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ENHANCED TRAINING ON SECURITY DURING THE TRANSPORT OF NUCLEAR AND OTHER RADIOACTIVE MATERIAL

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ABSTRACT
Since 2013, Argonne National Laboratory (Argonne) has conducted week-long training courses on security during the transport of nuclear and other radioactive material. The courses have been convened annually at Argonne, except in 2020 and 2021 because of COVID-19. The objectives of the transport security courses are to help participants gain a working knowledge and understanding of U.S. and international requirements and recommendations for security during all modes of transport. While COVID-19 prevented travel, it also provided opportunities to explore electronic delivery platforms using advanced learning tools, including web-based apps for categorization of materials and transport security plans; geofencing and extended-reality scenarios for transport security and emergency response exercises; and interactive audience survey systems. These new tools will greatly enhance future training on security during the transport of nuclear and other radioactive material.

INTRODUCTION
The U.S. Department of Energy Packaging Certification Program, Office of Packaging and Transportation, Office of Environmental Management has sponsored a training course on security during transport of nuclear material (NM) and other radioactive material (RAM), conducted annually by Argonne National Laboratory since 2013. The original pilot course covered both international and U.S. domestic transport security; in later years, it was divided into two separate, week-long courses, designated as Nuclear and Other Radioactive Material Transport Security – International, and Nuclear and Other Radioactive Material Transport Security – U.S. Domestic. The objectives of these two courses are to help participants gain a detailed working knowledge and understanding of international and U.S. domestic requirements, recommendations, and guidelines for security during the transport of NM and other RAM by all modes of transport. More specifically, the International Transport security course

addresses the recommendations and guidance from the International Atomic Energy Agency (IAEA) and the international regulatory requirements and recommendations from relevant international and regional modal transport organizations, whereas the U.S. domestic transport security course addresses the requirements of U.S. government agencies. Both courses provide guidance on how to develop transport security systems by following a graded approach and applying modern technologies; how to develop transport security plans (TSPs) that satisfy regulatory security requirements; how to apply rules of engagement for escort, guard force, and emergency response personnel; and how to communicate with stakeholders and the public during emergencies, among other topics. Both courses incorporate hands-on exercises involving TSPs, readiness reviews, and corrective actions; use of audience participation systems to enhance dialogue; and a field exercise using the ARG-US remote monitoring systems to track a mock shipment with "staged incidents." Both courses also make extensive use of tabletop exercises to facilitate learning through role-playing, discussions, and group reports [1].

Because of COVID-19, the transport security courses were not convened at Argonne in 2020 and 2021. While COVID-19 prevented travel, it also provided opportunities to explore electronic delivery platforms using advanced learning tools, including interactive audience survey systems and web-based apps. The following sections provide a summary description of the technical basis for a web-based app, called NM-TPT for Nuclear Material Transport Planning Tool, that automates categorization of materials for shipment and generates TSPs with security provisions satisfying all regulatory requirements. Other web-based apps used in the training courses include geofencing [2, 3] for the ARG-US TRAVELER, a system used in tracking and monitoring nuclear cargo conveyances [4] and extended virtual-reality scenarios for transport emergency response exercises [5, 6]. Experience in using the audience survey systems *Slido* and *Poll-Everywhere* in classes and exams is also briefly described.

CATEGORIZATION OF NUCLEAR MATERIAL FOR SHIPMENT

Figure 1 shows a decision chart on the determination of applicable RAM categorization and International Transport security provisions based on UN Model Regulations (UNMR) as applied via IMO, ICAO, IATA, ADR, ADN & RID, and the IAEA Nuclear Security Series (NSS)-9 Rev. 1 Recommendations (15 March 2020). Figure 2 shows a decision chart on the determination of applicable NM categorization and International Transport security provisions based on the Convention on Physical Protection of Nuclear Materials (CPPNM) and its amendment, NSS-13, and 26-G Recommendations (6 May 2020).

The flow charts for RAM and NM categorization in Figs. 1 and 2, respectively, are complex and driven by applicable requirements and recommendations with multiple decision points (Q1 to Q10) to complete categorization by applying all applicable security provisions. Twelve summary tables of International Transport security provisions for RAMs, four (RAM-1 to RAM-4) based on the UNMR and eight (RAM-5 to RAM-12) based on IAEA NSS-9, are provided at various decision points in Fig. 1, whereas fourteen summary tables—five (CPPNM-1 to CPPNM-5) based on CPPNM and Amendment, eight (NM-1 to NM-8) based on INFCIRC/225/Rev.5 (IAEA NSS-13), and one (NM-9) based on IAEA NSS-26-G—are provided for NMs at various decision points in Fig. 2. Each of these summary tables is followed by general and specific topics: for example, RAM-1 provides general security provisions specified in the UNMR for most RAM, transported by all modes; RAM-2 provides additional specific security provisions specified in UNMR for high-consequence RAM transported by all modes; RAM-3 provides additional, mode-specific security provisions specified in the UNMR for most RAM transported by road, rail, and inland waterway; and RAM-4 provides additional, subsidiary risks security provisions specified in the UNMR for high-consequence RAM transported by all modes. Following the mandatory UNMR security provisions for RAM categorization alone is a challenging task, as is following recommended security provisions as set forth in IAEA NSS-9, Rev.1.

