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From Canada with Love: Repatriating HEU to the U.S.

As part of a nonproliferation agreement, Canada and the U.S. undertook a multi-year campaign to ship liquid high-enriched uranium material from Chalk River to Savannah River.

BY GLEN JACKSON AND JEFFREY GALAN

State troopers and first responders at a TRM roadshow stop in Virginia. The display LWT cask can be seen at the far right in its shipping container. (Photos courtesy of DOE/NNSA)

Canada's Chalk River Laboratories.
(Photo: Wikimedia Commons/Padraic Ryan)

In March 2012, during the Nuclear Security Summit in Seoul, South Korea, the governments of Canada and the United States committed to work cooperatively to repatriate approximately 6,000 gallons of high-enriched uranyl nitrate liquid (HEUNL) target residue material (TRM) stored at the Chalk River Laboratories in Ontario to the U.S. Department of Energy's Savannah River Site in South Carolina. The announcement was part of a larger agreement between the two countries to reduce proliferation risks by consolidating high-enriched uranium at a smaller number of secure locations.

The TRM, which was the by-product of medical radioisotope production at Chalk River, was shipped to Savannah River's H-Canyon to be separated. Involving numerous government agencies, local governments, a tribal nation, contractors, and other stakeholders, the TRM shipping campaign took extensive coordination and planning. By the time the campaign was completed in January 2021, Atomic Energy of Canada Limited (AECL) had safely conducted 115 individual truck shipments of TRM covering approximately 150,000 highway miles.

The H-Canyon at the Savannah River Site in South Carolina.
(Photo: DOE-SRS)

Molybdenum-99 production

In the 1950s, molybdenum-99 was identified as a potentially useful medical radioisotope, as its decay product, technetium-99m, is a pure gamma emitter with a 6-hour half-life, making it ideal for diagnostic medical imaging. Tc-99m is used in approximately 80 percent of all nuclear medicine diagnostic procedures and in roughly 40,000 diagnostic and therapeutic nuclear medicine procedures performed daily in the United States, including diagnosis of heart disease, treatment of cancer, and study of organ structure and function. The short half-life, however, makes the distribution of the substance very challenging and means that it must be produced continuously to meet the medical community's needs.

In 1957, what is now Canadian Nuclear Laboratories (CNL) began using the National Research Universal (NRU) reactor at the Chalk River site to produce Mo-99—it was the first reactor able to commercially produce medical isotopes. The U.S. sent HEU fuel elements and targets to Canada for use in the production of medical isotopes. Until October 2016, CNL was one of the world's largest producers of medical isotopes used in the diagnosis and treatment of cancer and other serious diseases, producing approximately 60 percent (and at times 100 percent) of U.S. demand for Mo-99, as well as other isotopes such as iodine-131 and xenon-133.

The HEU targets were irradiated for approximately seven days in the reactors and then dissolved in a nitric acid

solution in order to separate out the Mo-99. CNL then transferred the HEUNL TRM—what was left after the Mo-99 was separated by dissolution—to a double-walled stainless steel vessel known as the fissile solution storage tank (FISST) at Chalk River. At the end of Mo-99 production, approximately 6,000 gallons of TRM were being stored in the FISST.

A PLAN TO REPATRIATE

The campaign to ship the TRM to SRS was part of the U.S.-Origin Nuclear Material Removal Program conducted by the DOE National Nuclear Security Administration's Office of Material Management and Minimization. That office works with civilian nuclear facilities around the world to remove or confirm the disposition of excess HEU and plutonium to ensure it does not fall into the hands of terrorists or other malevolent actors. Eliminating this material, kilogram by kilogram, that much further reduces the risk of such bad actors acquiring material for use in an improvised nuclear device, thereby achieving permanent threat reduction.

At CNL, the operational demands associated with maintaining isotope production, combined with constrained shielded facility capabilities, precluded the conversion of the TRM to a standard solid form (e.g., calcine). This necessitated the transport of the TRM in liquid form.

In 2008, AECL expressed interest in transporting this material to SRS for disposition. SRS staff conducted an engineering study that determined the site would need to develop a capability to remove the HEU liquid from the shipping cask and transfer it to H-Canyon.

Discussions then began between AECL and the DOE/NNSA. AECL would be responsible for transport activities from Chalk River to SRS, and the DOE/NNSA would be responsible for coordinating with organizations and states along the route in the United States. A contract was signed on September 28, 2012, detailing the plan.

The material would be transported by truck, and each shipment was planned to include two casks. Based on optimistic projections at that time, a total of 88 casks would be needed to make 44 shipments, and it was expected to take a year or less to complete all shipments.

HEUNL CANISTERS

Transporting liquid HEUNL material presented numerous first-time technical and regulatory challenges. To ship the material, AECL contracted with NAC International to design and license a canister to fit inside the company's NAC-LWT Type B package (LWT) for transporting the TRM directly to H-Canyon.

