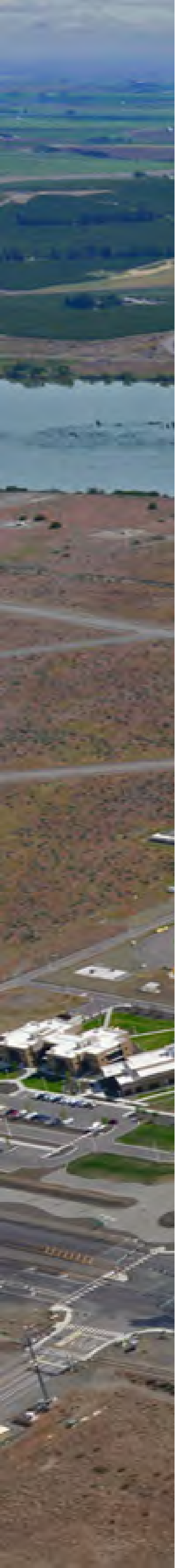

Microreactor Transportation Emergency Planning Challenges

Steven J. Maheras

Shane A. Foss

Ryanne E. Reed

DOE-NE Microreactor Program Winter Review Meeting
March 5-6, 2024

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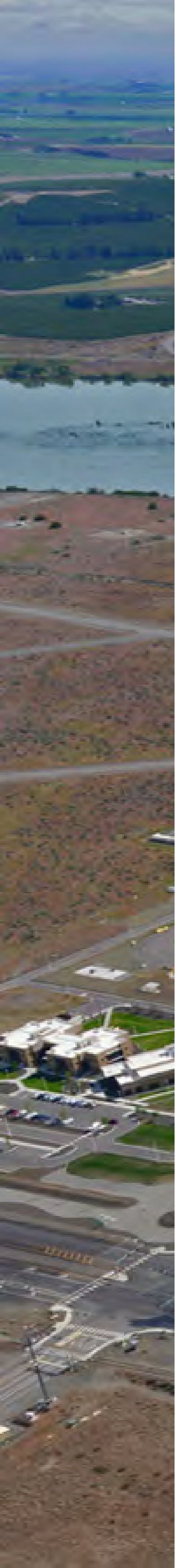
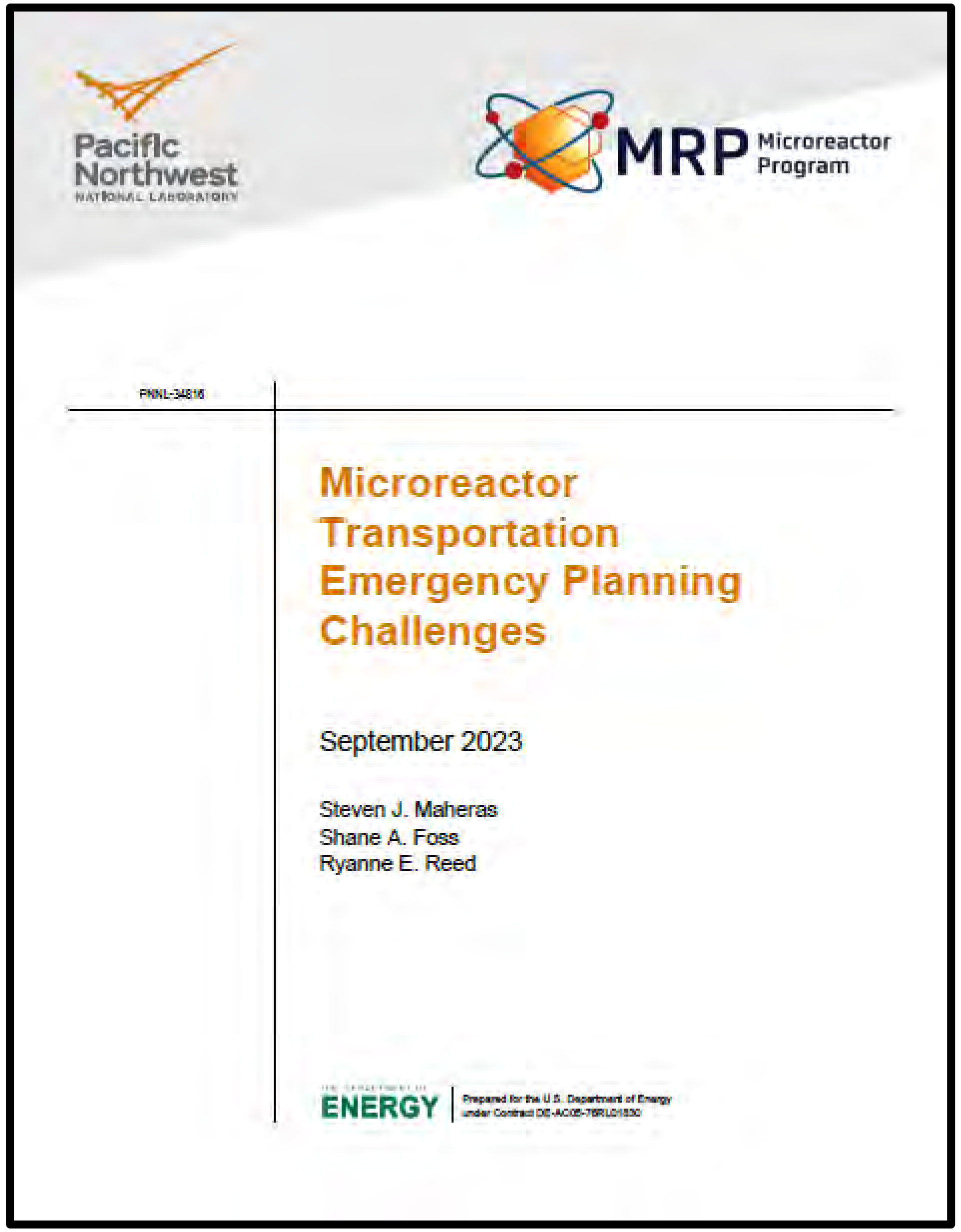


