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BUILDING PUBLIC UNDERSTANDING OF TRANSPORTING SPENT NUCLEAR FUEL BY RAIL IN THE UNITED STATES: LESSONS LEARNED FROM A RAIL ROUTING WORKSHOP

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ABSTRACT

The US Department of Energy (DOE) is planning for future large-scale transportation of commercial spent nuclear fuel (SNF) from multiple sites around the country to eventual disposal and/or consolidated storage facilities. Due to the size and weight of commercial SNF containers in the US, the majority of shipments are expected to move via railroad. However, through interactions with US State government and Tribal government representatives, DOE identified that while transport of radioactive materials via highway in the US is well-understood, there are significant information gaps with respect to transport of radioactive materials by rail. Through DOE's National Transportation Stakeholders Forum (NTSF), an ad hoc working group was established to engage State and Tribal government representatives, provide information, and answer questions relating to freight rail transport of radioactive materials. One of the main topics of stakeholder interest was understanding how rail transport routes for SNF would be identified. To address these questions, in summer 2017 DOE conducted a Spent Nuclear Fuel Routing Workshop (Routing Workshop) with rail carrier industry representatives and State and Tribal members of the NTSF SNF Rail/Routing ad hoc working group. The goals of the Routing Workshop were to exchange information in order to gain an understanding of how rail carriers determine rail transport routes in compliance with US Department of Transportation regulations, identify opportunities for State and Tribal input or participation in the route identification process, build common ground based on a shared goal of transport safety and security, and open a dialogue between the participants. This paper describes the Routing Workshop preparations, design, outcomes, and lessons learned.

The Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste (Standard Contract) (10 CFR Part 961) establishes the terms and conditions under which DOE will

take title to, transport, and dispose of SNF delivered to DOE by those owners or generators who execute the contract. This is a technical paper that does not take into account contractual limitations or obligations under the Standard Contract. For example, under the provisions of the Standard Contract, spent nuclear fuel in multi-assembly canisters is not an acceptable waste form, absent a mutually agreed to contract amendment. To the extent discussions or recommendations in this paper conflict with the provisions of the Standard Contract, the Standard Contract governs the obligations of the parties, and this paper in no manner supersedes, overrides, or amends the Standard Contract. This paper reflects technical work which could support future decision making by DOE. No inferences should be drawn from this paper regarding future actions by DOE, which are limited both by the terms of the Standard Contract and a lack of Congressional appropriations for completing a spent nuclear fuel repository.

INTRODUCTION

The US Department of Energy (DOE) is planning for future large-scale transportation of commercial spent nuclear fuel (SNF) from multiple nuclear power plant sites (see Figure 1.) to eventual disposal and/or consolidated storage facilities. Public trust and confidence in the ability of this material to be moved safely and securely is an important component of a successful transportation campaign [1]. Due to the size and weight of commercial SNF containers, the majority of shipments are expected to be moved by railroad [2, 3]. However, through ongoing interactions with US State government and Tribal government representatives, DOE has found that while trust and confidence among government representatives is generally strong for highway transport of radioactive materials in the US, rail transport of radioactive materials is less familiar to many public officials, raising concerns about SNF rail transport safety [4, 5].

The US Department of Transportation (DOT) regulates commercial transportation in the US, including commercial transportation of hazardous materials, including radioactive materials. Highway infrastructure in the US is publicly owned, and State and federal regulations determine which routes

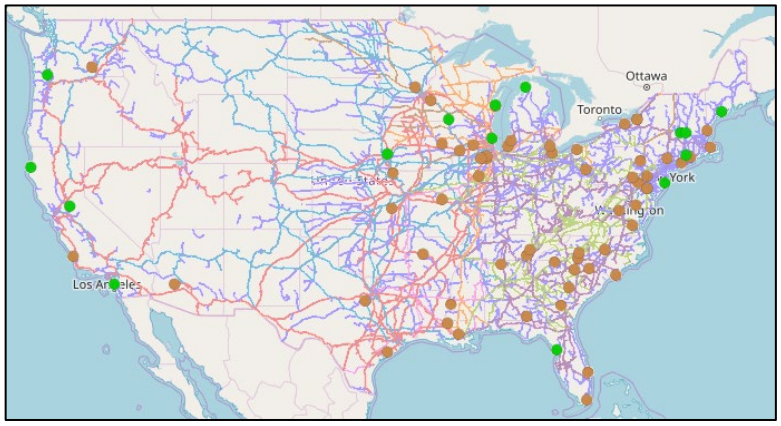

Figure 1. Map of US operating (brown dots) and shut down (green dots) commercial nuclear power plants and the US rail network. The rail network ownership is identified by color.

