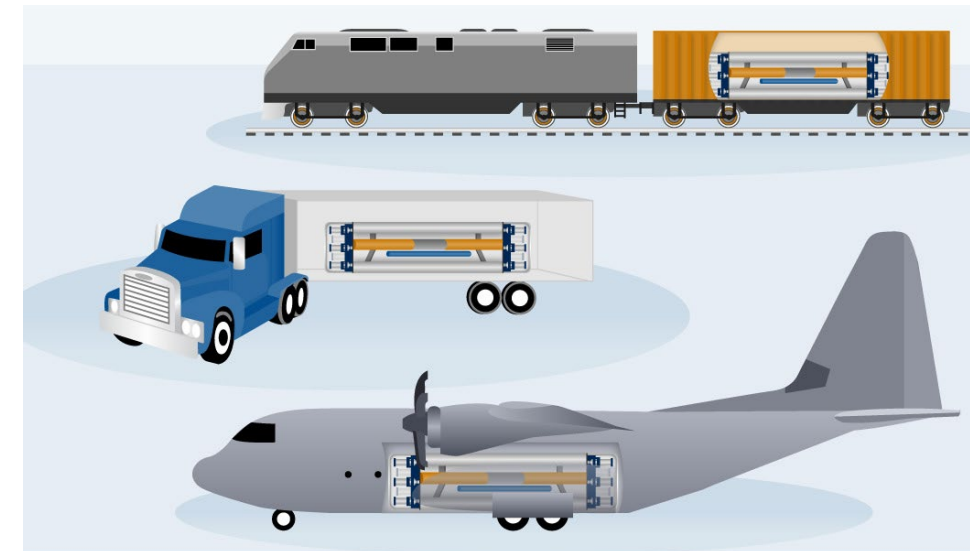


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Microreactor Transportation

- Current microreactor concepts include microreactor transport containing their unirradiated or irradiated fuel
- A microreactor with its unirradiated or irradiated contents is unlikely to meet the entire suite of NRC regulatory requirements in 10 CFR Part 71
- A risk-informed process will likely be used for NRC transportation package approval
 - Demonstrate equivalent safety and that risk to the public is low
 - This will probably require the use of compensatory measures



Source: GAO. | GAO-20-380SP

Current Transportation Approach

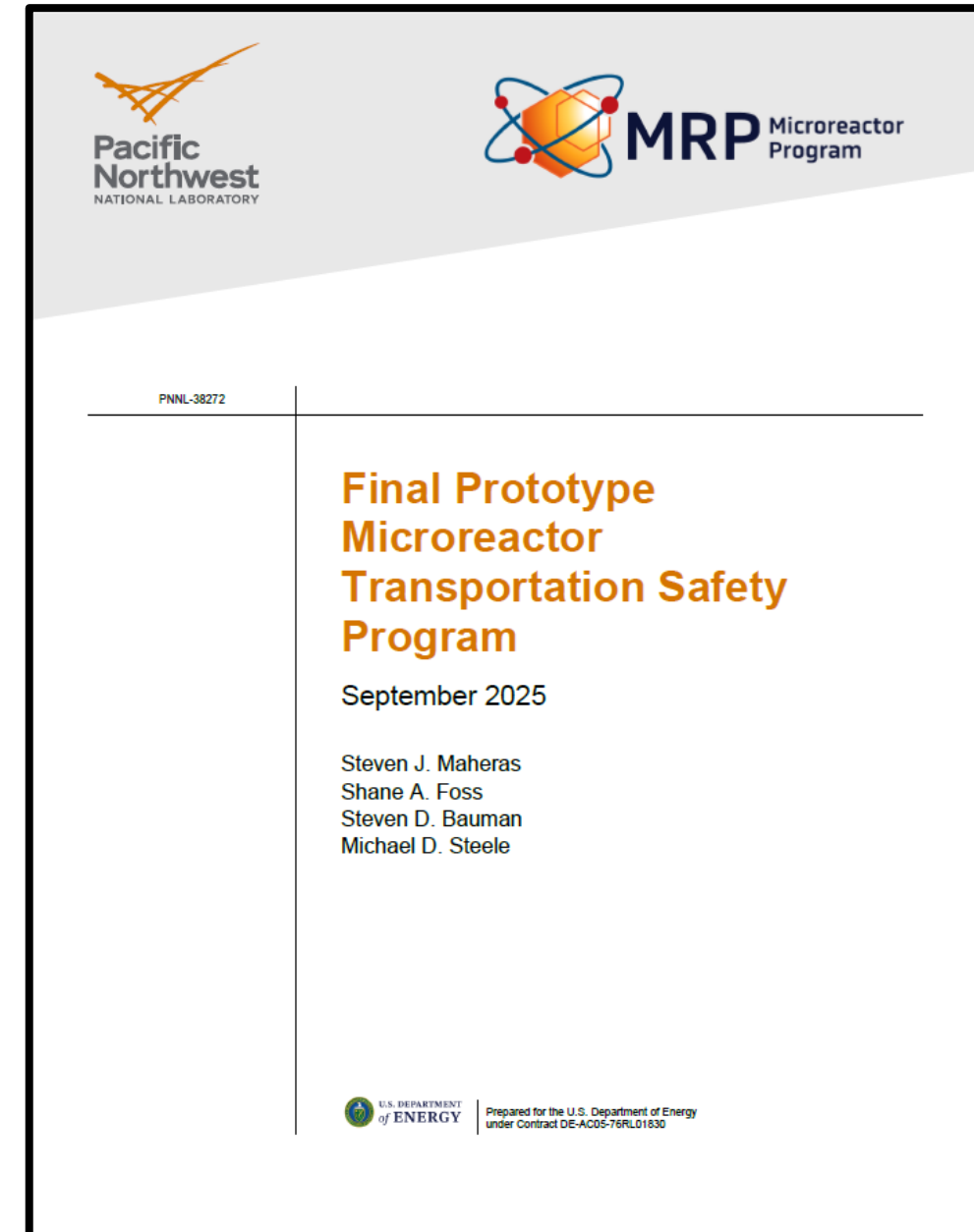
- The microreactor shipment would be a commercial shipment and would receive transportation package approval from the NRC using a risk-informed process
- Strategy is Crawl-Walk-Run
 - Concentrate on highway transport first – received NRC endorsement
 - Then other surface modes (rail and barge/ship) – evaluation of transport by maritime vessel has just started
 - Finally, air transport
- The microreactor containing its irradiated fuel would contain a highway route-controlled quantity 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 385 and 49 CFR 397)
 - For rail shipments this means that the transportation planning requirements in 49 CFR 172.820 would apply
- The microreactor would be fueled by LEU or HALEU (not HEU)
- For rail shipments, transport would be via Association of American Railroads (AAR) Standard S-2043 railcars

