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Considerations for the Maritime Transport of Category I Quantities of Fissile Materials

J. Lillo
U.S. Department of Energy – National Nuclear Security Administration, USA;

K.A. Dunn and N.C. Iyer
Savannah River National Laboratory, USA;

and

A. Gray and B. Whittard
International Nuclear Services, UK

To whom all correspondence should be addressed, email:
Jessica.Lillo@nnsa.doe.gov and Natraj.Iyer@srnl.doe.gov

Introduction

The U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) Office of Material Management and Minimization (M3) works to minimize civilian stocks of highly enriched uranium (HEU) and separated plutonium globally through the conversion of research reactors from HEU to low enriched uranium (LEU) fuel and, when possible, removal or disposition of weapons-usable nuclear material. To date, DOE/NNSA has removed or confirmed the disposition of over 7,130 kilograms (kg) of weapons-usable nuclear material from 47 countries and Taiwan. While the scope of materials eligible for return has evolved from the first shipments of U.S.-origin spent nuclear fuel to more recent shipments of unirradiated HEU and plutonium, the mission to minimize the use of weapons-usable nuclear material in civilian commerce has remained constant.

For each removal project, M3 and its partner country (or countries) work with all relevant stakeholders—including each country's regulator(s)—to identify the best method for removing excess weapons-usable nuclear materials. A key element of this process is determining the appropriate means of transporting the materials from the sending facility to the receiving facility, where the materials will be downblended or dispositioned. Relevant considerations include the form and quantity of material to be transported, specific regulatory requirements in the sending and receiving countries, cost factors, and geography.

The International Atomic Energy Agency (IAEA) has specific recommendations for the protection and transportation of materials based on the form and quantity concerned, as described in Information Circular 225 (INFCIRC/225/Rev. 5). The categorization of fissile materials is shown in Table 1. This paper will discuss transport considerations specific to Category I quantities of nuclear materials. As recommended by INFCIRC/225/Rev. 5, transportation of Category I quantities of HEU and plutonium carries special obligations, including the use of a dedicated transport vessel with the requisite security infrastructure; physical security posture to protect the cargo; and integration of a central command and control center into transport operations.

While each country will have its own regulations pertaining to the air transport of nuclear materials, in general, Category I-III quantities of U-235 materials may be transported by air. Transportation of plutonium, U-233, or irradiated U-235 materials; however, generally requires use of a maritime vessel—especially for transportation to the United States. For Category I ocean transports of plutonium and/or HEU, DOE/NNSA and its international partners have worked closely with the United Kingdom's

International Nuclear Services (INS) to facilitate the secure maritime transport of materials from Europe and Asia to the United States since 2012.

Table 1: Categorization of Nuclear Material
(Source: INFCIRC/225/Revision 5, *Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities*, IAEA 2011. Table 1, page 20.)

Material	Form	Category I	Category II	Category III
Plutonium	Unirradiated	2 kg or more	Less than 2 kg but more than 500 g	500 g or less but more than 15 g
Uranium-235 (^{235}U)	Unirradiated -Uranium enriched to 20% ^{235}U - Uranium enriched to 10% ^{235}U but less than 20% ^{235}U -Uranium enriched above natural, but less than 10% ^{235}U	5 kg or more	Less than 5 kg but more than 1 kg 10 kg or more	1 kg or less but more than 15 g Less than 10 kg but more than 1 kg 10 kg or more
Uranium-233 (^{233}U)	Unirradiated	2 kg or more	Less than 2 kg but more than 500 g	500 g or less but more than 15 g
Irradiated Fuel			Depleted or natural uranium, thorium or low enriched fuel (less than 10% fissile content)	

This paper will describe the international regulatory framework for Category I maritime transport, the application of this framework by International Nuclear Services, packaging considerations for Category I maritime transport, and the key considerations for developing a Category I maritime transport strategy and the attributes of the operational plan, using previously completed missions as examples.