can be used to transport hazardous materials (internationally known as dangerous goods). Freight rail infrastructure in the US, however, is privately owned by the rail carriers. Rail carriers determine routes for rail transport, in accordance with DOT regulations. These regulations require rail carriers transporting certain quantities of rail security sensitive materials[1], including SNF, in commerce to evaluate safety and security risks of their route options (49 CFR 172.820). The risk analyses must consider at least 27 prescribed factors that could affect the safety and security of a route, and carriers are "required to seek information from State and local officials regarding potential security risks to high-consequence targets along or in close proximity to those routes" [6]. The freight rail industry uses a proprietary software tool, the Rail Corridor Risk Management System (RCRMS), customized for each rail carrier's rail network, to perform these risk analyses. Due to security sensitivities, the RCRMS software is not available to DOE or to State and Tribal governments, contributing to the public's uncertainties about rail routes that may be used to move SNF out of nuclear power plant sites.

STAKEHOLDER ROUTING WORKING GROUP

DOE established the National Transportation Stakeholders Forum (NTSF) in 2010 to communicate with States and Tribes about the Department's shipments of radioactive waste and materials, as well as occasional high-visibility shipments that are nonradioactive. The purpose of the NTSF is to bring transparency, openness, and accountability to DOE's offsite transportation activities through collaboration with State and Tribal governments. The Department's Waste Isolation Pilot Plant (WIPP) transportation program, which ships transuranic waste from multiple DOE sites to a deep geologic repository in New Mexico, has been a primary discussion topic among State and Tribal NTSF members. The WIPP program uses legal-weight trucks operating on agreed highway routes. After more than a decade of uneventful transportation operations, State and Tribal governments that have experienced WIPP shipments through their jurisdictions are now well-versed in federal and local regulations governing highway transport of radioactive materials. In contrast, DOE has conducted relatively few radioactive materials shipping campaigns by rail, generating many questions from State and Tribal governments about how future rail shipments of such materials would be conducted, and what role States and Tribes will have in ensuring safe transport.

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[1] US Department of Transportation regulations define "rail security-sensitive materials" in 49 CFR Part 1580.100 as (1) A rail car containing more than 2,268 kg (5,000 lbs) of a Division 1.1, 1.2, or 1.3 (explosive) material, as defined in 49 CFR 173.50; (2) A tank car containing a material poisonous by inhalation as defined in 49 CFR 171.8, including anhydrous ammonia, Division 2.3 gases poisonous by inhalation as set forth in 49 CFR 173.115(c), and Division 6.1 liquids meeting the defining criteria in 49 CFR 173.132(a)(1)(iii) and assigned to hazard zone A or hazard zone B in accordance with 49 CFR 173.133(a), excluding residue quantities of these materials; and (3) A rail car containing a highway route-controlled quantity of a Class 7 (radioactive) material, as defined in 49 CFR 173.403.

The NTSF supports establishment of ad hoc working groups to address topical issues relating to radioactive materials transport. The NTSF's SNF Rail/Routing Ad Hoc Working Group (R/R AHWG) formed in 2015 to engage States and Tribes in the process of identifying, prioritizing, and working to resolve issues related to future rail shipments of SNF. The two topics of most interest to the group at the outset were 1. understanding the rail route selection process, and 2. exploring development of a rail safety inspection protocol similar to the inspection standard implemented for highway transport of transuranic waste to WIPP .

Soon after the R/R AHWG was established, the concept of conducting a "routing workshop" with rail carriers was proposed. However, many State and Tribal members of the group did not yet feel well-enough versed in understanding rail operations and requirements to have those discussions with rail carriers. The group therefore focused first on understanding the basics of rail freight transport through a series of informational webinars. Rail experts from government and industry presented on rail inspection disciplines, the role of the federal and State governments in regulating rail transport, and how rail carriers perform safety and security risk analyses to identify hazardous materials transport routes. Once the R/R AHWG felt more comfortable conversing about freight rail transport, the idea of conducting a routing workshop was revisited. The R/R AHWG members agreed to pursue a routing workshop with participation from the rail industry for the purposes of exchanging information and improving their understanding of rail carrier operations, the regulatory framework for freight rail, and considerations for identifying future routes for SNF transport.