Microreactor Transportation Accomplishments

- FY2025 Transportation Accomplishments
 - Prototype microreactor transportation safety program
 - Recommendations for revising ANSI N14.24, *American National Standard for Highway Route Controlled Quantities of Radioactive Materials – Domestic Barge Transport*
- Collaboration Activities
- Exclusion Zone/Dose Rate Study
- FY2026 Transportation Activities
 - Shock and Vibration Functions and Requirements Document for MARVEL
 - Shock and Vibration Test Plan for MARVEL
 - Transportation and Artificial Intelligence (AI)

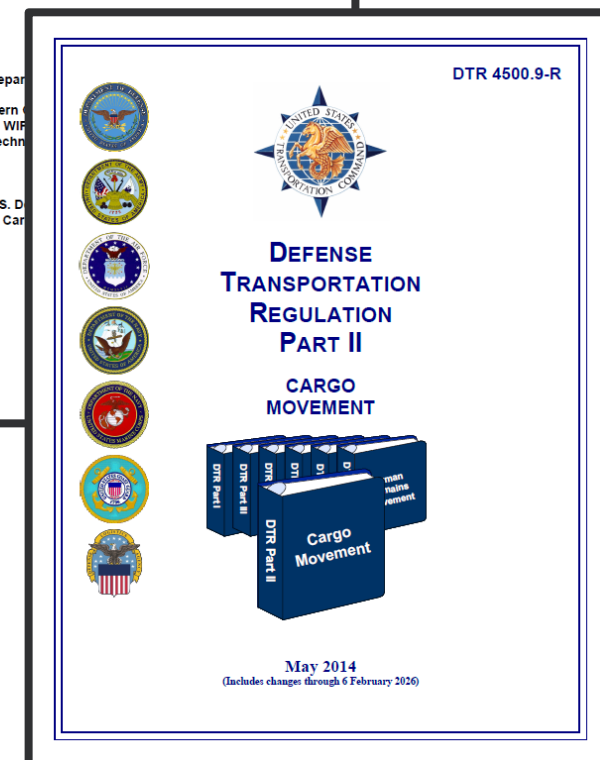
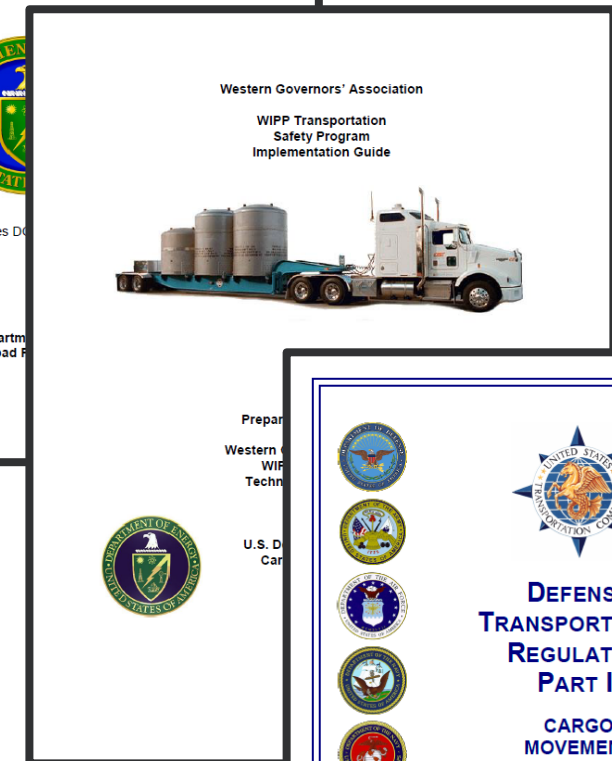
FY2025 Accomplishments – Prototype Microreactor Transportation Safety Program