International Regulatory Framework

The regulatory framework for international maritime transport is comprehensive and mature. This body of regulations are embedded in a series of IAEA safety guides and standards, Codes issued by the International Maritime Organization (IMO), and Codes and Conventions issued by the United Nations (UN) and national regulatory bodies. Table 2 lists some of the IAEA safety standards and guides pertaining to safe transport of nuclear materials while Table 3 lists some of the IMO codes related to maritime transport.

Table 2: IAEA Safety Standards and Guides

IAEA Guides and Regulations for Safe Transport of Nuclear and/or radioactive Materials	
IAEA SSR-6 Rev1 (Safety Standard Series)	Regulations for Safe Transport of Nuclear Materials
IAEA SSG-33 (Specific Safety Guide)	Advisory Materials for IAEA Regulations for Safe Transport of Radioactive Materials
IAEA TS-G-1 Series (Specific Safety Guide)	Advisory Materials for IAEA Regulations for Safe Transport of Radioactive Materials
IAEA TS-G-1.2 (ST-3) (Safety Standard Series)	Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material Safety Guide
IAEA TS-R-1 (Safety Standard Series)	Regulations for Safe Transport of Radioactive Materials

Table 3: IMO Transport Codes

International Maritime Organization Codes for Maritime Transport	
INF	The Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium, and High-Level Radioactive Wastes in Flasks on Board Ships
IMDG	International Maritime Dangerous Goods Code
ISPS	International Ship and Port Facility Security Code
SOLAS	International Convention for the Safety of Life at Sea
MARPOL	The International Convention for the Prevention of Pollution from Ships
ISM	International Safety Management

Safety: The IAEA's Regulations for the Safe Transport of Radioactive Material, Safety Standard Series-6, Revision 1 (SSR-6), apply to the transport of radioactive material by all modes on land, water, or by air, including transport that is incidental to the use of the radioactive material. It covers all operational considerations associated with transport, including the design, manufacture, maintenance, and repair of transport packaging, as well as the preparation, consigning, loading, carriage (including in-transit storage), unloading, and receipt at the destination. These requirements were adopted into the UN Model Regulations as well as the IMO's mandatory International Maritime Dangerous Goods (IMDG) Code.

All organizations involved in maritime shipping are required to comply with the International Convention for the Safety of Life at Sea (SOLAS), which sets the minimum safety standards in the construction, equipment, and operation of merchant ships, regardless of their cargo. Chapter IX of SOLAS requires compliance with the International Safety Management (ISM) Code, which is an international standard for the safe operation of ships and pollution prevention.

In addition to these primary standards, merchant vessels involved in the transport of nuclear materials are required to comply with the IMO's International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Waste on Board Ships. Under this code, every aspect of ship construction, equipment, manning, and operation must comply with domestic and international regulations.

***Security*:** The Convention for the Physical Protection of Nuclear Materials (CPPNM) is the only international legally binding undertaking related to physical protection of nuclear material. The original

convention was signed in Vienna and New York on 3rd March 1980 and the amended CPPNM came into force in on the 8th May 2017 following the ratification of 102 State Parties. Among other requirements, the amended CPPNM places a number of legal obligations on State Parties concerning the physical protection of nuclear materials in use, storage, and during transport (including international transport).

Key elements of the CPPNM related to the transport of nuclear materials include:

- Article 2A legally obligates State Parties to "establish, implement and maintain an appropriate physical protection regime applicable to nuclear material and nuclear facilities under its jurisdiction." To meet this obligation, State Parties are required to establish and maintain a legislative and regulatory framework to govern physical protection, establish or designate a competent authority or authorities responsible for the implementation of the legislative framework, and take other appropriate measures necessary for the physical protection of nuclear material.

- Article 3 of the amended CPPNM is focused primarily on the international transport of nuclear materials and states that each State Party "shall take appropriate steps within the framework of its national law and consistent with international law to ensure as far as practicable that, during international nuclear transport, nuclear material within its territory, or on board a ship or aircraft under its jurisdiction insofar as such ship or aircraft is engaged in the transport to or from that State, is protected at the levels described in Annex I."