The LWT cask is a lead-lined package with a cylindrical cavity designed to enable the shipment of HEU and various types of spent nuclear fuel by reconfiguring the internal components (baskets) that secure the shipped material within the cavity. For the TRM project, several designs were developed for the inner canister, with the final design consisting of four self-contained canisters placed in the LWT.

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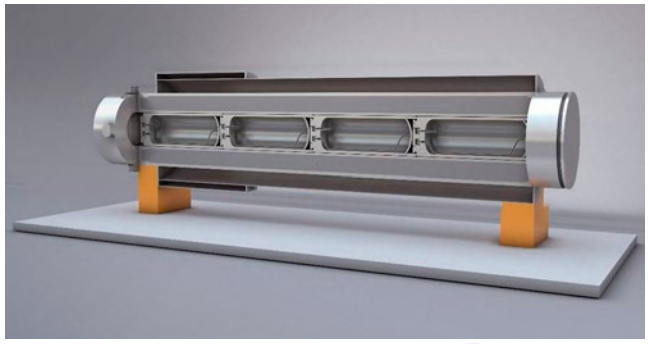


Top: A cutaway view of a LAC-LWT Type B cask showing how the four 15-gallon canisters fit inside the cask.

Bottom: The completed TRM canisters. The white strips are plastic slides designed to allow the canister to easily slide in and out of the LWT cask.

To handle the loading of the HEUNL at CNL and the unloading at SRS, both CNL and SRS had to design, fabricate, and install specialized equipment and processes. Transfer hoses and fittings for all the equipment designed for use in Canada also had to work at SRS. To ensure this interoperability of processes and equipment for loading and unloading, engineers from Savannah River National Laboratory worked in conjunction with CNL engineers to design the withdrawal and transfer systems, as well as the transfer system and processing equipment that would be used during the unloading operation at H-Canyon.

Challenges in Canada included determining how to remove the material from the FISST and safely transfer it to the canisters (while accurately measuring what had been transferred for material control and accountability purposes) and loading the filled canisters into the LWT. Challenges at SRS included determining how to safely remove the canisters from the LWT and then fully emptying the HEUNL from the canisters while, again, accurately measuring volume.

NEPA review

The National Environmental Policy Act (NEPA) requires U.S. federal agencies to assess the environmental effects of their proposed actions prior to making decisions. A comprehensive environmental impact statement (EIS), completed in 1996, addressed the DOE's decision to accept and manage foreign research reactor spent fuel, as well as certain target material. A NEPA supplemental analysis, completed in 2015, specifically evaluated the transportation of the TRM material from Canada to SRS.

In an effort to halt the TRM shipments, several U.S.-based environmental interest groups filed suit in federal court against the DOE/NNSA on August 12, 2016. The plaintiffs alleged that the DOE/NNSA violated NEPA by not preparing a new or adequately supplemental EIS prior to the planned transportation. The DOE/NNSA negotiated an accelerated path for resolution of this case by voluntarily refraining from undertaking any TRM shipments until the case was decided.

On February 2, 2017, the court ruled in favor of the DOE/NNSA, concluding that the government met its NEPA obligations, and an order was issued dismissing the plaintiffs' case. The DOE/NNSA then began the TRM transportation campaign, with the first shipment conducted on April 15, 2017.

Transportation planning

To conduct the campaign, the DOE/NNSA closely coordinated with its Canadian partners, the shipping contractor, a tribal nation, and multiple U.S. federal and state agencies—including the Department of Homeland Security and the Federal Bureau of Investigation—to ensure that the material would be transported safely and securely. The DOE/NNSA also provided specialized training free of charge to prepare emergency responders for any potential transportation accidents involving radioactive material.

While the DOE/NNSA is not a Nuclear Regulatory Commission licensee and therefore not subject to enforcement actions, the decision was made to conduct all DOE Foreign Research Reactor Spent Nuclear Fuel Acceptance Program shipments in compliance with NRC regulations. The DOE/NNSA, through its management directives, orders, and contractual agreements, ensured the protection of public health and safety by imposing on its transportation activities standards equivalent to those of the NRC.

All TRM shipments complied with NRC regulatory requirements for the specific highway routing that each shipment had to follow. Each chosen route was reviewed and approved by the NRC to ensure it met applicable security and safeguards requirements, and all information regarding shipping dates, times, and routes was secured and managed according to NRC "information safeguards" regulations.

Transportation coordination

To ensure the successful, safe, and efficient transportation of the TRM by truck, a transportation plan was developed that identified the necessary responsibilities, requirements and procedures, transportation activities, organizational responsibilities, and emergency preparedness guidelines, as well as other methods for achieving safe transport. This plan was prepared under the direction of the DOE/NNSA in cooperation with the states and tribe along the route, along with the Southern States Energy Board, the Council of State Governments Northeastern Office, and the transportation contractor and commercial carrier.