ROUTING WORKSHOP

Planning

In determining their goals for the workshop, the members of the R/R AHWG discussed that in past planning for potential transportation of SNF, avoiding population exposure was a primary driver for route identification [7]. AHWG members generally agreed that during normal conditions of transport of SNF, population dose exposure is fairly insignificant. What concerns State and Tribal governments, according to views expressed by AHWG members, is the radiation exposure that could result from a security threat or transportation incident. A Spent Nuclear Fuel Routing Workshop (Routing Workshop) would help State and Tribal governments understand how rail carriers assess safety and security risks in determining routes. DOT regulations require rail carriers consult with State and Tribal governments; one of the potential outcomes from conducting a Routing Workshop would be that State and Tribal governments could be better informed to converse knowledgeably with rail carrier representatives about routing issues. In addition, a Routing Workshop could open lines of communication with rail carriers for exchanging relevant safety and security information in the future.

With State, Tribal, and federal government staff in agreement to participate, the next step was ensuring rail carrier industry participation. DOE staff reached out to the Association of American Railroads

(AAR), an industry group representing North American freight rail carriers whose members include all the major (Class I) freight rail companies operating in the US. Following discussions on the meeting purpose, expectations for rail carrier attendance, and agreement on ground rules that addressed anti-trust, pricing, and competition concerns, AAR staff agreed to facilitate the invitation of rail carriers to participate in the Routing Workshop. Representatives from CSXT, BNSF, Union Pacific (UP), and Kansas City Southern (KCS) agreed to participate.

Workshop Goals and Ground Rules

The primary goals of the Workshop, as identified by R/R AHWG members, were to: 1. develop a better understanding of respective responsibilities and challenges; 2. build common ground based on shared interests; and 3. start a dialogue among DOE, rail carriers, and State and Tribal government representatives for information exchange. While the State and Tribal members learned that many routing decisions would ultimately be made by the rail carriers, the R/R AHWG hoped to better understand how carriers conduct routing, what criteria they use, and what their regulatory requirements are. The R/R AHWG members also wanted to have the rail carriers understand the level of interest in rail routing shared by State and Tribal government representatives, as well as their willingness to discuss routing considerations in helping to inform route analyses and selection.

The substance of the Routing Workshop centered on discussion of hypothetical routes for transportation of SNF by rail from actual nuclear power plant facilities to hypothetical sites. Volunteers from the R/R AHWG were solicited to identify one or more nuclear power plant sites in or near their jurisdictions, and explore hypothetical rail routes from those sites, taking into consideration route factors that might be of importance to their local governments, as well as what they know of DOT rail routing regulations. Table 1. shows the participating jurisdictions, nuclear power plant points of origin for their hypothetical routes, and the Class I rail carriers for those routes. The State and Tribal participants used DOE's Stakeholder Tool for Assessing Radioactive Transportation (START) web-GIS tool to explore route options [8]. START is a decision-support tool capable of generating and analyzing route options for transporting radioactive materials by highway, rail, or water modes.

All participants were directed to use "geographically neutral" hypothetical destination sites for their hypothetical routes, and most used destinations near the geographic center of the continental US. Since the Routing Workshop meeting would include representatives of multiple rail carriers, some of whom are business competitors, a ground rule was set for participants to explore hypothetical routes limited to a single rail carrier's network, usually defined by the Class I carrier servicing, or nearest to, the nuclear power plant origin. Other ground rules prohibited discussion of rail transport pricing or rates, and an agreement that rail carriers would present the results of their own hypothetical rail route analyses using the same origins and destinations as the State and Tribal R/R AHWG members – but because the risk information is deemed security sensitive by the railroads, no digital or hard copies of their routing work would be provided.

During the Routing Workshop, R/R AHWG members each made a presentation of the routes they evaluated from their selected nuclear power plant origin site. Then, the rail carriers presented the routes they identified for the same points of origin and destination based on evaluation with the RCRMS tool. The group discussed which route attributes might be prioritized in certain locations and why, the rail carriers' process for consulting with State and Tribal governments, and operational factors that may affect routes. In general, the hypothetical routes developed by the State and Tribal members of the R/R AHWG were very similar, if not exact, to the routes the rail carriers presented.

Table 1. State and Tribal jurisdictions represented in the Routing Workshop. Nuclear Power Plants are located within the representative's jurisdictions, except where indicated in parentheses.