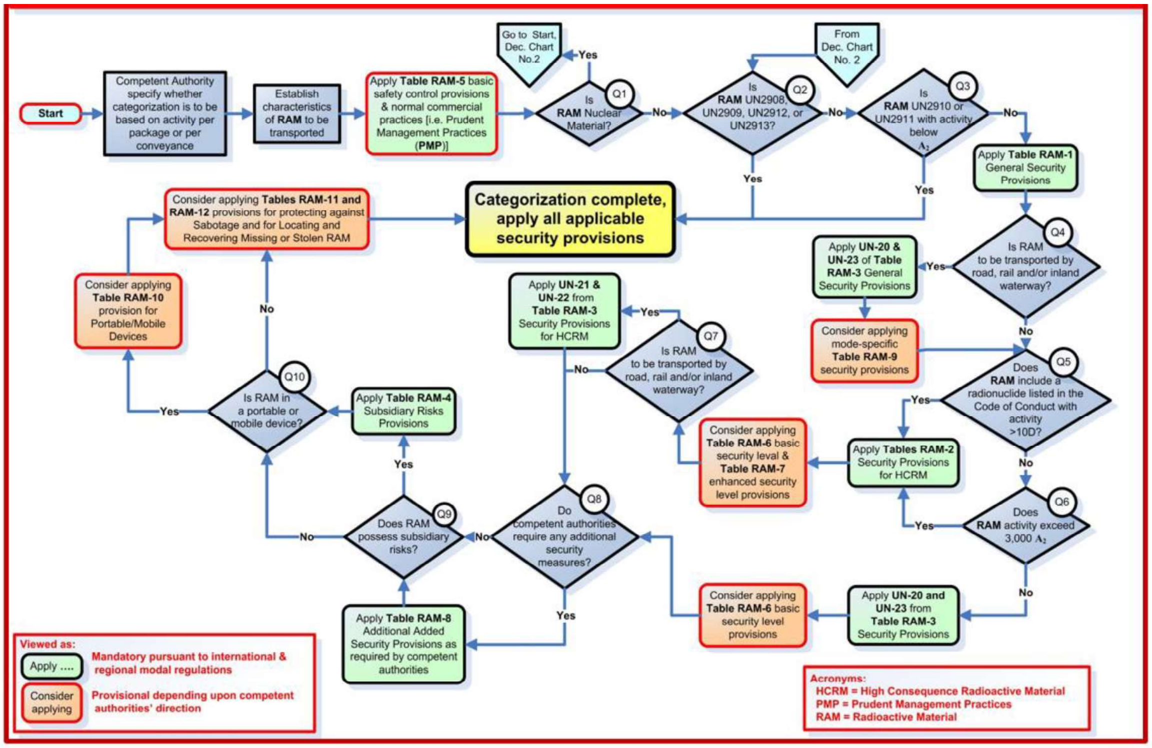

Figure 1. Determination of applicable <u>radioactive material</u> categorization and International Transport security provisions based on UN Model Regulations as applied via IMO, ICAO, IATA, ADR, ADN & RID, and NSS-9 Rev. 1 Recommendations (15 March 2020)