- Develops the elements of a prototype transportation safety program that describes what should be contained in a vendor-developed microreactor transportation safety program, and identifies the unique elements associated with microreactor transport
 - Report builds on Microreactor Transportation Emergency Planning Challenges
 - Draft report (M4) – 03/31/2025
 - Final report (M2) – 09/30/2025



Microreactor Transportation Safety Program Based on Successful Transportation Programs

- Waste Isolation Pilot Plant (WIPP) TRU Waste Transportation Plan
- WIPP Transportation Safety Program Implementation Guide (PIG)
- Domestic and Foreign Research Reactor Shipments
- DOE Transportation Emergency Preparedness Program (TEPP)
- Commercial Vehicle Safety Alliance (CVSA) Level VI inspection procedures
- Defense Transportation Regulations (DTR 4500.9-R)
- U.S. Department of Transportation (DOT), U.S. Nuclear Regulatory Commission (NRC), and U.S. Department of Energy (DOE) regulations, orders, manuals, guidance, etc.



Contents of Transportation Safety Program

- Transportation Roles and Responsibilities
- Transportation Planning
- Transportation Mode and Route Selection
- Carrier Selection
- Transportation Packaging
- Advance Notification of Shipments
- Public Information
- Emergency Management Considerations
- Inspections
- Security
- Safe Parking
- Shipment Tracking
- Weather and Road Conditions
- Medical Preparedness
- Training and Exercises
- Program Evaluation
- Training and Qualification Program

Unique Elements Associated with Microreactor Transport

- Due to the unusual nature of microreactor designs
 - Increased time may be required for transportation planning
 - Increased coordination with States and Tribes along transportation routes may be required
 - There may be the desire to perform an increased number of en route inspections
 - There may be an increased need for public information and communications regarding microreactor transport
 - There may be calls for increased microreactor-specific training, and there may be additional microreactor-specific training modules that are 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

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 Transportation Safety Program.



Increased Radiation Dose Rates in the Vicinity of Microreactors

- It is likely that microreactors 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 Transportation Safety Program
 - Workers performing CVSA Level VI inspections would be exposed to much higher dose rates, which would need to be factored into the Transportation Safety Program

Step	Item	Inspection Level					
		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	
17	Inspect Left Saddle Tank Area	X	X		X	X	
18	Inspect Trailer Front	X	X		X	X	

Step	Item	I	II	III	V	VI	VIII
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

Transportation Package Approval Versus 10 CFR 50.59

- In the traditional non-risk-informed 10 CFR Part 71 transportation package approval process, changes to the design of a transportation package must be approved by NRC. However, NRC regulation 10 CFR 50.59 allows minor and non-safety effecting 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 lengthen the time and costs required for transportation planning

Use of a Risk-Informed Transportation Package Approval Process

- It is not necessarily anticipated by the NRC that a risk-informed approach can be applied to specifically address or resolve the normal conditions of transport performance objectives (10 CFR 71.71)
- In the traditional non-risk-informed 10 CFR Part 71 transportation package approval process, NRC activities are subject to a categorical exclusion and a 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

FY2025 Accomplishments – Barge Transport

- The successful commercial deployment and redeployment of microreactors may require transport by barge or ship
 - Deployment and redeployment of microreactors to Alaska would likely require transport by sea from the west coast of the US to a port such as Anchorage, Alaska
- The ANSI Standard for barge transport of spent nuclear fuel (N14.24) has not been updated since 1985 and is significantly out-of-date, and does not include consideration of microreactor transport
 - Over the past 40 years since the standard was first published, significant changes have taken place in the maritime industry, making these recommendations necessary
 - For example, the classes of barges discussed in ANSI N14.24 are no longer available
- In addition, the U.S. Coast Guard Navigation and Vessel Inspection Circular for Domestic Barge Transport of Radioactive Materials/Nuclear Waste (NVIC 2-87) has not been revised since 1987
- The objective of this work was to develop recommendations for the revision of N14.24 that will be transmitted to the ANSI N14 Committee
 - Barge consultant subcontracted to assist