- The CPPNM obligates State Parties to make specific arrangements and meet defined standards of physical protection for international shipments of nuclear material for peaceful purposes (plutonium, uranium 235, uranium 233 and irradiated fuel), according to Annexes I and II and IAEA INFCIRC/225 and NSS-14). Unique attributes relevant to Category I transport as described in IAEA INFCIRC/225 Rev 5, Section 6 (Figure 1) include:

  - Competent authority approval of transport plan;
  - Competent authority approval of initiation of transport;
  - Physical security (guards) of cargo during transport;
  - Physical protection of cargo during transport;
  - Transport Control Center with frequent two-way communication with convoy; and
  - In the case of ocean transport, the requirement for a dedicated transport vessel.

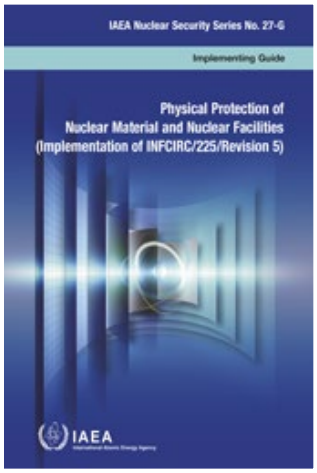

Figure 1: INFCIRC 225/Rev. 5

Application of International Regulatory Framework at INS

Safety: The UK's Maritime Coastguard Agency (MCA) is responsible for administering and enforcing the mandatory requirements of SOLAS, including the ISM Code, ISPS Code, and INF Code. MCA regularly visits INS's vessels to ensure compliance with these requirements. IAEA Nuclear Security Series No. 14, *Nuclear Security Recommendations on Radioactive Material and Associated Facilities* (NSS-14), provides recommendations for the secure transport of radioactive material, including for the international transport of Category I nuclear materials by road, rail, sea, and air. The UK's nuclear security regulations include the legal obligations of the amended CPPNM and generally exceed the recommendations of NSS-14 due to the maturity of the UK's nuclear security sector.

The UK's Office for Nuclear Regulation (ONR) is the competent authority responsible for all transport safety licensing activities in the United Kingdom. Using the IAEA's SSR-6 standards, ONR plays a key role in the approval of the transport plan, include package safety, transport safety, and security.

***Security*:** In line with the United Nations Convention on the Law of the Sea (UNCLOS), INS must comply with all relevant UK legislation concerning the physical protection of nuclear materials. The Nuclear Industries Security Regulations (NISR) of 2003 outline the core legislative requirements that Duty Holders in the UK need to comply with to ensure the security of nuclear materials in use, storage, or transport. The regulations also extend to the protection of Sensitive Nuclear Information (SNI) and the determination of trustworthiness through the UK's security vetting and aftercare arrangements.

Under the NISR 2003, only approved Class A Carriers are permitted to transport Category I quantities of nuclear materials domestically and internationally. To achieve this status, Duty Holders must submit a Transport Security Statement (TSS) to ONR for approval. In addition to this requirement, all transports of Category I nuclear materials require a Transport Security Plan (TSP) that is submitted no later than 30 days prior to the planned transport for approval by ONR. The TSP describes the detailed arrangements for the transport including route, timing, and security handovers.

Supporting the NISR 2003, are the ONR's Security Assessment Principles (SyAPs), which describe the security outcomes by which Duty Holders are required to achieve approved carrier status and secure security plan approval for the transport of Category I nuclear materials. The SyAPs document consists of 10 Fundamental Security Principles covering leadership and management, organizational culture, competence management, nuclear supply chain management, reliability, resilience and sustainability, physical protection systems, cyber security and information assurance, workforce trustworthiness, policing and guarding, and emergency preparedness and response.

Underlying these regulations is the UK's design basis threat (DBT), commonly known as the Nuclear Industries Malicious Capabilities (Planning) Assumptions (NIMCA) document. The NIMCA outlines the hypothesised capabilities of the threat that Duty Holders are required to protect against and includes information on adversarial numbers and capabilities (including weapons and explosives) over land-based and marine-based threat vectors. This document is used in conjunction with SyAPs to enable Duty Holders to demonstrate they meet the security objectives.