Microreactor Transportation Emergency Planning Challenges – Accomplishments

- Microreactor Transportation Emergency Planning Challenges – September 2023
- Microreactor transportation presentations and panels
  - Waste Management Conference, February 26-March 2, 2023, Phoenix, Arizona
  - Transportation Core Group Meeting, March 7-8, 2023, Washington, DC
  - National Transportation Stakeholders Forum Meeting, May 22-25, 2023, St. Louis, Missouri
  - Transportation Core Group Meeting, September 6-7, 2023, Prairie Island Indian Community, Red Wing, Minnesota
  - Western Interstate Energy Board, November 8-9, 2023, Idaho Falls, Idaho
  - INMM 37th Spent Fuel Management Seminar, January 17-18, 2024, Alexandria, Virginia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MRP Microreactor Program
PNNL-34816
Microreactor Transportation Emergency Planning Challenges
September 2023
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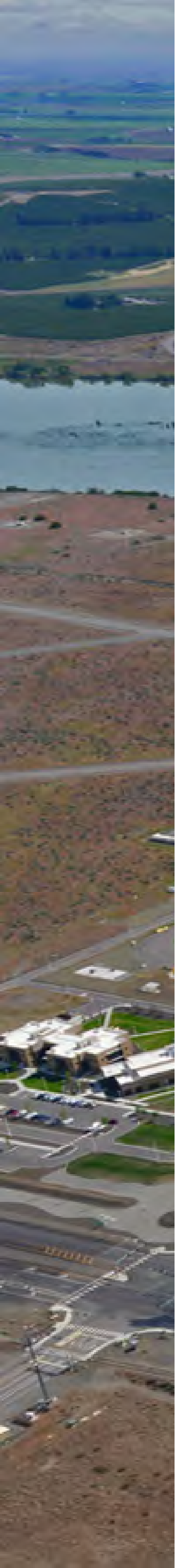
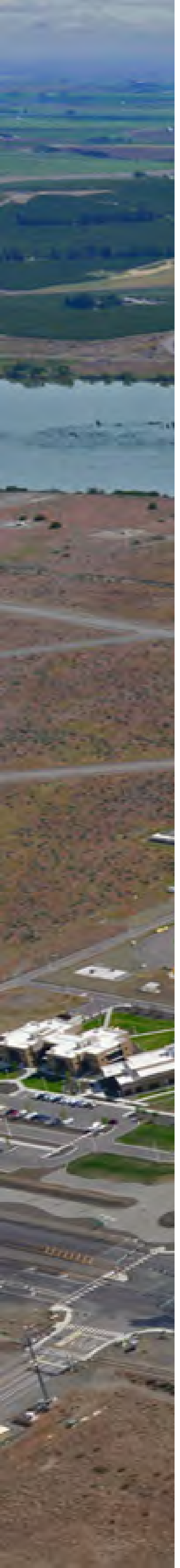
ENERGY | Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830