United States
Coast Guard

NVIC 2-87
18 Feb 1987

NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 2-87

Subj: Domestic Barge Transportation of Radioactive Materials/Nuclear Waste

1. **PURPOSE.** The purpose of this circular is to call the attention of Coast Guard field units, marine surveyors, the domestic barge transportation community, and others to American National Standards Institute (ANSI) Standard N14.24-1985 HIGHWAY ROUTE CONTROLLED QUANTITIES OF RADIOACTIVE MATERIALS - DOMESTIC BARGE TRANSPORT.
2. **BACKGROUND.**
 - a. The nuclear industry, working through ANSI, develops standards for safety of radioactive materials transportation methods and equipment. Among the standards developed by the ANSI Committee on Transportation of Fissile and Radioactive Materials is ANSI Standard N14.24-1985 HIGHWAY ROUTE CONTROLLED QUANTITIES OF RADIOACTIVE MATERIALS - DOMESTIC BARGE TRANSPORT, approved by ANSI July 23, 1985. Both the Coast Guard and the Department of Energy are represented on the ANSI Committee and participated in preparing this standard.
 - b. When used to describe a shipment of radioactive materials, a "Highway Route Controlled Quantity" means a large quantity of radioactive material based not on the weight or volume of the material, but on its total level of radioactivity (see 49 CFR 173.401(1)). A shipment of radioactive material that is highway route controlled must, under the Department of Transportation's Hazardous Materials Regulations, be operated on routes that minimize radiological risk. These Regulations require highway carriers to consider the accident potential, transit time and population density of their intended routes; to operate, wherever possible on preferred routes in accordance with DOT guidelines; and to have a written route plan, which must be filed with the DOT's Office of Hazardous Materials Transportation.

ANSI N14.24-85 ■ 0724150 0008889 4 ■

ANSI®
N14.24-1985

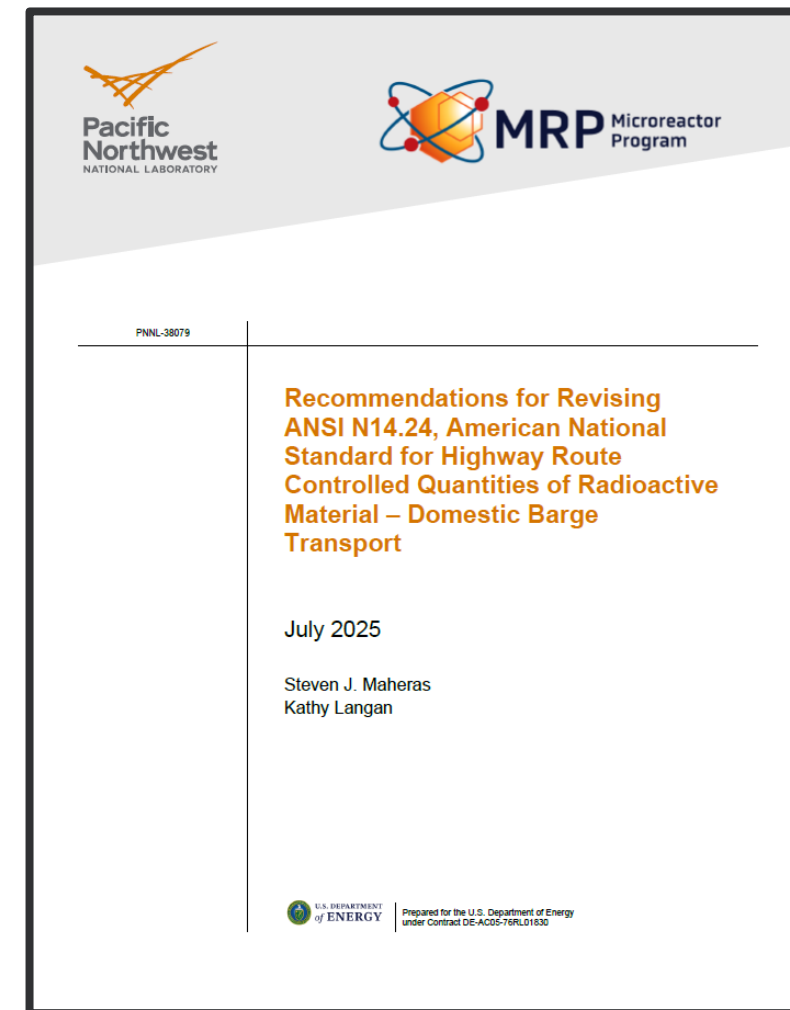
American National Standard
for Highway Route Controlled Quantities
of Radioactive Materials –
Domestic Barge Transport