An additional UK requirement for Category I transports of nuclear materials is the use of armed escort services from the UK's Civil Nuclear Constabulary (CNC) Strategic Escort Group (SEG). The CNC is an armed police force in charge of protecting civil nuclear sites and nuclear materials in use, storage and transport. The SEG is a highly trained escort unit that works closely with the UK's Royal Navy to ensure the highest standards.

Packaging Considerations

In general, packaging HEU and plutonium materials for transport requires consideration of the material quantity, type, and characteristics; sending and receiving locations; storage condition(s); material attractiveness; conformity with receiving facility requirements; and compatibility with the identified disposition pathway. Based on these considerations, DOE/NNSA works with its international partner to identify the appropriate Type B nuclear material transport package(s) for Category I-III movements. Category I transports of HEU and/or plutonium materials may also require consideration of the availability of large numbers of Type B packages, criticality safety indexes (CSI), and configuration of the cargo within the holds, as relevant.

Type B nuclear material transportation packages used for international transport of fresh HEU and plutonium are designed, constructed, maintained, loaded, and sealed in accordance with performance standards recommended by the IAEA and adopted and enforced by national competent authorities to consensus standards. After review by the national competent authority (e.g., the Nuclear Regulatory Commission or Department of Energy in the United States) a certificate of approval, sometimes called a Certificate of Compliance (CoC), is issued. The CoC details the permissible content(s) for the package or cask and its functional parameters.

To export U.S. certified Type B packages, the U.S. Department of Transportation (DOT) must also issue a Competent Authority Certificate (CAC), endorsing the package description and authorized radioactive contents from the CoC. The CAC and the appropriate technical basis for the use of the selected package are included in the application by the material owner (in the partner country) to validate the package certificate and use the package for transport. DOT must also issue a CAC to import or export Type B packages certified by a non-U.S. competent authority, re-validating the package description and authorized radioactive contents. A CAC may also be required from countries through which the material will transit, as applicable.

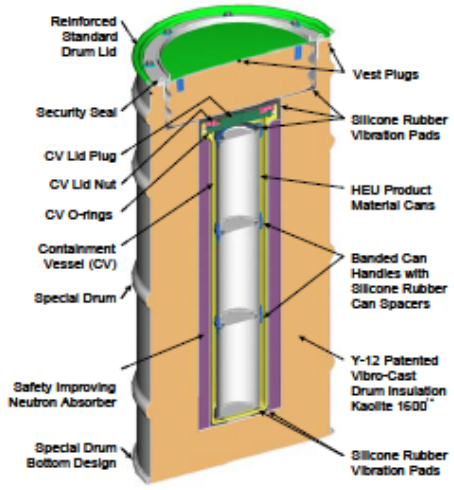

Figure 2(a): Schematic of ES-3100 Type B Package Used for Unirradiated HEU Materials

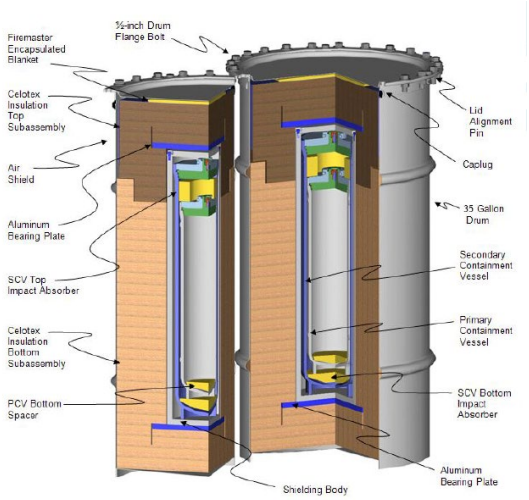

Figure 2(b): Schematic of 9975 Type B Package Used for Plutonium Materials

DOE/NNSA and its international partners have extensive experience certifying Type B transport packages for fresh HEU and plutonium materials. DOE and commercial packages have been routinely used for the Category I transport of fresh HEU and plutonium. DOE/NNSA and its partners have used the ES-3100 (Figure 2a) and TN BGC1 Type B packages for fresh HEU as well as the 9975 Type B package (Figure 2b) and Croft's Safekeg packages for plutonium materials. Because of the regulatory requirements to certify the package for transport, it is key to select the package or cask as early as possible so that sufficient time can be devoted to the regulatory approval process.