FY2024 Activities

- Revising Microreactor Transportation Emergency Planning Challenges Report
  - M3 milestone (due 09/30/2024) funded from FY2023 carryover
- Microreactor Panel at Waste Management 2024 Conference, March 10-15, 2024
- National Transportation Stakeholders Forum Meeting, June 3-6, 2024
- IAEA Spent Fuel Management Conference, June 10-14, 2024



Collaboration Activities

- Working closely with the DoD Strategic Capabilities Office (SCO)
  - Project Pele
  - Presented risk-informed transportation package approval methodology to NRC Advisory Committee on Reactor Safeguards (ACRS)
    - ✓ ACRS Subcommittee – November 17, 2023
    - ✓ Full ACRS – December 6, 2023
    - ✓ Endorsement of methodology by NRC expected Q2 FY2024
- Working closely with Army Reactor Office (ARO) and the Army Office of the Chief of Engineers (OCE)
- Working closely with NRIC on maritime transport of microreactors

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Development and Application of Risk Assessment Approach for Transportation Package Approval of a Transportable Nuclear Power Plant for Domestic Highway Shipment

November 2022

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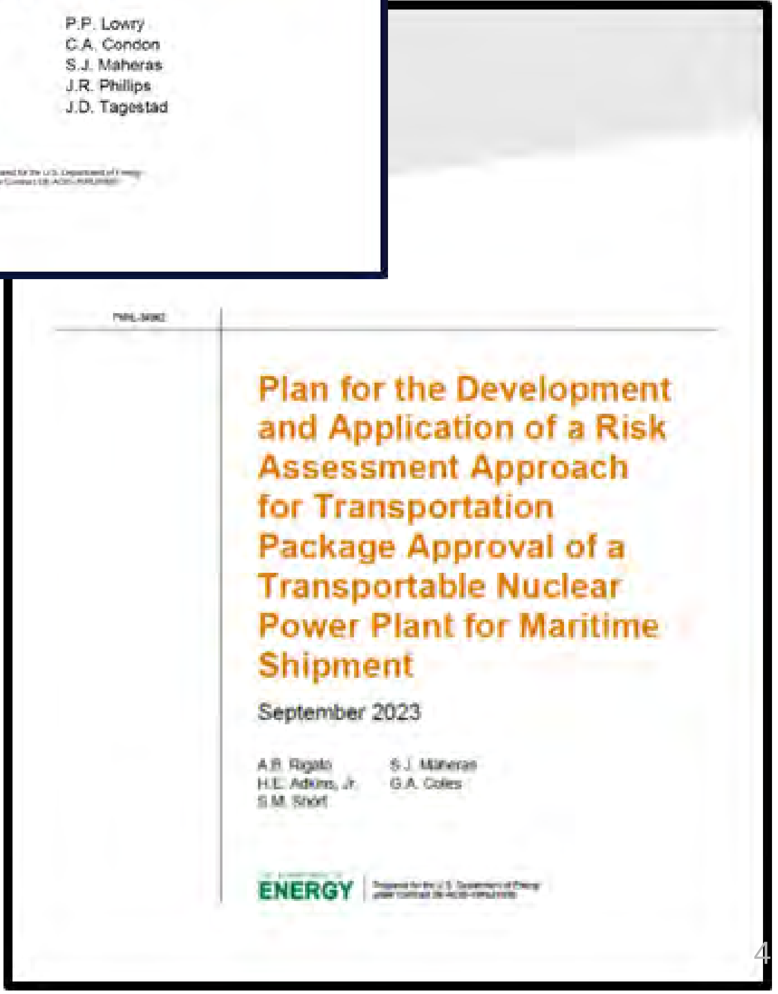
U.S. DEPARTMENT OF ENERGY



Plan for the Development and Application of a Risk Assessment Approach for Transportation Package Approval of a Transportable Nuclear Power Plant for Maritime Shipment