Secretariat
Institute of Nuclear Material Management

Approved July 23, 1985
American National Standards Institute, Inc

ANSI N14.24 Recommendations – Summary

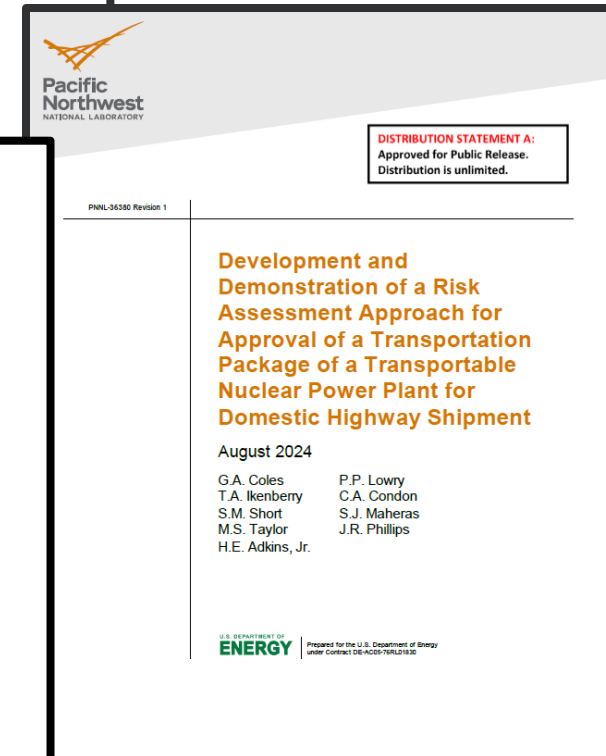
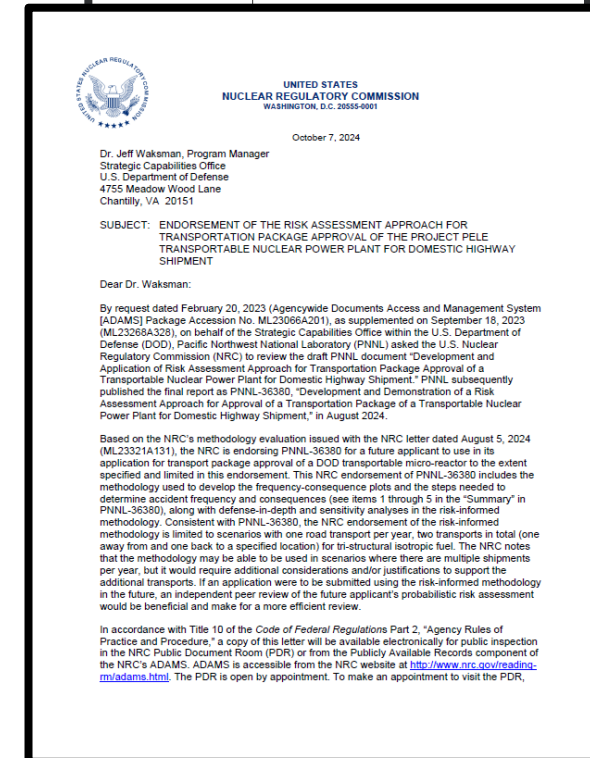
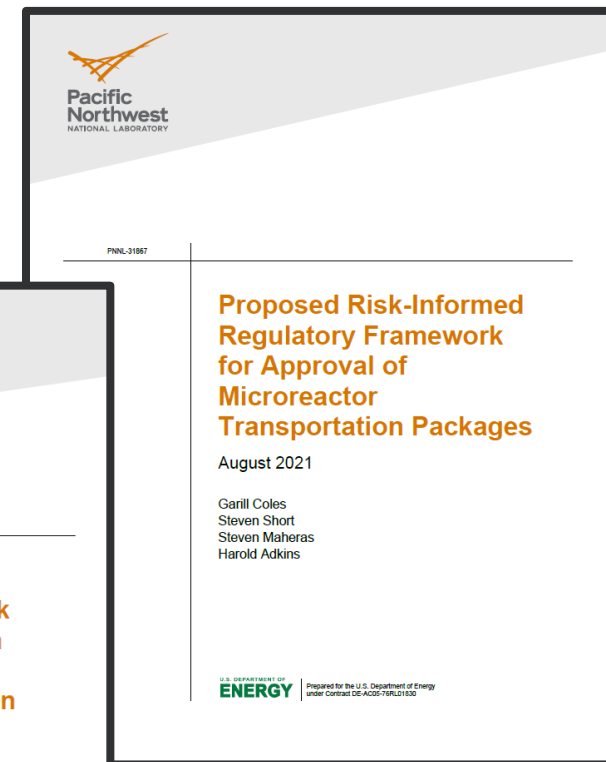
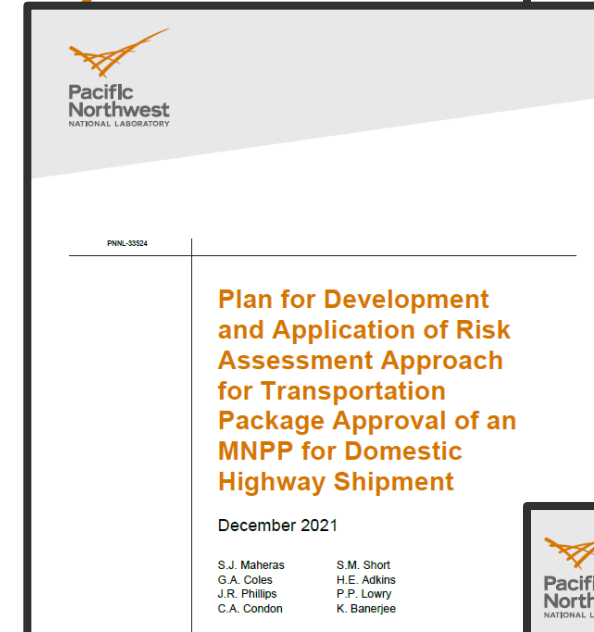
- Recommendations are concentrated in 10 areas:
 1. Reduced restraint values for attaching radioactive cargo to barges
 2. Availability of qualified barges
 3. Use of marine industry guidelines and standards
 4. Use of realistic sea states
 5. Potential modification of barges
 6. Certificates of Inspection
 7. Removal or update of outdated items
 8. Reflection of current barge operations
 9. Inclusion of current industry best practices
 10. Minor revisions.
- The most significant recommendations on updating ANSI N14.24 are in the areas of restraint values and availability of barges. Many of the other recommendations are current industry practice for any heavy cargo barge shipment and are not specific to radioactive material shipments.
- The recommendations could be used by the ANSI N14 *Committee on the Packaging and Transportation of Radioactive Material and Non-Nuclear Hazardous Materials* to revise ANSI N14.24.