For ease of handling before, during, and after transport, the designated packages are frequently arranged on a pallet and then staged and tied down in an International Standards Organization (ISO) container.

Operations Implementation

***Safety Arrangements*:** Category I transport of nuclear materials by sea requires INF3 class purpose-built vessels. All of the vessels INS operate are certified to INF3 under the IMO's INF Code and, therefore, offer the highest levels of maritime safety. The vessels have built-in redundancies (e.g., to separate main engines, steering gears, etc.) and have been constructed with a double-hull and enhanced collision protection. Given the exacting standards and approximately three year duration for design, construction, and commission, there are very few INF3 class vessels in operation.

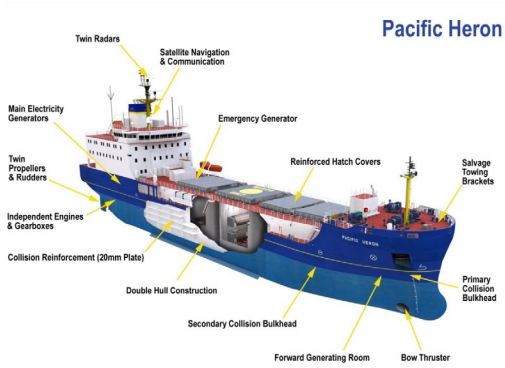

Figure 3: INF3 class vessel with redundant safety systems
(Source: International Nuclear Services)

Key characteristics of an INF3 compliant INF3 vessel (Figure 3) include:

- A double hull with extra-thick steel plates;
- Extra-strength hatch covers;
- Two engines, propellers, and rudders;
- Enhanced buoyancy;
- Dual navigation communications, monitoring, and cooling systems;
- Continuous satellite tracking system;
- Additional fire-fighting equipment to include hold spray and flooding systems; and
- Additional electrical generators.

***Security Arrangements*:** Transport of Category I nuclear materials requires detailed planning through a Transport Security Plan (TSP) to ensure the level of physical protection is adequately maintained throughout the entire life cycle of the transport, including any changes of transport mode. As such, planning arrangements often begin many months to years prior to the transport and involve a wide range of stakeholders, including government officials, regulators, police and security forces, port officials, carriers, and consigning sites and/or facilities. The operational implementation of security arrangements is described using INS protocols as an example.

To satisfy the obligations placed on State Parties under the CPPNM, bilateral and trilateral meetings are held between involved security representatives to discuss and agree upon the arrangements for the handover of security responsibility as the vessel enters and departs the territorial waters of another State. These arrangements are then reflected in a 'Record of Discussion' document that is signed by the respective involved governments and agencies. In the case of INS vessels, this document considers interoperability arrangements between the UK's CNC escort and assets on-board (Figure 4) and the security forces of other involved States. Additionally, in collaboration with CNC, INS will prepare the TSP, outlining the detailed security arrangements for the transport, and submit it to ONR at least 30 days in advance of the movement.

Figure 4: Typical Security Assets on an INF3 Vessel

The TSP will detail the people, assets, infrastructure, procedures, and processes that are integrated to form the operational security posture. It will also provide an overview of the transport, key dates, times, routes, organizations, and contact details of those involved; describe the handover of responsibility for security;

and detail all emergency response arrangements. It will demonstrate how the arrangements support the tactical plans of the CNC to ensure they are able to meet their 'concept of operations' and mission to deter, delay, and deny any attempted theft and/or sabotage of nuclear materials in line with the UK's DBT. INS's arrangements adopt or exceed the good practices outlined in the various IAEA security recommendations and guidance documents. All crew members are UK citizens and hold a national security vetting (NSV) clearance in line with the UK's security regulations.