September 2023

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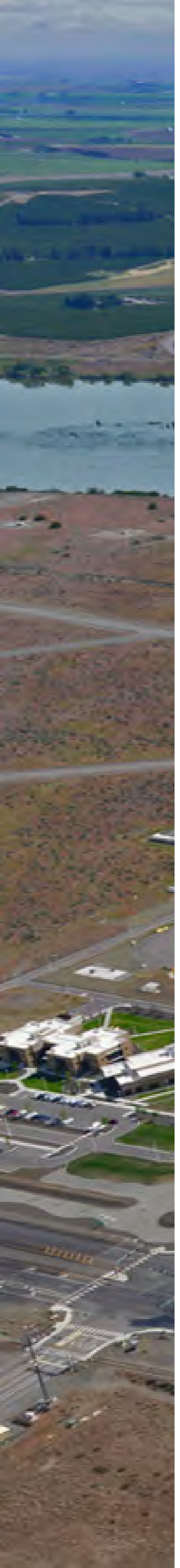

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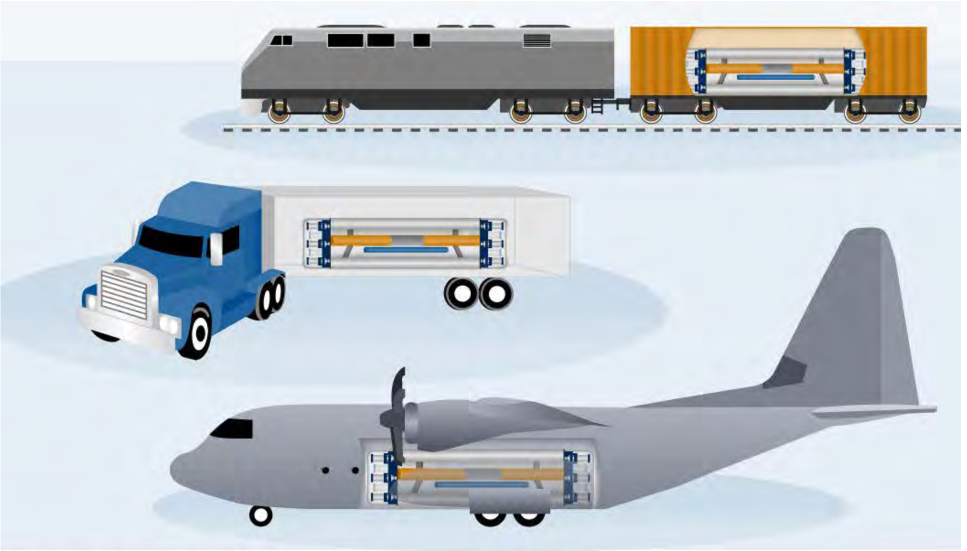
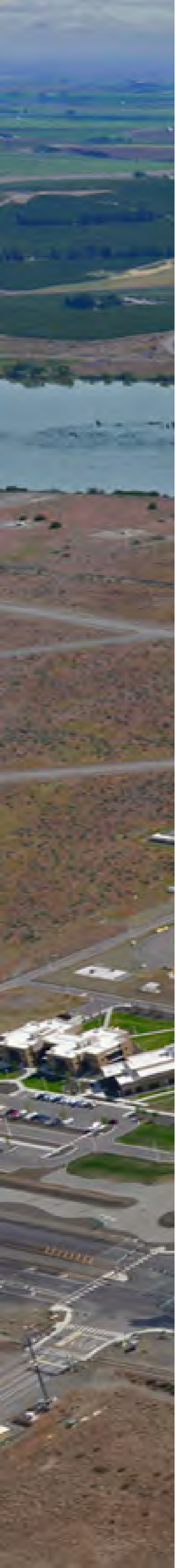
Microreactor Transportation

- Current microreactor concepts are to transport the microreactor containing its 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