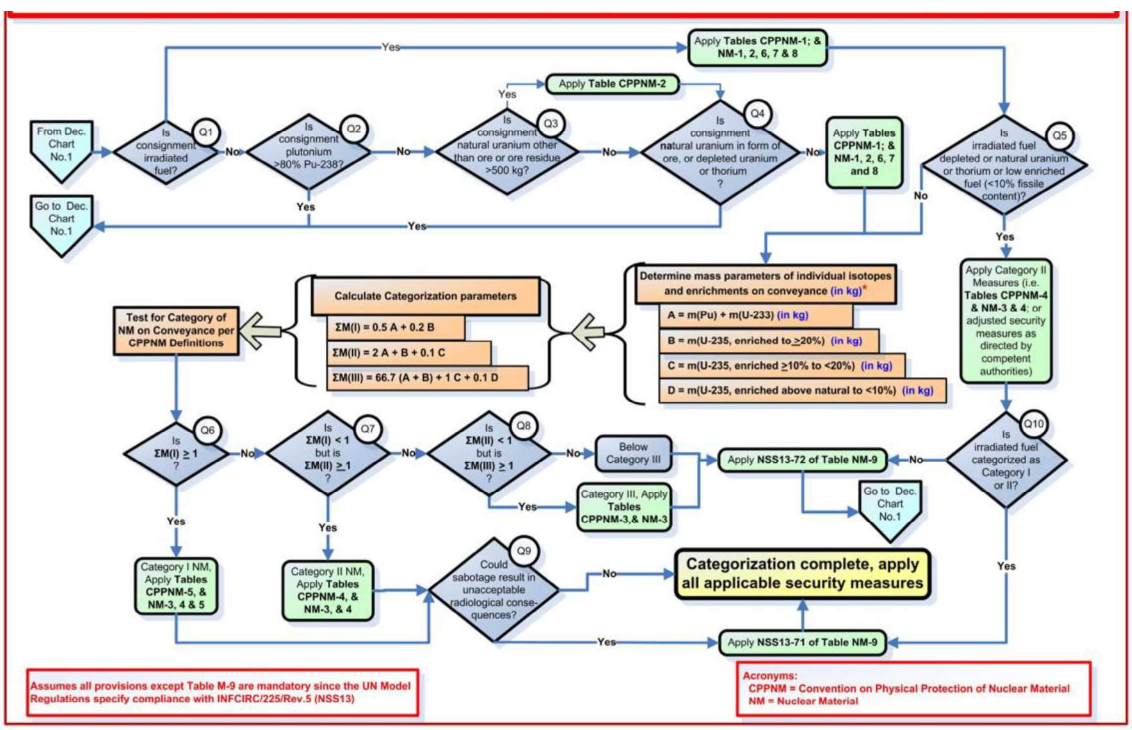

Figure 2. Determination of applicable <u>nuclear material</u> categorization and International Transport security provisions based on the CPPNM and its amendment, NSS-13, and 26-G Recommendations (6 May 2020).

TRANSPORTATION SECURITY PLAN

A typical TSP for NM and RAM shipment contains sections on scope, objectives, description of the shipment and material to be transported, administrative requirements, personnel qualifications, information management, transport security measures, and emergency response. Figure 3 shows three major topics—6. Information Management; 7. Operational Transport Security / Physical Protection Measures; and 8. Emergency Response, each with associated subtopics—that are included in the TSP. The check boxes to the right of each TSP topic and subtopic show organizations (DOT, NRC, ICAO, IMO, IAEA) that give requirements or recommendations for RAM and NM. Notice that for NM, the IAEA INFCIRC recommends inclusion of all topics and subtopics in the TSP, whereas for NM, all organizations except NRC require or recommend inclusion of the 7b subtopic Operations Communication, Command and Control; Shipment Tracking in the TSP. Together with the material categorizations for RAM and NM in Fig. 1 and Fig. 2, preparation of a TSP with Required/Recommended security provisions is akin to preparation of Federal, State and local income tax, in that a web-based app (described in the next section) should greatly ease the burden, as would TurboTax when filing income taxes.

TSP Topic	RAM			NM	
	DOT	NRC	ICAO/ IMO	NRC	INFCIRC/ 225
6. Information Management					
a. Information Security		X	X	X	X
b. Records Retention	X	X		X	X
c. Confidentiality		X	X	X	X
d. Protection of Information	X	X	X	X	X
7. Operational Transport Security / Physical Protection Measures					
a. Primary and Alternate Routes, Intermodal Transfers, Storage in Transit, Stopping Places	X	X	X	X	X
b. Description of Security System	X	X	X	X	X
○ Equipment and Modes of Transport	X	X	X	X	X
○ Operations Communications, Command and Control; Shipment Tracking	X	X	X		X
○ Escort, Guards and Response Force Personnel	X	X	X	X	X
○ Additional Security Measures	X	X	X	X	X
○ Maintenance and Testing of Systems and Equipment	X	X	X	X	X
8. Emergency Response					
a. Non-tactical Emergency Response				X	X
b. Tactical Emergency Response				X	X
c. Incident Communication					X
d. Notification of Relevant Agencies					X

- **RAM:** Radioactive Material
- **NM:** Nuclear Material
- **DOT:** U.S. Department of Transportation
- **NRC**: U.S. Nuclear Regulatory Commission
- **ICAO:** International Civil Aviation Organization;
- **IMO:** International Maritime Organization
- **INFCIRC/225:** IAEA The Physical Protection of Nuclear Material

X: **Required/Recommended**

Figure 3. Summary of organizations' requirements and recommendations for topics to be included in the Transportation Security Plan (TSP) for shipment of radioactive material (RAM) and nuclear material (NM).

WEB-BASED NUCLEAR MATERIAL TRANSPORTATION PLANNING TOOL (NM-TPT)

A web-based app that automates the decision processes for categorization of RAM and NM, shown in Figs. 1 and 2, respectively, has been developed for use in Argonne's transport security training classes. Use of the web-based NM-TPT begins with loading the app, identified by the Course ID NP711 as shown in the top panel of Fig. 4; moving downward, each panel provides information and guidance to the user and step-by-step instructions. The last panel at the bottom of Fig. 4 presents three choices: Decision Process, Supporting Documents, and Lecture Modules.