Numerous federal, state, tribal, and commercial entities were involved in the supporting the TRM shipping campaign. Primary among them were the following:

- **DOE/NNSA:** Had overall responsibility for the TRM shipping campaign in the United States.
- **AECL:** Had overall responsibility for the TRM shipping campaign in Canada.
- **Secured Transportation Services (STS):** Had

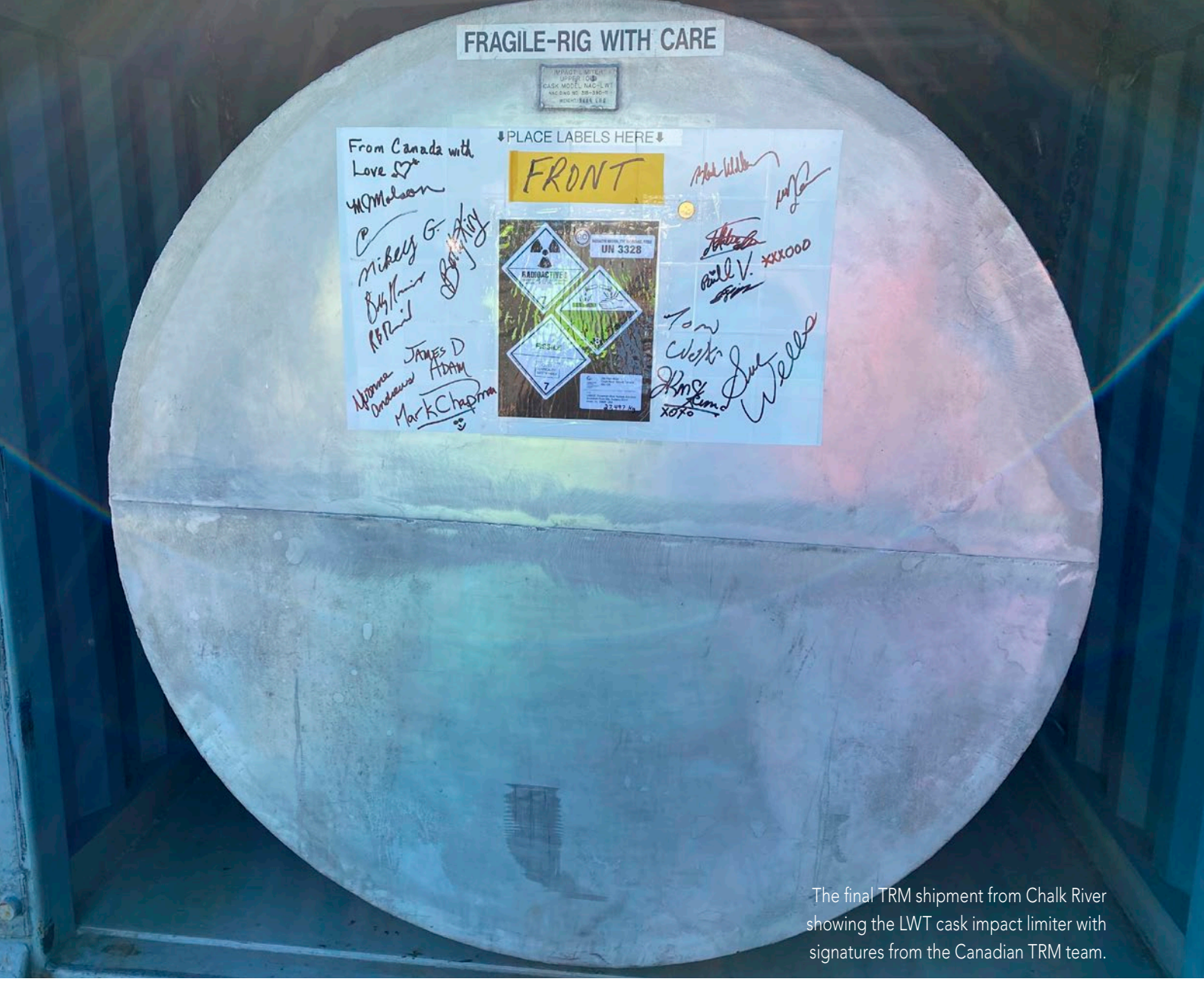
A loaded TRM shipment ready for transport to Savannah River.

responsibility for overall management of transportation in Canada and the United States.