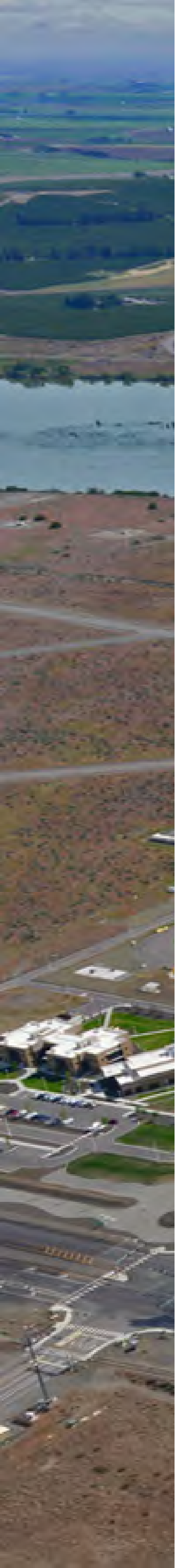


Source: GAO. | GAO-20-380SP



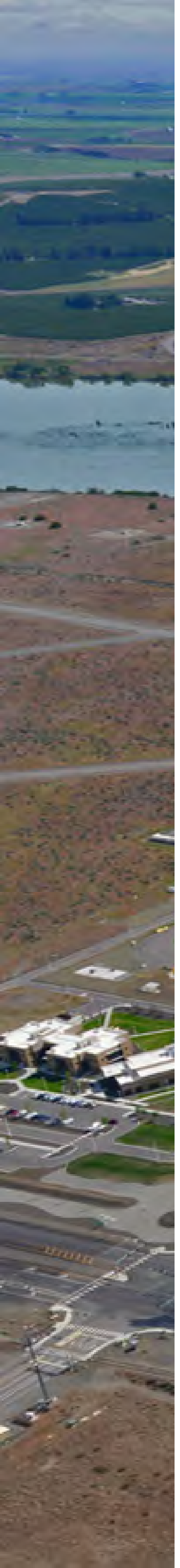
Current Transportation Approach

- 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
  - Then other surface modes (rail and barge/ship) – evaluation of transport by 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 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



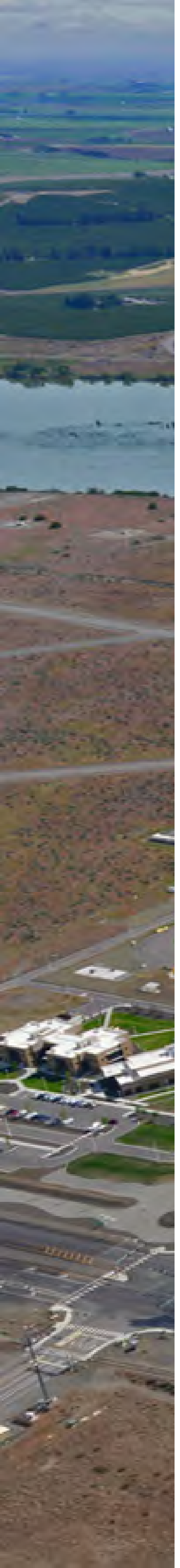
Areas Examined In Identifying Microreactor Transportation Emergency Planning Challenges

• Assignment of Responsibility	• Accident Assessment
• Emergency Response Organization	• Protective Response
• Emergency Response Support and Resources	• Radiological Exposure Control
• Emergency Classification System	• Medical and Public Health Support
• Notification Methods and Procedures	• Recovery, Reentry, and Post-Accident Operations
• Emergency Communications	• Exercises and Drills
• Public Education and Information	• Radiological Emergency Response Training
• Emergency Facilities and Equipment	• Responsibility for the Planning Effort: Development, Periodic Review, and Distribution of Emergency Plans



Results of Evaluation

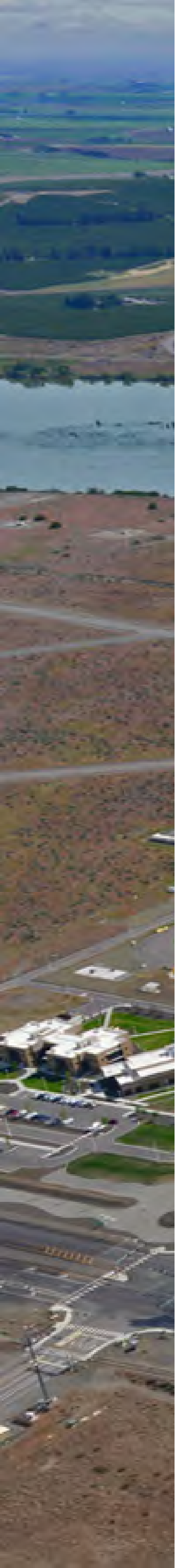
- Microreactor transportation emergency planning challenges organized into cross-cutting challenges and specific transportation emergency response challenges
- This presentation will discuss several cross-cutting transportation emergency planning challenges
  - Use of hazardous materials in microreactor designs
  - Revisions to the DOT Emergency Response Guidebook
  - Potential compensatory measures
  - External Engagement, Emergency Response Training, and Accident Recovery Plans
- Discussions with States and Tribes also discussed