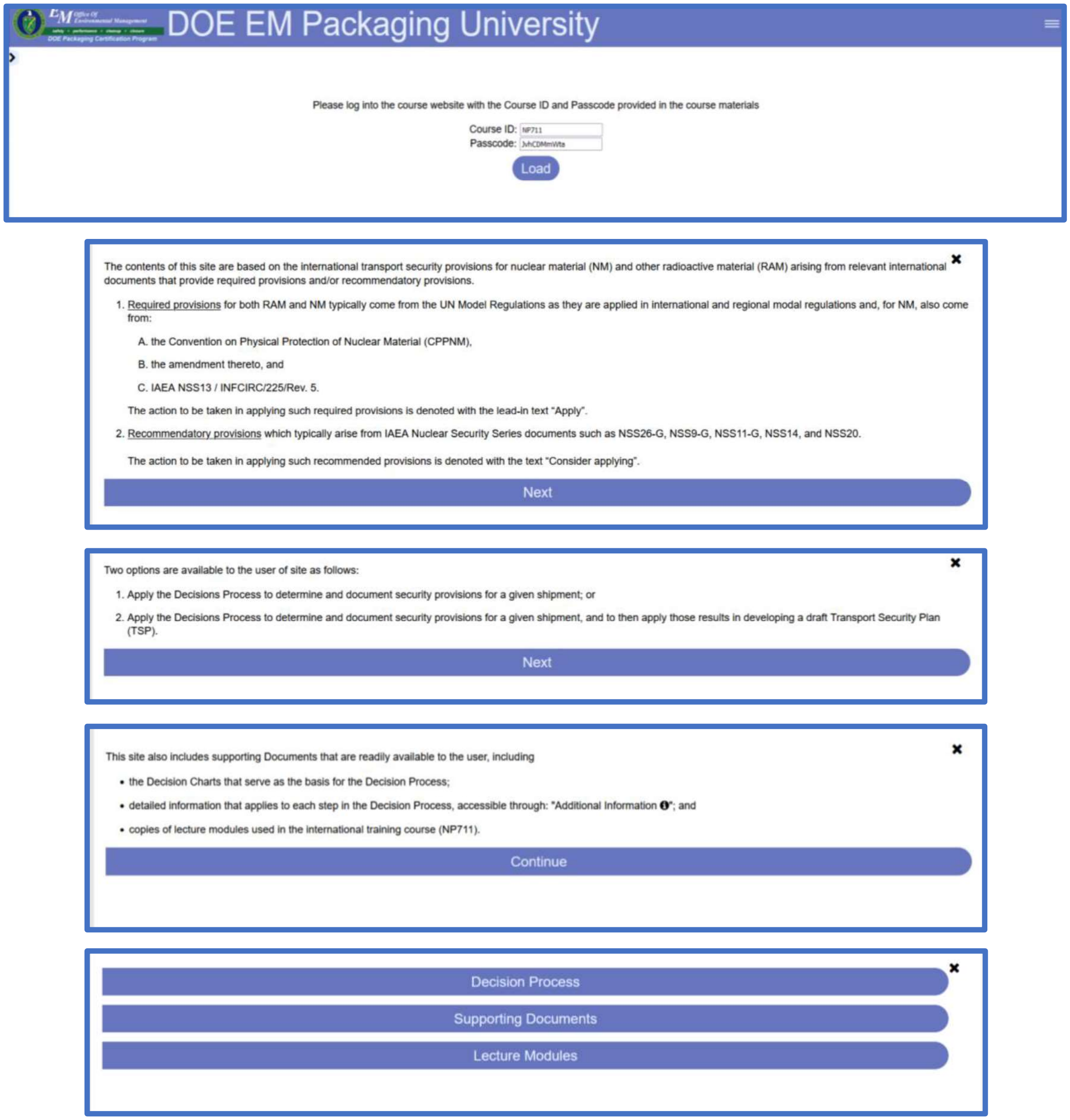

Figure 4. Images from Nuclear Material Transportation Planning Tool (NM-TPT), a web-based app for use in the transport security training course NP711.

Clicking the Supporting Documents button shows a list of seventeen documents, A1 to A17 (Fig. 5), each of which can be downloaded as a pdf. For example, A1 contains the decision charts for determination of categorization of RAM and NM and International Transport security provisions that meet the regulatory requirements in Figs. 1 and 2, whereas A16 and A17 provide, respectively, Guide to Summary Tables of Security Provisions-International and Summary Tables of Security Provisions-International.