- **Corridor states/tribe:** Had responsibility for providing security escorts, establishing procedures, and providing personnel and equipment to take charge of emergency situations if necessary. This included the Seneca Nation of Indians, along with the states of New York, Pennsylvania, West Virginia, Virginia, Maryland, North Carolina, South Carolina, and Georgia.
- **FBI:** Provided threat assessments and coordinated with each state's fusion center regarding overall security planning.
- **Savannah River Nuclear Solutions:** Established an integrated baseline planning schedule and provided logistical and administrative support to implement the TRM shipping campaign. Took responsibility for the TRM upon arrival at SRS.
- **CNL:** Prepared all TRM shipments for departure in Canada.
- **Commercial motor carrier:** Had responsibility for safely transporting the TRM from Canada to SRS and returning empty transport packages to the vendor or Chalk River.
- **NRC:** Approved the U.S. ports of entry and certified the routes of movement plans submitted by STS.
- **TRANSCOM:** The DOE's unclassified Transportation and Communications Tracking System, was used to monitor the progress of the TRM shipments. TRANSCOM utilized onboard satellite GPS to track the truck shipments as they made their way from Chalk River to SRS.
- **Transportation Emergency Preparedness Program (TEPP):** DOE-wide program that integrated the transportation emergency preparedness activities under a single program to address the emergency response concerns of state, tribal, and local officials affected by the shipments.
- **Commercial Vehicle Safety Alliance (CVSA):** All equipment and drivers used to transport TRM received a Level VI inspection per the Enhanced North American Inspection Standards of the CVSA at Chalk River before the start of every shipment and prior to departure from the U.S. port of entry. Each state a shipment passed through had the option to conduct their own CVSA Level VI inspection. Several states did exercise this option at the beginning of the shipping campaign, until they gained confidence in the Level VI inspections that were conducted before a shipment left the U.S. port of entry.

TRM ROADSHOW

The TRM campaign was the first time irradiated HEUNL would be shipped internationally into the United States. Most jurisdictions had little experience in providing security escorts and responding to highway incidents involving radioactive materials in large quantities. To inform and educate local community first responders, state agency points of contact, and tribal representatives,



The final TRM shipment from Chalk River showing the LWT cask impact limiter with signatures from the Canadian TRM team.

the NNSA, AECL, CNL, NAC International, and STS teamed up to conduct "TRM roadshows" with these stakeholders.

Each TRM roadshow consisted of a static display of an actual NAC-LWT cask, TRM canisters, and the transport truck at the stakeholder's locations. The roadshow gave stakeholders the opportunity to examine all the safety measures that would be in place during the transport of the TRM through their areas and aimed to give them an understanding of the makeup of the HEUNL. Over the course of two weeks, more than a dozen roadshows were conducted along the two interstate highway routes.

Prior to the commencement of TRM shipments, the DOE/NNSA reached out to the tribal nations along the U.S. transportation corridors and conducted in-person briefings with tribal leaders, including conducting TRM roadshow events. In addition, the DOE/NNSA complied with the NRC rule "Advance Notification to Native American Tribes of Transportation of Certain Types of Nuclear Waste." The DOE/NNSA also used the National Transportation Stakeholders Forum to meet with the tribal partners to share information about the TRM campaigns and extended the free TEPP training along the highway routes to interested tribes.

The DOE/NNSA provided free specialized TEPP training courses for emergency responders along the two highway routes for many years, even though the probability of an event was extremely low. A component of TEPP, the Modular Emergency Response Radiological Transportation Training, provided first responders with training on the how to properly respond to a radiological incident. Over the course of the campaign, the DOE/NNSA conducted more than 100 training classes in seven states, attended by more than 2,000 participants.

Conducting the shipments

The TRM campaign began in April 2017 and made quick progress, with 17 shipments completed in the first five months. A core team of shipment planners conducted weekly calls to discuss near-term shipments and long-term plans for the campaign. The TRM campaign was undertaken concurrently with a spent nuclear fuel shipment campaign from the NRU and National Research Experimental (NRU/NRX) reactors, also located at Chalk River. The NRU/NRX and TRM campaigns used the same cask, trucks, and highway routes and were often conducted as joint shipments, moving two casks at a time. This streamlined the campaigns and limited the impact on the corridor states and tribe.

Every shipment was tracked on the DOE's TRANSCOM system, and the team provided regular updates to the various security and programmatic organizations actively following its progress. Once a shipment arrived at SRS, the full cask was off-loaded and an empty cask was placed back on the truck for the return trip to Canada.

The four-year shipping campaign involved 115 separate truck shipments and covered approximately 150,000 miles, equal to traveling around the earth six times. In the end, the TRM removal team successfully completed all shipments without incident, despite loading, unloading, and shipping material year-round in all weather conditions, from freezing Canadian winters to broiling southern U.S. summers. More than 161 kilograms (354 pounds) of HEU were returned during this multi-year campaign, which marked another important step in the global effort to minimize the civilian use of HEU.

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