For Category I nuclear material transports, INS and the CNC, with the support of a range of intelligence agencies, also collect and assess a transport-specific threat assessment. This assessment is obtained many months, sometimes up to six months, prior to the proposed shipment and is monitored on a constant basis until the transport is completed. Should the threat level toward the shipment change at any time, the transport will not be undertaken, or if already underway, the updated circumstances will be shared with the operational security command team immediately using established and tested routes for action.

To ensure the highest levels of operational capability are maintained and tested for Category I transports, interoperability training, known as Maritime Integration Training (MIT), between the crew and CNC, is conducted regularly using a rigorous training package that simulates threat-based scenarios to test the on-board command team. This training package has been established by INS and the CNC, with support from the UK's Royal Navy's Flag Officer Sea Training (FOST) team. Prior to each shipment, INS and the CNC conduct a formal MIT in the presence of the ONR and FOST to demonstrate that INS and the CNC are fulfilling their legal and regulatory obligations and requirements to effectively respond to a range of realistic threats, as defined in the UK's DBT.

Per the INFCIRC 225 Rev 5 requirements, a Transport Control Center (TCC) is maintained both by the shipper and the transporter. All INS operations are supported by two 24/7/365 transport control centers that have redundant secure two-way communications with the vessel and can track the progress of the shipment. These control centers also have direct communication with INS's emergency response structure and its various stakeholders and response organizations, including the UK armed forces.

Emergency Preparedness & Response Arrangements (EP&R): An important element of the Transport Security Plan concerns the EP&R arrangements in place to deal with a wide range of scenarios. INS places great importance on its ability to respond to any incident or emergency in a timely, coordinated and effective manner. INS's arrangements have been developed in accordance with 'Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material', commonly known as TS-G-1.2, and INFCIRC/225/Rev. 5. The objective of INS's EP&R strategy is to 'take all reasonably practicable measures to prepare for possible security and safety events and to mitigate their consequences should they occur'.

INS's EP&R arrangements have matured over its 40 year history and cover a large range of emergency situations from security incidents to conventional safety events. The EP&R arrangements also cover unplanned situations that may not be strictly considered as an emergency. These are all detailed in what are known as the INS 'Emergency Response Procedures' (ERPs). INS's operations are multi-agency in nature and as such, it is critical to work effectively with a range of stakeholders in the event of an emergency. INS's response structure has multiple levels of resilience and is supported by a range of technical roles (security, technical, communications, etc.).

Figure 5: Trained radiological teams for routine and emergency response

Stakeholder Engagement: Transports of Category I quantities of nuclear material require the participation of a variety of participants and stakeholders. From the sending facility operators preparing the material for transport, the regulators responsible for approving each aspect of the transport, the vessel operators, and port operations teams on both ends of the transport. Coordinating this wide ranging group and ensuring that each stakeholder has all relevant information as early as possible requires frequent communication as well as secure and established channels for disseminating that information. For previously completed removals of HEU and plutonium, DOE/NNSA and its partner countries devote a significant amount of time during the early stages of the project identifying affected parties, establishing roles and responsibilities, and determining internal and external communication protocols. Throughout the project, this plan should be updated and modified to ensure it encompasses all relevant stakeholders.

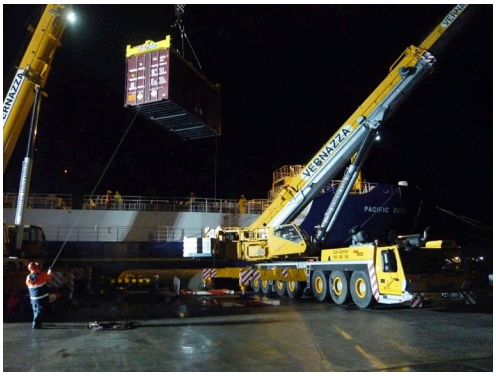

Figure 6: Loading Vessel with cargo for voyage

At the same time, sensitive shipment information should only be shared with those who have an established need-to-know. Nuclear transports, especially of Category I quantities of material, are security-sensitive with the public disclosure of key information increasing the threat against the vessel(s). The nature and quantity of information shared in advance of, during, and following completion of a transport will depend on the classification of the cargo being transported and the security regulations of the countries involved. Working together in an established trilateral or bilateral basis, the States should identify and define which information is sensitive and needs to be protected and establish a protocol for doing so. In the case of Category I transport, the outcome of this process may mean withholding very specific information around timing, precise routes, physical security measures, and quantities of materials.