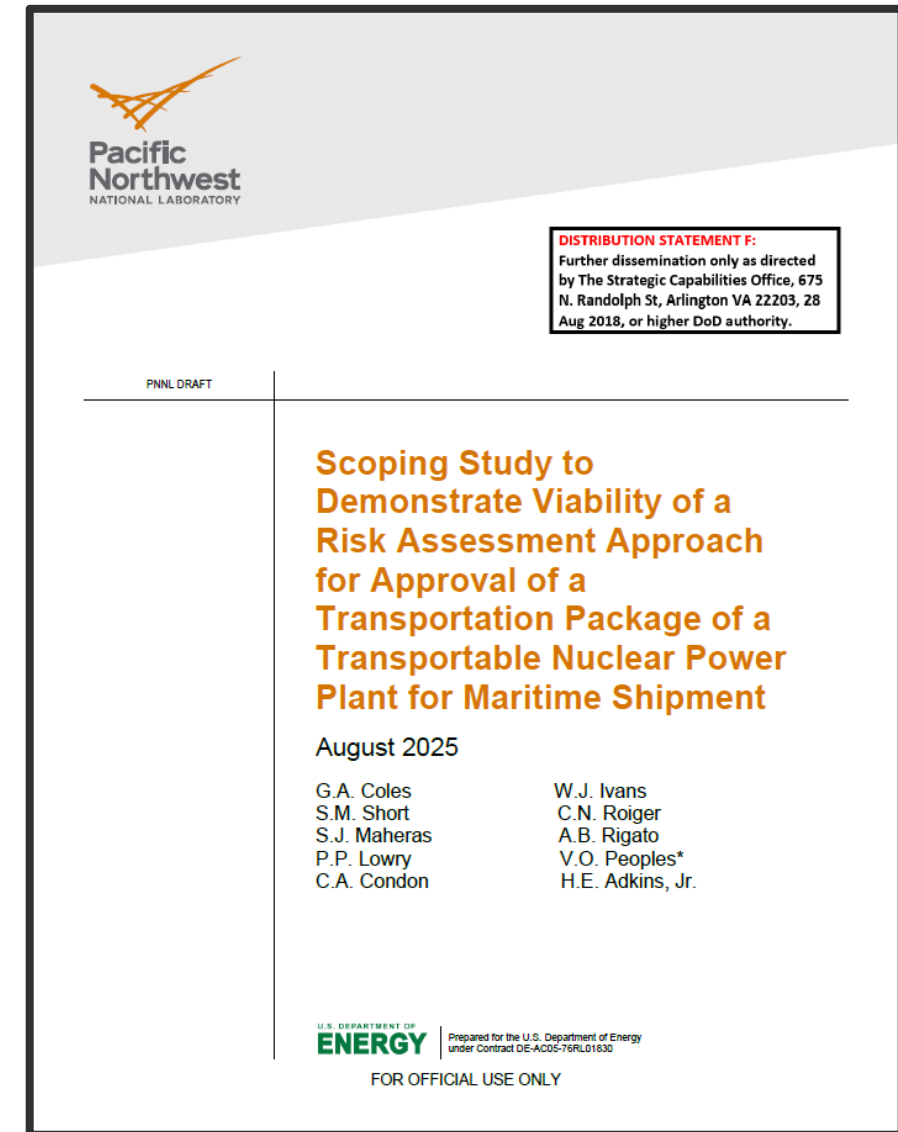
Collaboration Activities – U.S. Department of Defense/War (DoD/DoW) Strategic Capabilities Office (SCO)

- Risk Informed Transportation Package Approval for Domestic Highway Shipment of a TNPP Methodology Document
 - Final report published and docketed
 - [ML24268A101 - 1. PNNL-36380 Rev 1, "Development and Demonstration of a Risk Assessment Approach for Approval of a Transportation Package of a Transportable Nuclear Power Plant for Domestic Highway Shipment August 2024" \(8/21/2024\)](#)
 - [ML24268A102 - 2. List of Updates to 2024 Version of Pele PRA Report \(8/21/2024\)](#)
 - Endorsement letter published and docketed
 - Endorsement of the Risk Assessment Approach for Transportation Package Approval of the Project Pele Transportable Nuclear Power Plant for Domestic Highway Shipment. Docket No. 71-9396. U.S. Nuclear Regulatory Commission. Washington, D.C. October 7, 2024. <https://www.nrc.gov/docs/ML2427/ML24271A054.pdf>