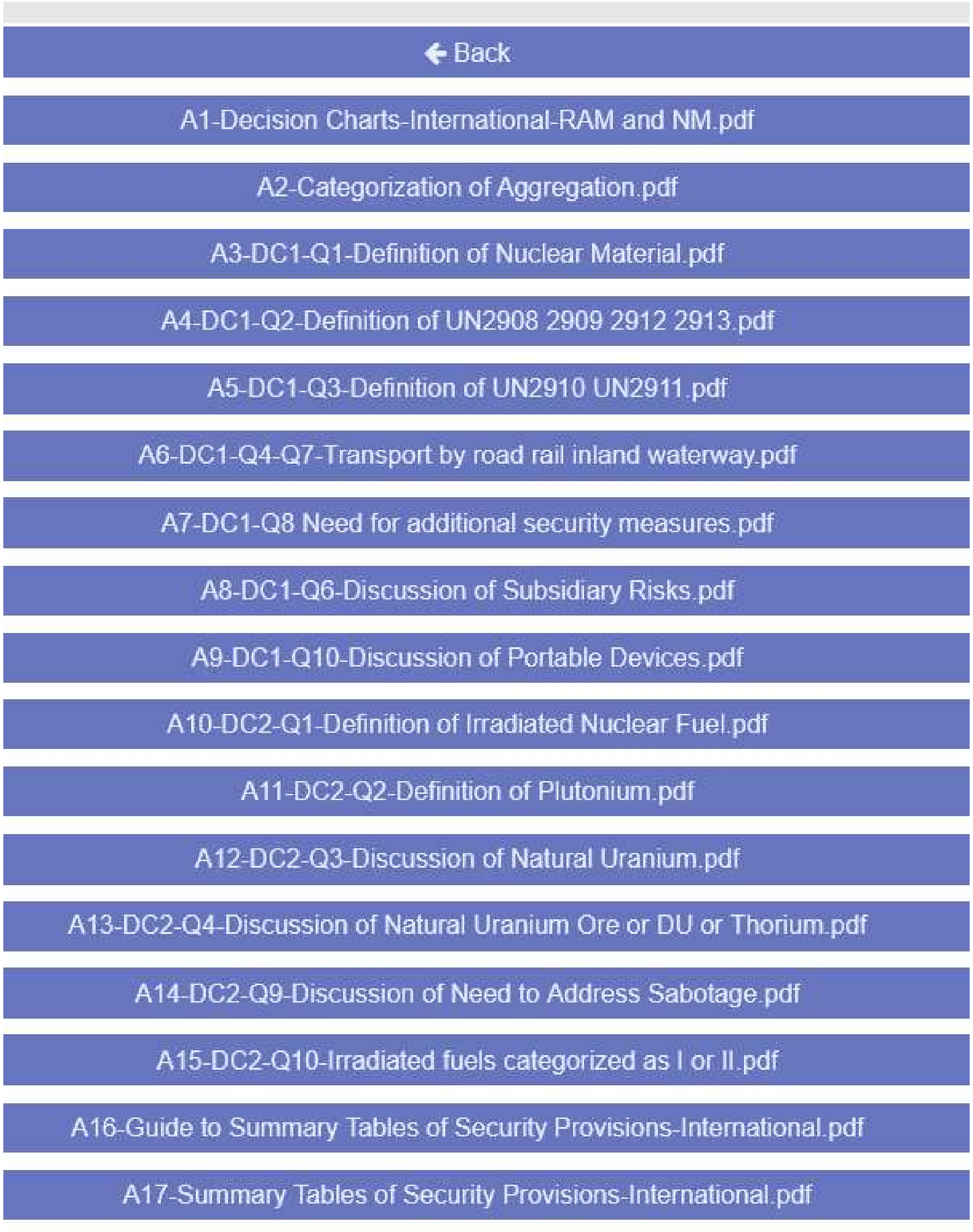

Figure 5. Supporting documents A1 through A17

The Lecture Modules, when selected, will download the pdf slides used in the transport security training course NP711; they are maintained and updated each season so as to remain current. When the Decision Process button is selected, an electronic worksheet (Fig. 6) is provided for establishing the characteristics of materials to be transported. Completing the worksheet is recommended, as it facilitates answering future questions and serves as a basis for developing an automated draft TSP for shipment.