Lessons Learned

DOE/NNSA and INS, along with their international partners have undertaken numerous Category I maritime transports, removing significant quantities of HEU and plutonium for downblending and disposition. Each of these campaigns have required detailed planning and execution based on the principles and guidelines outlined in this paper. Based on this experience, the authors have identified some key lessons learned for a safe and secure Category I transport.

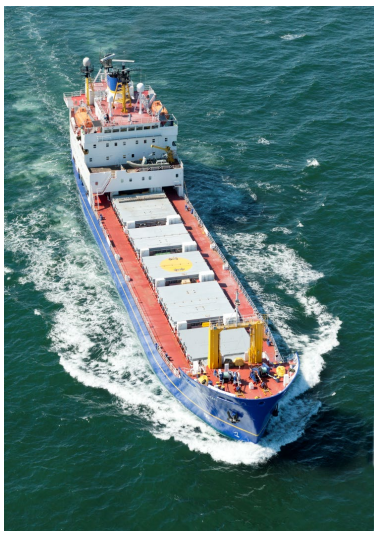

Figure 7: INF3 class vessel on Category I transport

Early planning is essential. Each project is unique so it is critical that the sending, receiving, and transporting country work together early in the process to identify all project activities, interdependencies, and associated regulatory requirements. Without an integrated project schedule or clear understanding of project requirements, delays or other project risks are likely to occur.

Regulations, guidelines, and best practices must be adhered to and considered early. The principles and requirements outlined in INFCIRC/225/Rev. 5 as well as all relevant national and international transportation and safety regulations must be incorporated into the transport plan from the earliest stages. National safety and security regulations are not uniform across all States and it may also be necessary

to find creative approaches to meet all affected countries' requirements when they do not exactly align.

Information security is critical to incident-free transport. The sending, receiving, and transporting countries should work collaboratively to identify all sensitive shipment information and develop procedures to protect that information from public release. Understanding the need to balance security considerations with transparency, the parties should also develop a comprehensive communications plan to define the extent of proactive announcements, identify roles and responsibilities for press inquiries, and ensure that information shared is accurate and transparent, while maintaining operational security.

Coordination and internal communication is a continuous process. Category I transports generally require a year or more of planning before execution. From the earliest stage of the project to final receipt of the cargo, the transportation plan is likely to undergo multiple changes. Even while in transit, weather or security considerations may impact the final schedule. It is essential that all affected parties are informed of these changes and have a clear understanding of their role and expectations for the project. Identifying roles and responsibilities early in the process and continuously updating and mapping those roles as the project progresses is a first step to ensuring the project team has the latest information. Once it is clear who should receive new information, it is also critical that channels for disseminating that information are established. These channels may also need to be updated based on the phase of the project or the sensitivity of the information shared.

Summary

Over the past ten years, DOE/NNSA and its international partners have worked with INS to facilitate the secure maritime transport of plutonium and HEU as part of global efforts to minimize the use of weapons-usable nuclear materials in civilian commerce. The transportation of Category I quantities of nuclear materials by sea requires the use of INF3 class dedicated vessels, specially trained crews, competent authority engagement and approval, close integration of the project team—frequently across three or more countries—and stakeholders, as well as a command and control structure for operations implementation.

In addition to these requirements, DOE/NNSA and INS have learned through the execution of these projects that it is also essential to begin planning early and to incorporate all elements of the transport as removal project activities are highly interdependent. Incorporating IAEA, national, and international regulations into the project plan from the start is also key to the safe and secure transport of Category I quantities of nuclear materials. Finally, internal project communication should be clear, frequent, and secure while external stakeholder engagement should be coordinated and balance security and transparency considerations. While great progress has been made minimizing HEU and plutonium materials, significant quantities of materials remain and DOE/NNSA, INS, and their international partners will apply these lessons learned to future efforts to minimize weapons-usable material inventories.

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