State/Tribal Government Representative	Nuclear Power Plant Site	Servicing Rail Carrier(s)
Prairie Island Indian Community	Prairie Island Nuclear Generating Plant (MN)	Canadian Pacific
New Mexico	San Onofre Nuclear Generating Station (CA)	BNSF
Arizona	Palo Verde Generating Station	Union Pacific
Illinois	Zion Nuclear Power Station	Union Pacific
Vermont	Vermont Yankee Nuclear Power Plant	NECR short line interchanging to CSXT
Tennessee	HB Robinson Nuclear Generating Station (SC)	CSXT
Arkansas	Arkansas Nuclear One	Union Pacific

Hypothetical Route Examples and Discussions

Figures 2-5 show four hypothetical rail routes from nuclear power plants generated for the workshop by the State and Tribal R/R AHWG members using START. A representative from the Prairie Island Indian Community (PIIC) presented two hypothetical routes from the Prairie Island Nuclear Generating Plant selected for the workshop - a southern route on the Canadian Pacific (CP) line that heads away from the PIIC reservation, and a northern route through the PIIC lands (see Figure 2.). The hypothetical northbound rail route would run six miles through the Tribe's reservation and trust lands. The PIIC reservation and surrounding areas are rich in cultural resources, with burial mounds located both on and off the reservation and the Tribe would prefer to schedule future SNF shipments to avoid occurring during Tribal ceremonies. The Tribe is also concerned that a transportation accident would impact the Tribe economically, with public perception of danger from SNF shipments affecting their casino business, which is the Tribe's primary source of income.

Staff from AAR presented on behalf of CP. From the rail carrier's perspective, the likely route to carry SNF from the Prairie Island Plant was the southbound route, moving away from the PIIC reservation. The northbound route through the Twin Cities would require interchange to another carrier in St. Paul, Minnesota, and would be a much longer route. The AAR representative stated that scheduling of SNF

shipments around large gathering events could be managed through engagement with the shipper and local jurisdictions.

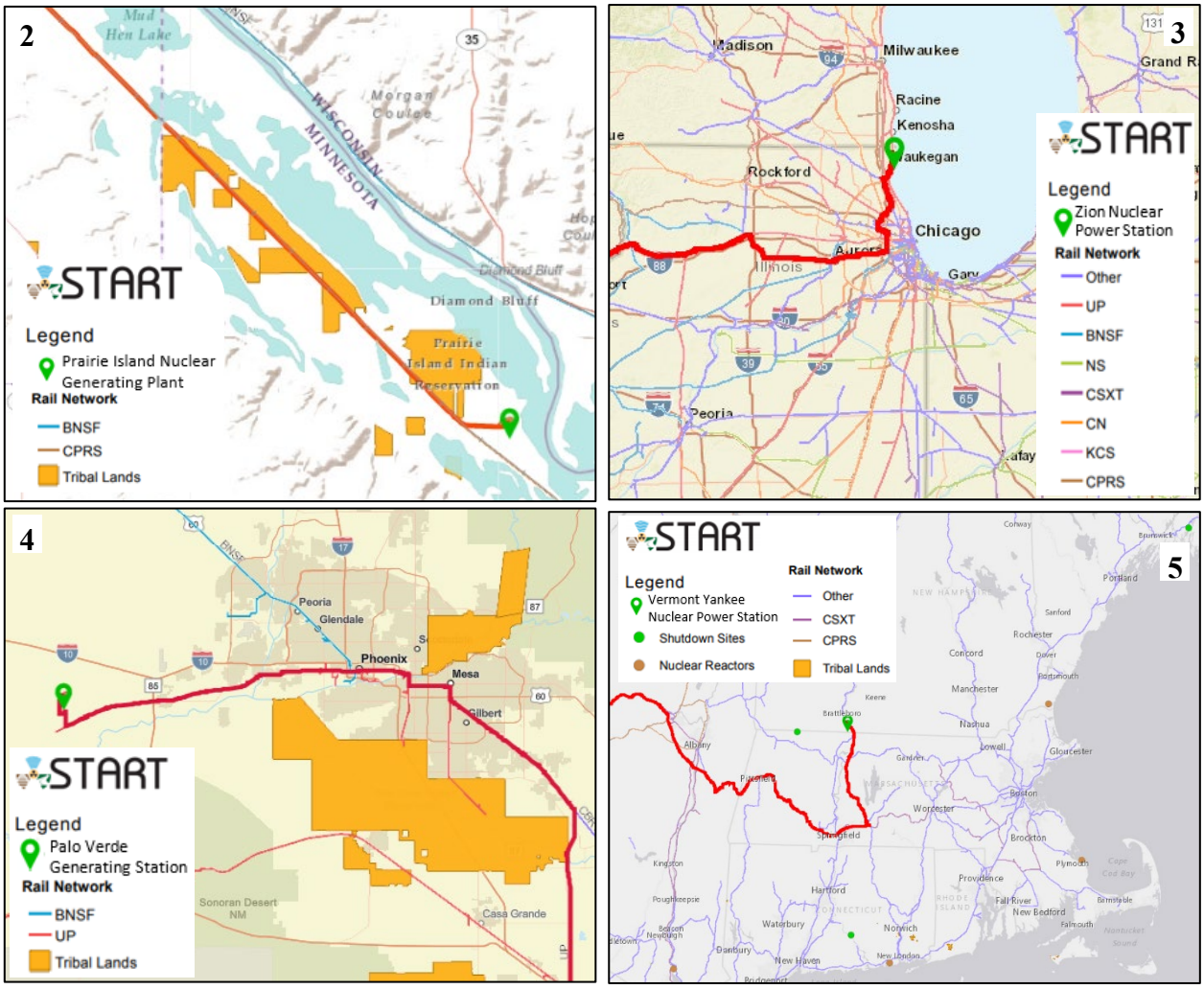
Representatives from the State of Illinois presented a hypothetical rail route originating at the Zion Nuclear Power Station north of Chicago traveling west (see Figure 3.). An alternate route was also presented that avoided Chicago and instead went north through Wisconsin, but they observed that the alternate route added significant mileage and increased population exposure. Key issues of interest for Illinois were impacts to the city of Chicago, as well as potential security concerns. The representatives from UP agreed with the Illinois representatives' assessments, and pointed out that the alternate route through Wisconsin and Minnesota would not be a viable option due to the added mileage and population already mentioned, which would result in higher safety and security risk scores in the RCRMS tool.