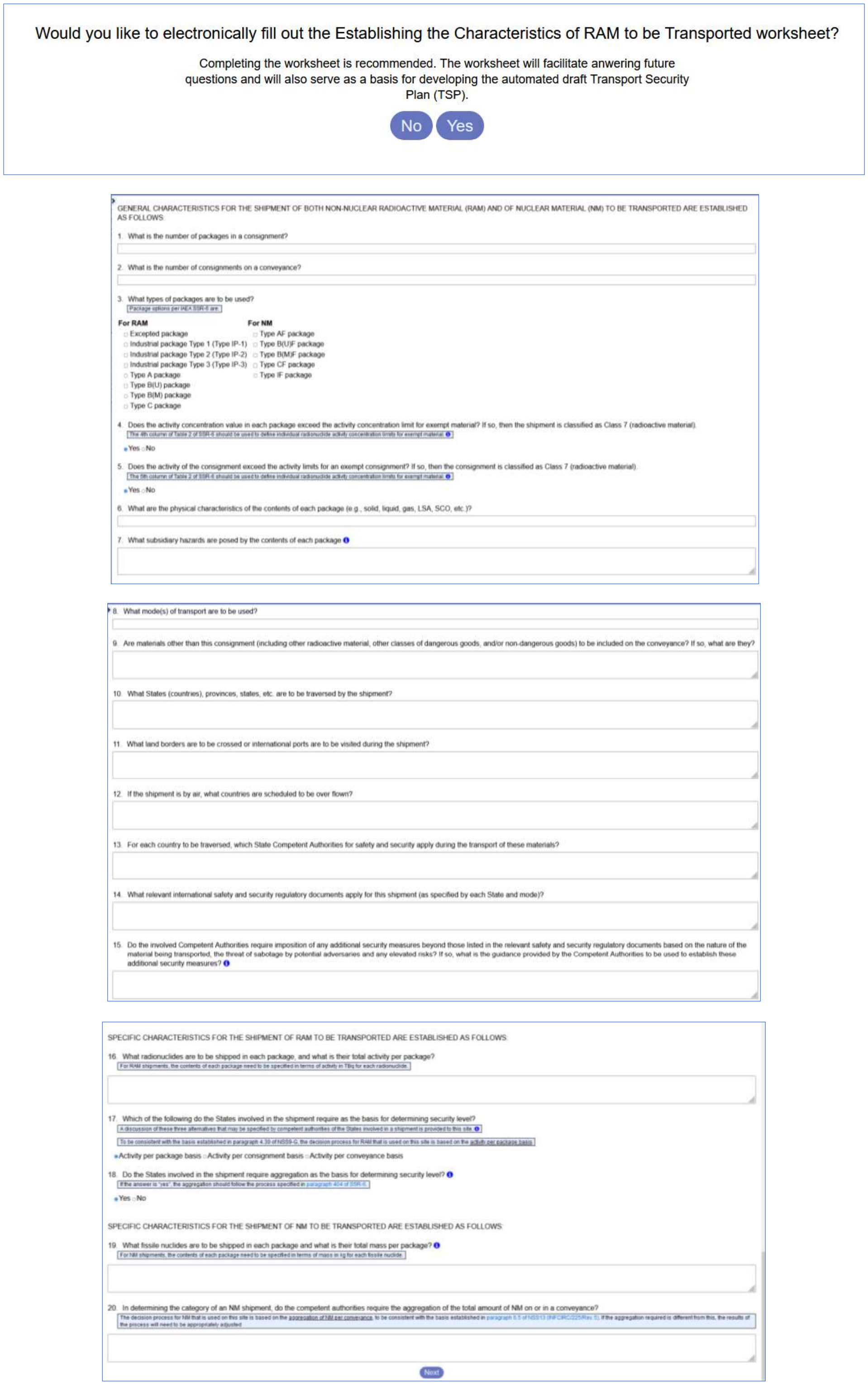

Figure 6. Electronic worksheet for establishing the characteristics of materials to be transported.

Figure 7 shows the subsequent flow path of the web-based NM-TPT, with additional decision points (No/Yes) highlighted in red. At the decision point “Chart complete. Press ‘Done’ to generate a PDF of security provisions, or TSP to continue on to create a Transport Security Plan,” if TSP is chosen, the user is taken through eleven additional steps to “Transport Security Plan complete. Press ‘Done’ to generate the resulting documentation.”