Use of Hazardous Materials in Microreactor Designs

- Beryllium-containing materials are currently being investigated for use in microreactors as replacements for graphite as a neutron moderator (Cheng et al., 2022)
- Beryllium is a hazardous material and if these beryllium-containing materials were incorporated into a microreactor, the presence of these materials would have to be considered in the transportation emergency response planning for these specific microreactors
- Sodium-containing heat pipes are being investigated for use in some microreactors, such as the Westinghouse eVinci microreactor
- Sodium is a hazardous material and the presence of sodium would have to be considered in the transportation emergency response planning for these microreactors, specifically in two areas:
  - The ability of sodium in combination with water to exacerbate releases of radioactive material during a transportation accident, and
  - The need to modify transportation accident fire-fighting guidelines if sodium was present

Source: Cheng B., E. M. Duchnowski, D. J. Sprouster, L. L. Snead, N. R. Brown, and J. R. Trelewicz. 2022. “Ceramic Composite Moderators as Replacements for Graphite in High Temperature Microreactors.” Journal of Nuclear Materials. Volume 563.



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Emergency Response Guidebook (ERG)

- The DOT Pipeline and Hazardous Materials Safety Administration ERG provides first responders with a manual to help deal with hazardous materials transportation accidents during the critical first 30 minutes after the accident
- Emergency responders are trained to use the shipping papers, numbered placard, or orange panel number to determine which emergency response guide to use in responding to the accident
- The emergency response guides were not developed based on transportation accidents involving microreactors containing irradiated fuel
- The ERG would have to be expanded to include a guide that is specific to microreactor transportation accidents
- The guide may have to be fuel-type specific because of the differences in potential releases from different microreactor fuel types
- The guide may also have to be modified to account for the presence of hazardous materials such as beryllium or sodium

GUIDE 165 RADIOACTIVE MATERIALS (FISSILE/LOW TO HIGH LEVEL RADIATION)

POTENTIAL HAZARDS

HEALTH
- Radiation presents minimal risk to transport workers, emergency response personnel and the public during transportation accidents. Packaging durability increases as potential radiation and criticality hazards of the content increase.
- Undamaged packages are safe. Contents of damaged packages may cause higher external radiation exposure, or both external and internal radiation exposure if contents are released.
- Type AF or IF packages, identified by package markings, do not contain life-threatening amounts of material. External radiation levels are low and packages are designed, evaluated and tested to control releases and to prevent a fission chain reaction under severe transport conditions.
- Type B(U)F, B(M)F and CF packages (identified by markings on packages or shipping papers) contain potentially life-endangering amounts. Because of design, evaluation and testing of packages, fission chain reactions are prevented and releases are not expected to be life-endangering for all accidents except those of utmost severity.
- The rarely occurring "Special Arrangement" shipments may be of Type AF, BF or CF packages. Package type will be marked on packages, and shipment details will be on shipping papers.
- The transport index (TI) shown on labels or a shipping paper might not indicate the radiation level at one meter from a single, isolated, undamaged package; instead, it might relate to controls needed during transport because of the fissile properties of the materials. Alternatively, the fissile nature of the contents may be indicated by a criticality safety index (CSI) on a special FISSILE label or on the shipping paper.
- Some radioactive materials cannot be detected by commonly available instruments.
- Water from cargo fire control is not expected to cause pollution.

FIRE OR EXPLOSION
- These materials are seldom flammable. Packages are designed to withstand fires without damage to contents.
- Radioactivity does not change flammability or other properties of materials.
- Type AF, IF, B(U)F, B(M)F and CF packages are designed and evaluated to withstand total engulfment in flames at temperatures of 800°C (1475°F) for a period of 30 minutes.

PUBLIC SAFETY
- **CALL 911. Then call emergency response telephone number on shipping paper.** If shipping paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.
- **Priorities for rescue, life-saving, first aid, fire control and other hazards are higher than the priority for measuring radiation levels.** • Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.
- Stay upwind, uphill and/or upstream. • Keep unauthorized personnel away.
- Detain or isolate uninjured persons or equipment suspected to be contaminated; delay decontamination and cleanup until instructions are received from Radiation Authority.

PROTECTIVE CLOTHING
- Positive pressure self-contained breathing apparatus (SCBA) and structural firefighters' protective clothing will provide adequate protection against internal radiation exposure, but not external radiation exposure.

EVACUATION

Immediate precautionary measure
- Isolate spill or leak area for at least 25 meters (75 feet) in all directions.

Large Spill
- Consider initial downwind evacuation for at least 100 meters (330 feet).

Fire
- When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

In Canada, an Emergency Response Assistance Plan (ERAP) may be required for this product. Please consult the shipping paper and/or the ERAP Program Section (page 390).