A representative from the state of Arizona presented a hypothetical route originating at the Palo Verde Generating Station heading east on UP (see Figure 4.). The representative noted that the route goes through the heart of downtown Phoenix, AZ, as well as through residents' backyards. While the route is open desert once a shipment passes through the cities of Phoenix, Mesa, and Tempe, the main concern is Phoenix. The representative explained that on any given Sunday, the population in the city could increase by over 200,000 due to concerts, sporting events, or activities at the city's convention center. Chase Field, where the Arizona Diamondbacks baseball team plays, is located just 800 meters (~0.5 miles) from the railroad tracks, and people often walk on the tracks. Given these concerns, route scheduling would be extremely important for any shipments passing through the Phoenix area.

During discussion of the hypothetical routes, a UP representative remarked that he found the multi-modal options in START intriguing since they provided more potential options to route around certain areas such as a city center. The group discussed the feasibility of using heavy-haul truck to rail inter-modal transport from sites such as Palo Verde or Zion to route around urban areas. However, while it could be feasible to use intermodal transport for a small number of shipments, the group noted that it would be less practical for a large-scale shipping campaign, conducted over many years, where both the origin and destination are served directly by rail, as the Palo Verde site is.

A representative from UP presented their hypothetical route from Palo Verde and found that UP's route matched the Arizona representative's route. The shipment would go through Phoenix and Tucson, which yielded the shortest distance and lowest overall route safety risk rating. In addition, two alternate routes were developed for comparison—one going through Ft. Worth, TX, and another through San Antonio, TX—but UP found that the net effects in both of those scenarios created an overall increase in distance, which increased security and safety risks. The UP representative also stated that safety and security risks also increase when night time versus daytime populations are considered.