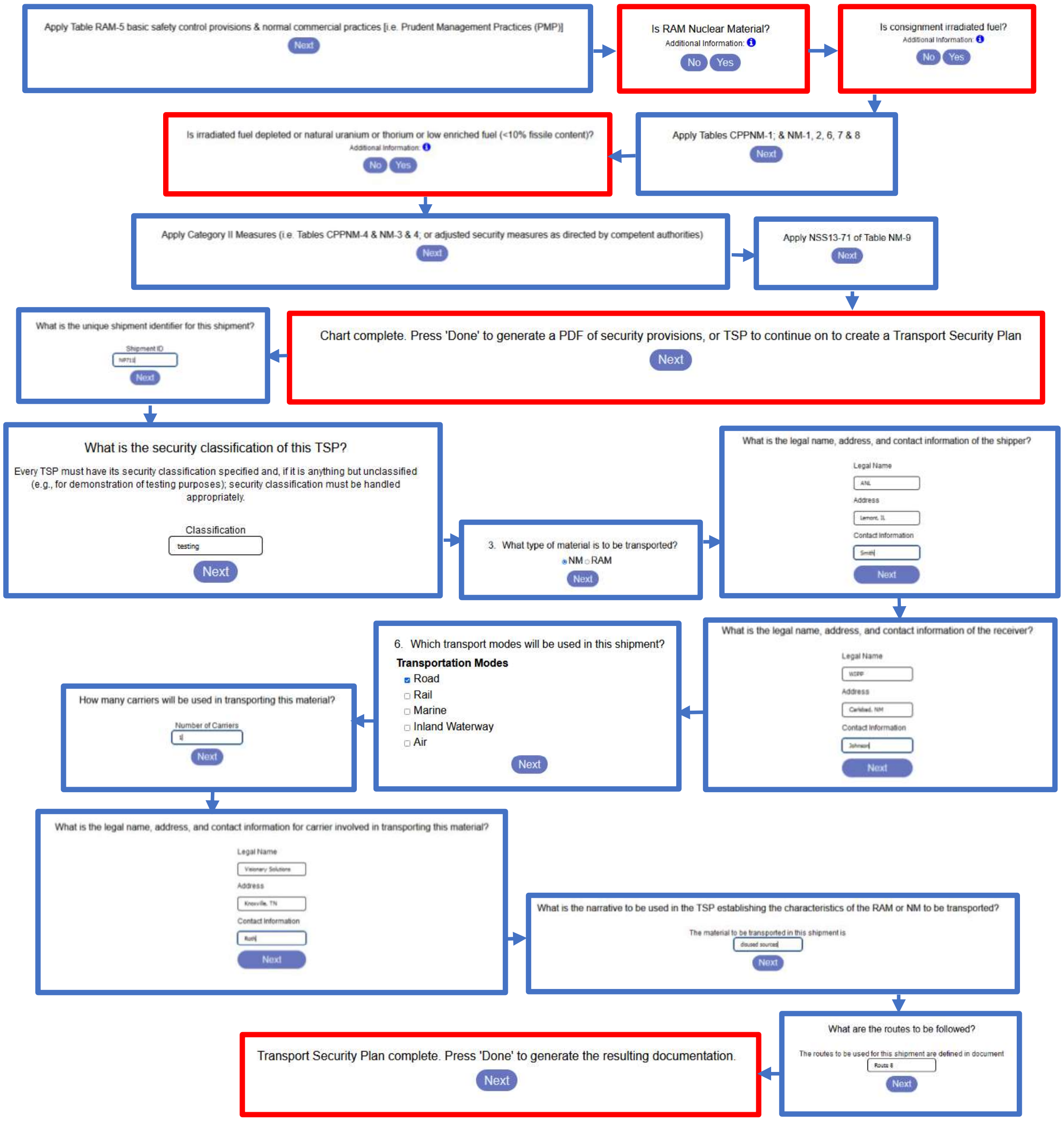

Figure 7. Subsequent flow path in web-based NM-TPT to generate a draft TSP for shipment after completing the electronic worksheet depicted in Fig. 6.

WEB-BASED GEOFENCING

A secured server-based geofence app has been developed for the ARG-US TRAVELER that enables establishment of virtual geographic boundaries for vehicle shipments of RAM [2, 3]. An established geofence, defined by the ARG-US TRAVELER's Global Positioning System via cellular or satellite communication, will trigger alarms automatically when a tracked vehicle en route with a shipment violates it, via either location or travel time. Advanced notification of shipment arrival and border crossing, and immediate notification to stakeholders when emergencies occur, are other key features enabled by the geofence app. The four basic building blocks in constructing a geofence for vehicle shipment are Zones, Legs, Route, and Trip. A Trip is arranged by stitching Zones together to form a Route, which provides an itinerary that specifies where a vehicle shipment should or should not be, relative to the amount of time that has passed since the start of the defined Route. Each Route must have one or more Legs. A Leg is a combination of single Zones, each of which is a geographic area of interest, and an activity window, which is the time period of interest. Each Leg is also marked as either Inclusive or

Exclusive. An Inclusive Leg indicates that the vehicle is expected to traverse the given Zone during the activity window, whereas an Exclusive Leg indicates that the vehicle should not traverse the given Zone during the activity window. Like NM-TPT, a web-based ARG-US geofence zone formation tool has been developed for training and used for the ARG-US TRAVELER in NM and RAM shipment. The tool shows the steps for creating a buffer polygon across a desired route to be uploaded to the ARG-US secured server and used as an inclusive Leg. A companion video has been produced to help clarify the steps because without a visual aid, they can be difficult to follow in constructing a geofence for an NM or RAM shipment. Details of this web-based geofencing tool can be found in reference [4].