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RADIOACTIVE MATERIALS (FISSILE/LOW TO HIGH LEVEL RADIATION) **GUIDE 165**

EMERGENCY RESPONSE

FIRE
- Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques.
- If it can be done safely, move undamaged containers away from the area around the fire.
- Do not move damaged packages; move undamaged packages out of fire zone.

Small Fire
- Dry chemical, CO_2, water spray or regular foam.

Large Fire
- Water spray, fog (flooding amounts).

SPILL OR LEAK
- Do not touch damaged packages or spilled material.
- Damp surfaces on undamaged or slightly damaged packages are seldom an indication of packaging failure. Most packaging for liquid content have inner containers and/or inner absorbent materials.

Liquid Spill
- Package contents are seldom liquid. If any radioactive contamination resulting from a liquid release is present, it probably will be low-level.

FIRST AID
- Call 911 or emergency medical service.
- Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves.
- Medical problems take priority over radiological concerns.
- Use first aid treatment according to the nature of the injury.
- Do not delay care and transport of a seriously injured person.
- Give artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult.
- In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
- Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.

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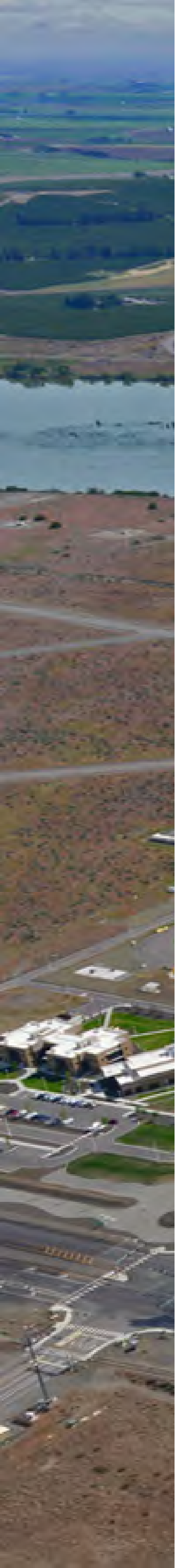
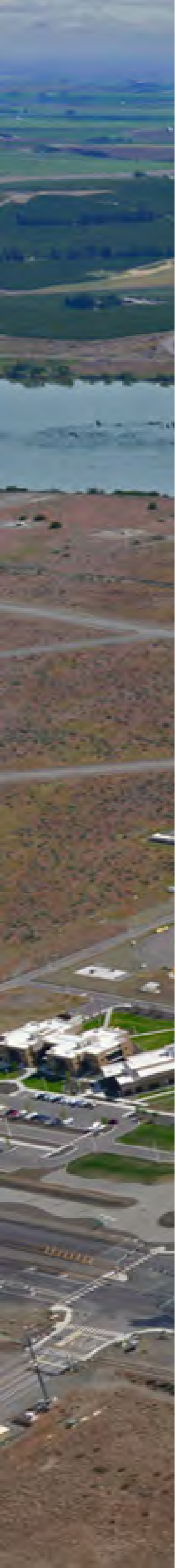


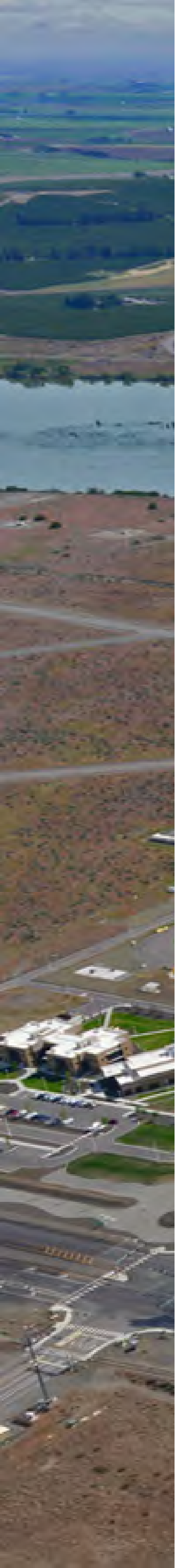
Potential Compensatory Measures

- Microreactors containing irradiated fuel shipped by highway would be highway route-controlled quantities (HRCQ) (> 3000 A_2) shipments and would need to meet the routing requirements in 49 CFR Part 397
  - The use of interstates, beltways around cities, state identified preferred routes could be considered as compensatory measures
- Microreactors will likely be overweight/overdimension and will require state permitting when transported by highway
  - Specific heavy haul truck or superload permit requirements could be considered as compensatory measures