A representative from the State of Vermont presented a hypothetical route originating at the Vermont Yankee Nuclear Power Station heading south on the New England Central Railroad (NECR) a short



Figures 2 – 5. Figure 2: A hypothetical rail route (in red) from the Prairie Island Nuclear Generating Plant heading north on the Canadian Pacific (CPRS) rail line through the Prairie Island Indian Community (PIIC) reservation and Trust Lands. Figure 3: A hypothetical rail route (in red) from the Zion Nuclear Power Station on the Union Pacific (UP) rail line through the Chicago, IL metropolitan area. Chicago is a major freight rail hub. The map also shows the other rail carrier networks operating in the Chicago area. Figure 4: A hypothetical rail route (in red) from the Palo Verde Generating Station on the Union Pacific (UP) rail line through Phoenix, AZ. Figure 5: A hypothetical rail route (in red) from the Vermont Yankee Nuclear Power Station on the NECR short line connecting to the CSXT Class I rail line through Massachusetts. SNF moved from other nuclear power plant sites in Maine, New Hampshire, Massachusetts, and Connecticut could similarly connect to CSXT in western Massachusetts for transport out of the Northeast.

line that interchanges in Palmer, MA with CSXT, a Class I Rail line and heads west into New York State. The representative's goal for identifying a rail route was minimizing risk and population exposure. A representative from CSXT presented their hypothetical route from the point where NECR interchanges with CSXT in Palmer, MA. The preferred route travelled through Buffalo, NY and Cleveland, OH, and Indianapolis, IN, matching the Vermont representative's route. CSXT did consider

an alternate route through Cincinnati, OH and Louisville, KY. It was a shorter route, however, CSXT would not select that route because it included two larger urban areas, which increased the route risk calculation above the other route.

LESSONS LEARNED AND NEXT STEPS

One of the main lessons learned from the Routing Workshop was that hypothetical rail transport routes developed by R/R AHWG members using DOE's START tool compared well to the routes developed by rail carriers using their proprietary RCRMS routing tool. With this initial validation of START, State and Tribal governments can use it with some confidence to answer questions about how SNF may move through their jurisdictions. While routing results from START and the rail carriers were very similar, there were some differences. The reasons for differences in routes between the tools were discussed and explained by the rail carriers and added to the lessons learned. One significant difference is that START uses an 800 meter (~0.5 miles) buffer distance to calculate route population density (a common distance for environmental assessments involving potential radiological exposure), while RCRMS considers populations within 322 meters (0.2 miles) – which can result in very different population density factors. Another difference was that some rail carriers operate certain track segments in one direction only (e.g., northbound or southbound) for operational efficiency. START might produce a route using a given rail segment, when in reality, the carrier would use a parallel segment 48 km (30 miles) west because of their preference to use them as one-way segments. This kind of information is not easily available to those outside of the rail industry, and provided some valuable insight on how rail carrier operations can influence routing.

Another lesson learned from the Routing Workshop was through the discussion of the relative weighting of safety and security risks. Prior to the Routing Workshop the State and Tribal members of the R/R AHWG had expressed concerns about radiation exposure that could result from a security threat or transportation incident. The rail carriers informed the group that the RCRMS tool weighs safety and security equally. However, within the rail industry, there is a general view that safety is more important based on the data for rail accidents. One carrier indicated that their corporate decisions often opt for the safer route since they have never had a terrorist incident, which would fall under "security risk." This perspective is a valuable one for States and Tribes to consider in their own planning and communications regarding radioactive materials transportation safety and security.

Another lesson learned related to the DOT requirement for rail carriers to consult with State and Tribal governments. CSXT relayed that for the past nine years, they had requested input from State and Tribal governments whose jurisdictions they operate in on security considerations for their routing risk analyses, but to date they have not received any responses. This was a surprise to all of the R/R AHWG members – many of whom are interested in avenues for State and Tribal input in rail carrier route selection, and it identified a gap in communications within their own government organizations.

The rail carriers also stated that because of the public's fear of radioactivity and the potential impact of an accident, railroads would rather not ship high-visibility shipments like SNF, but their status as "common carriers" requires them to transport any material that meets DOT regulations. Rail carriers share the States' and Tribes' interest in ensuring future SNF rail shipments move safely and uneventfully. It was recognized by all participants that effective communication to the public about safety and risks of SNF shipments in the future would be important.

The discussions and outcomes of the Routing Workshop were written up in a detailed summary to serve as a record of issues resolved and a useful reference. Now that the participating State and Tribal representatives have a better understanding of rail carrier operations, DOT regulations, and risk considerations for rail routes, the R/R AHWG considers the topic of "understanding the rail route selection process" for future SNF shipments to be resolved for the time being. The R/R AHWG has now moved on to its second priority item, development of a proposed rail safety inspection protocol for trains transporting SNF and high-level radioactive waste, intended to be conducted by Federal rail inspectors, or State rail inspectors authorized by DOT's Federal Railroad Administration.

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