Maritime Risk-Informed Transportation Package Approval Scoping Study

- Risk Informed Transportation Package Approval for OCONUS Maritime Shipment of a TNPP Methodology Document
 - Completed draft document and submitted to NRC on 8/18/2025 for review
 - Engagement meetings with NRC to commence in March
 - Applied concepts and lessons learned from the domestic highway study to maritime shipment involving X-Energy and Nuclear Transport Solutions to receive additional TNPP and transport ship information to support viability of an endorsed approach for approval of maritime shipment of a TNPP package
 - ✓ Revamped a Next Generation Nuclear Plant (NGNP) model to perform MAR predictive evaluations with X-Energy (featured in a topical submitted to NRC to support installation energy initiatives)
 - Endorsement targeted for end of CY26



DoD/DoW Operational Energy Capability Improvement Fund (OECIF)

- Maritime Nuclear Asset Transportation Capability Development (MNATC)
 - In-Depth Study to Analyze Maritime Options Available to the DoD To Transport Nuclear Reactors
 - Subset of Study will also Examine Options to Retrofit a DoD Cargo Vessel or Procure Vessels to Meet INF Code Requirements and DoD Objectives

- Legal and Regulatory Taxonomy for Maritime Nuclear Defense Applications (TMNDA)
 - In-Depth Study to Analyze Legal and Regulatory Frameworks, Gaps and Seams Relevant to DoD Maritime Nuclear Reactors
 - Subset of Study will also Examine Options and DoD Objectives
 - Goal is to meet requirements to achieve sustainable, reliable and scalable microgrid with reserve power capability for operations and expeditionary support

- Target completion for both studies end of FY26

Military Sealift Command

10 large medium speed roll-on/roll-off ships

USNS Gilliland
USNS Gordon
USNS Benavidez
USNS Mendonca
USNS Shughart
USNS Watson
USNS Yano
USNS Bob Hope
USNS Brittin
USNS Fisher



5 roll-on/roll-off/ container ships

USNS SGT Matej Kocak
USNS LCPL Roy M. Wheat
USNS 1st LT Larry L. Martin
USNS PFC Eugene A. Obregon
USNS MAJ Stephen W. Pless



Maritime Administration

27 roll-on/roll-off ships

MV Cape Decision
MV Cape Diamond
MV Cape Domingo
MV Cape Douglas
MV Cape Ducato
MV Cape Edmont
MV Cape Race
MV Cape Ray
MV Cape Rise
MV Cape Washington
MV Cape Wrath
MV Cape Kennedy
MV Cape Knox
MV Cape Taylor
MV Cape Texas
MV Cape Trinity
MV Cape Victory
MV Cape Vincent
GTS ADM William Callaghan
MV Cape Henry
MV Cape Horn
MV Cape Hudson
SS Cape Inscription
SS Cape Intrepid
SS Cape Isabel
SS Cape Island
MV Cape Orlando



8 fast sealift ships

SS Antares
SS Denebola
SS Altair
SS Bellatrix
SS Pollux
SS Regulus
SS Algol
SS Capella



6 auxiliary crane ships

SS Comhusker State
SS Flickertail State
SS Gopher State
SS Gem State
SS Grand Canyon State
SS Keystone State



2 aviation logistics support ships

SS Wright
SS Curtiss



1 offshore petroleum discharge system

SS Petersburg



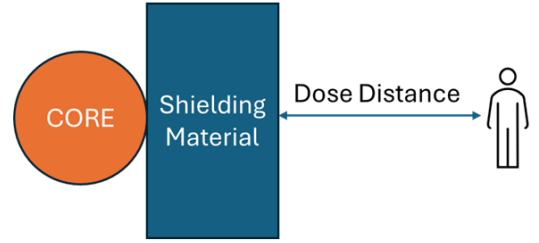
2 heavy lift ships

SS Cape May
SS Cape Mohican



Exclusion Zone/Dose Rate Study

- Performed preliminary DOT exclusion zone/shielding study for Rian Bahrn (NE-5 DAS) and DOE Microreactor Program
 - ORNL, INL, and PNNL Team
 - Calculation tool has three reactor types, multiple power levels, accounts for shielding and exclusion zone distance, decay time, costs, weights, etc.
 - Study looked at impacts of expanding exclusion zone distance, increasing shielding, varying decay times, and different dose rates limits, etc.
 - Study will be refined after additional engagement with DOT