Other Potential Compensatory Measures

- Other potential compensatory measures include:
  - Increased exclusion zone around the microreactor because of possible radiation dose rate increase
  - Real time health/fitness onboard monitoring/diagnostics of reactor package
  - Escorting of the reactor forward and aft for the entire route
  - Rolling road closures
  - Travel at reduced speeds
  - Choosing a route that avoids bodies of water (balanced by quality of road)
  - Controls for bridges over bodies of water (bridge inspection, speed reduction, close bridge to other traffic)
  - Judicious use of time-of-day and day-of-week restrictions
  - Avoid shipping during severe weather
  - Conduct training for emergency responders along the route

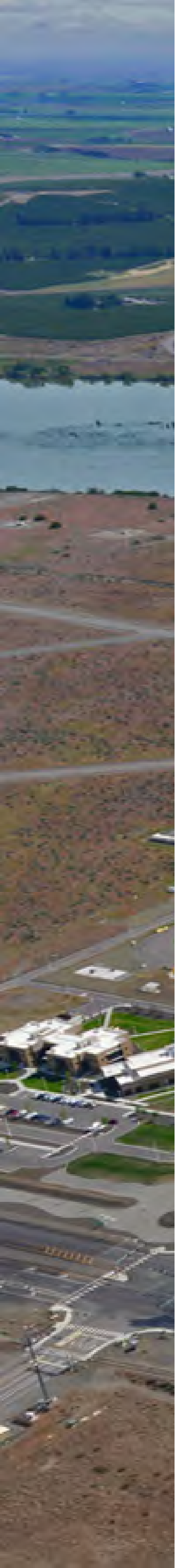


Potential Issue Associated with Compensatory Measures

- It is likely that NRC microreactor transportation package approval would be conducted using a risk-informed process and the microreactor containing irradiated fuel may not meet the 10 mrem/hr at 2 meters from the conveyance dose rate limit contained in 49 CFR 173.441 and 10 CFR 71.47
- As a result, the microreactor may require a stand-off distance of approximately 30 meters to obtain a dose rate of 10 mrem/hr, depending on the amount of shielding and storage time
- This could have implications for transportation emergency response planning if external package dose rates keep responders and recovery crews from meeting necessary objectives for recovery and mitigation

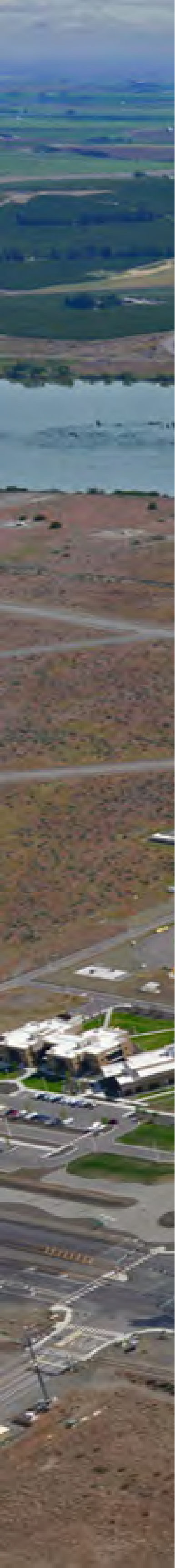
External Engagement, Emergency Response Training, and Accident Recovery Plans

- Conducting external engagement prior to transporting a microreactor containing its irradiated fuel
  - A microreactor containing its irradiated fuel has not been shipped in the U.S., and State and Tribal emergency responders along potential routes are likely to be unfamiliar with microreactor transport
  - This engagement could take 2 to 3 years
- Potential need to conduct emergency response training along transport routes
- Potential need to develop transportation accident recovery plans



Discussions with States and Tribes

- In general, the transportation emergency response community is not familiar with microreactors or the concept of transporting a microreactor containing its irradiated fuel
- The purpose of the discussions was to obtain State and Tribal perspectives on the potential emergency planning challenges associated with the transportation of a microreactor containing its irradiated fuel
- The challenges may differ from shipments of spent nuclear fuel in Type B transportation casks (the current paradigm)
- Some challenges are likely to be mode-specific (i.e., different for shipment by truck, rail, air, and vessel)
- Some challenges will be design-specific, e.g., presence of other hazardous materials



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Thank you