WEB-BASED EXTENDED-REALITY SCENARIOS

Extended reality, including virtual reality and augmented reality, is increasingly used in nuclear training and education, including emergency preparedness and response. Argonne has developed a transport emergency response training course that employs web-based extended-reality scenarios in class exercises [5]. During the course, students are introduced to transportation accidents that require them to conduct incident scenes and packaging assessments requiring multiple skill sets. The instructor can rapidly cycle through training variables, including packaging damage, increased radiation levels, and other scene hazards (e.g., fire, damaged power lines, fuel leaks), thereby reducing the time needed to set up and conduct the evolutions, as well as minimizing students' ability to predict the scenario by observing training-aid setup. The instructor can fully test the range of postulated scenarios, including those with beyond-design-basis damage and radiation levels. An example of a recent scenario development was simulated radiation measurement using a mass attenuation coefficient transport model integrated with multiplayer voice and visual interactions in virtual reality on an Oculus Quest 2. The multiplayer scenarios included real-time voice communications and simulated physical interaction in the synthetic environment (e.g., pointing at a hazard, such as a downed power line; showing a personal radiation detector display; and approaching the scene either together or from separate angles). The proof-of-concept scenes use Photon Unity Networking and Photon Voice. These web-based tools allow users of the app to connect to a web server and participate in the training scene remotely, with up to 10 simultaneous connections. The positions and states of users and grabbable objects are synchronized across clients so that all users can see all other users and interact with the same objects in the scene. This approach allows students to train in realistic emergency scenarios that are either too hazardous for in-person training or not feasible for in-person training because of facility restrictions, while still maintaining realistic joint operations among students in multiple disciplines (e.g., radiation specialists and law enforcement). Details of this web-based extended-reality scenario training tool can be found in reference [6].

DISCUSSION

Both *Slido* and *Poll-Everywhere* are online audience survey systems that turn one-way slide presentations into engaging conversations, with live polls or surveys that are designed to elicit anonymous student responses to questions. Because the instructors get the aggregated feedback instantly, the entire class can continue the discussion by exploring the reasons behind the differences in the responses to the survey. This type of learning benefits everyone in the class. Furthermore, the associated analytics and metrics provide summaries and objective measures of students' achievement of the learning objectives of the courses.

Ongoing development of web-based apps for the transport security training courses at Argonne has also included blockchain for the ARG-US TRAVELER. Blockchains are often referred to as Distributed Ledger Technology because a blockchain is essentially a ledger of recorded transactions that is distributed or shared with multiple participants. These transactions include participants querying, reading, or writing data through a smart contract. The blockchain stores these transactions in records known as “blocks.” Each block (except for the genesis, or first block) is linked to a previous block, creating a blockchain. Data in a block, once entered, cannot be changed; thus, blockchains are immutable. The majority of participants must reach consensus before a transaction takes place and is synchronized across the network. Blockchains are thus decentralized—there is no central authority in control, allowing full real-time access. The existing ARG-US TRAVELER system implementation relies on a centralized relational database to store all the information collected by the monitoring units. Seeking to improve the information security of the data collected by the ARG-US TRAVELER, Argonne researchers are developing a new blockchain prototype that implements a distributed ledger system based on the Hyperledger Fabric platform, which is an enterprise-grade, distributed ledger platform that is modular and versatile. Unlike widely used public blockchains, such as Bitcoin and Ethereum, Hyperledger Fabric offers a scalable and secure platform that supports private transactions and confidential contracts. This architecture allows for solutions developed with Hyperledger Fabric to enable trust, transparency, and accountability. Details on the progress of the implementation of the block prototype for the ARG-US TRAVELER can be found in reference [7].

CONCLUSIONS

Since the inception of the transport security training effort in 2013, its goal has been to improve the ability of the participants to prevent those with malicious intent from stealing, diverting, or attacking shipments of NM and other RAM. Those trained to date have come from North America, Europe, the Middle East, and Asia. Participants have included representatives from regulators; consignors, carriers, consignees, and shipping brokers; and State/regional inspection, escort, enforcement, and response personnel. Training-course lecturers have included experts from U.S. domestic organizations, including the NRC, DOE, and FBI; and from international organizations, including the IAEA, World Institute for Nuclear Security (WINS), World Nuclear Transport Institute (WNTI), and Risk Management Solutions. The breadth of experience and knowledge developed through these training courses has also been used to contribute significantly to two WINS Best Practice Guides focused on transport security [8, 9], a case study on electronic tracking [10], and the WINS Academy training module on Transport Security Management [11]. The knowledge and experience base developed through the convening of the transport security training courses that have been discussed in this paper could be used to leverage future transport security educational efforts worldwide to support capacity building [12] and next-generation security [13, 14]. Significant enhancement can be expected in the future training courses conducted by Argonne researchers on security during the transport of NM and other RAM, which will also incorporate the latest work by Argonne on transport safety, security and safeguards of NM and other RAM [15] and culture analysis for international nuclear transport [16].

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This paper was written by Yung Liu in honour of Ronald Pope, who passed away on March 24, 2023, before the start of the DOE Packaging University training course on Quality Assurance of Radioactive Material Packaging, March 27–31, 2023. In addition to the development of the transport security courses, Mr. Pope has played a seminal role in the development of the Packaging QA and the ASME Code training courses at Argonne, and he has made numerous contributions to the packaging community worldwide over the 64 years of his professional career.

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