Parameter	Dropdown selection	Notes
Select Reactor	HTPM	Mandatory selection SFM: Sodium-cooled fast microreactor HTPM: High-temperature helium-cooled prismatic microreactor HPMR: Heat pipe-cooled microreactor
Reactor Power	1 MWt	Choose reactor power based on the reactor design: SFM=10 or 30 MWt; HTPM=1, 10, or 30 MWt; HPMR=5, 15, or 30 MWt
Cooldown Interval (months)	0	Mandatory entry: Only enter integer value between 0 and 36 (i.e., up to 3 years)
Shielding Material	Stainless Steel	Optional: Lead, Stainless Steel, Tungsten, Concrete
Shielding Thickness (cm)	40	Mandatory selection if Shielding Material selected
Dose Rate Distance (m)	10	Mandatory selection
Electricity Market	U.S Grid Wholesale	Choose the electricity market Assumed wholesale electricity price for the U.S Grid is 40\$/MWh Assumed wholesale electricity price for Alaska Railbelt is 100\$/MWh Assumed wholesale electricity for Island communities and remote mining is 200 \$/MWh Assumed wholesale electricity for remote defense installations 300 \$/MWh Assumed wholesale electricity for remote arctic communities is 450 \$/MWh
Dose Rate (mrem/h)	93.00	Calculated dose rate using point gamma source; gamma emissions grouped into 48 or 37 energy bins and used the formula listed in the Additional Notes section; this rate includes assumed buildup of 10% and skyshine dose, which is assumed to be 5% of the unshielded dose
Reactor Weight (metric ton)	33.00	Weight of the reactor in metric ton
Shielding Weight (metric ton)	87.00	Weight of the shielding material in metric ton
Cost for Shielding (\$)	\$ 870,000.00	Using a base unit price of \$2,000/ton for lead, \$10,000/ton for stainless steel, \$50,000/ton for tungsten, and \$750/ton for concrete
Lost Revenue from Downtime (\$)	\$ -	Assuming discount rate of 7%, levelization period of 30 years, and 30% thermal efficiency

Additional Notes

SFM core height is 4 m and 5.5 m for 10 and 30 MWt, respectively, and each has a core radius of 0.84 m
 HTPM core radius is 1.3 m (1 and 10 MWt) or 2 m (30 MWt) and height is 2.4 (1 MWt) or 3.2 m (10 and 30 MWt)
 HPMR core radius is 1.12 m, 1.4 m, and 1.7 m for 5, 15, and 30 MWt, respectively, and each has a height of 2 m
 For stainless steel, mass attenuation coefficient of iron is used
 No self-shielding or shielding from internal core components or reactor vessel is considered in this assessment
 Shielding design includes an annular cylinder surrounding the reactor, along with 10 cm-thick shielding at both the top and bottom
 Formula:

$$\dot{D} = 0.014BS \frac{ME}{d^2} \exp\left(-\left[\frac{\mu}{\rho}\right] \rho t\right)$$

\dot{D} : Dose rate in mrem/h
 B: Buildup, 1.1 (assumed)
 S: Skyshine, 1.05 (assumed)
 M: Activity in MBq
 E: Energy in MeV
 d: Distance in m from the shield or core
 μ/ρ : Mass attenuation coefficient (cm²/g)
 ρ : Density (g/cm³)
 t: Shielding thickness (cm)

FY2026 Transportation Activities – Transportation Shock and Vibration

- Develop a Plan for Shock and Vibration Testing at INL for MARVEL
 - Offsite highway travel from Idaho Falls to INL facilities at MFC, and onsite highway travel on the INL site, taking advantage of the existing road infrastructure at INL
 - ***NOTE: There are no plans to physically ship the MARVEL microreactor at this time***
- As a first step, a Functions and Requirements Document would be developed
- As a second step, a Shock and Vibration Test Plan would be developed
- Using MIL-STD-810H, *U.S. Department of Defense Test Method Standard, Environmental Engineering Considerations and Laboratory Tests*, as starting point
- Leveraging Project PELE Microreactor Test and Evaluation Master Plan (TEMP), Package Performance Study (PPS) Functions and Requirements Document (F&RD), Project PELE Reactor Health Monitoring Information System (HMIS) Data Collection and Monitoring Requirements
- PNNL and INL collaborating on this activity.
- Functions and Requirements Document (M4) – 05/31/2026
- Shock and Vibration Test Plan (M3) – 09/30/2026

FY2026 Transportation Activities – Transportation and Artificial Intelligence

- Explore use of Artificial Intelligence (AI) to Prepare Microreactor Transportation Safety Analysis Reports
 - This activity will investigate the use of AI to expedite the preparation of microreactor transportation safety analysis reports (SARs) and propose a methodology for doing so.
 - Two initial considerations
 - ✓ Proprietary nature of data used in transportation SARs could limit use of AI to vendor-specific applications
 - ✓ Withholding of data for security reasons could also limit use of AI to vendor-specific applications
 - As the activity progresses, there will be opportunities for collaboration with industry and National Laboratories
 - ✓ Savannah River National Laboratory had a nascent effort focused on writing Chapter 1 (General Information) of a transportation SAR
 - Draft Feasibility Assessment (M4) – 04/30/2026
 - Final Feasibility Assessment (M3) – 08/31/2026



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Thank you

