PROJECT SUMMARY

HQ WBS: 21.1.1.10

INTERNATIONAL ATOMIC ENERGY AGENCY

27th International Training Course on the Physical Protection of Nuclear Materials and Nuclear Facilities

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Project Description and Background

Sandia National Laboratories (SNL) has hosted the International Training Course on the Physical Protection of Nuclear Materials and Nuclear Facilities since 1978. This course is the flagship training course of the International Atomic Energy Agency (IAEA). On behalf of the National Nuclear Security Administration (NNSA), SNL manages, develops, and coordinates all course materials, and works closely with the IAEA to arrange all logistical details for the course.

ITC-27 incorporated several new approaches based on feedback and experience with ITC-26 and earlier versions of the course. An important update was a greater emphasis on field exercises. ITC-27 staff heavily utilized the Integrated Security Facility (ISF) at SNL. The physical protection system at this mock facility—an area that formerly housed Category I nuclear material—provides many opportunities for hands-on, real world training in the design and evaluation of a physical protection system (PPS).

In addition, the ITC-27 staff worked closely with the IAEA on course materials, instituting a peer review process to ensure all course materials were aligned with Nuclear Security Series No. 13 and other relevant international guidance documentation from the IAEA. Through its updates, ITC staff also addressed the changing audience of course participants, which now primarily includes both operators and regulators of research reactors and nuclear power plants rather than of Category I facilities. ITC staff updated the course materials to better reflect the concerns of current participants.

Finally, the ITC staff incorporated an improved method of evaluation to capture participants' satisfaction with the updated course and to gather feedback concerning future improvements.

Scope and Purpose

This document provides a brief description of ITC-27, including a summary of lessons learned and key recommendations for future development efforts.

Customers and Stakeholders

ITC-27 was funded and sponsored by NNSA's Office of Nuclear Security Cooperation (NA-21). The IAEA is a key stakeholder. SNL was the key contributor to this activity, along with subject matter experts from Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Y-12 National Security Complex, Oak Ridge National Laboratory, and Gregg Protective Services.

ITC Staff

ITC-27 employed a small core team, composed of members with crosscutting experience and capabilities who were well-versed in practices related to international training. This approach worked well and was key to this effort's success. The core team was led by the Course Director, Greg Baum, who was responsible for the successful management and execution of the course, as well as the overall vision for ensuring course materials were relevant, updated, and reflected the current state of the international audience and IAEA guidance documents.

The Course Director was supported by the Course Coordinator, Sondra Spence, who was responsible for executing the Course Director's vision and managing all aspects of coordination between ITC staff and subject matter experts. The Course Director and Coordinator relied heavily on the logistics team, which included Michael Kline, Carla Sanchez, and Stephanie Kelly. The logistics team was responsible for ensuring all course participants were well cared for and that all logistical details leading up to and throughout the execution of the course were managed efficiently and effectively. The final staff member was the Instructional Designer, Janet Chapman. The instructional designer played a key role in ensuring that the course materials were updated and

maintained for high quality, were reflective of IAEA guidance, and were designed with participant learning in mind.

Participants
A total of 52 attendees from 40 different countries attended ITC-27.

Project Milestones
ITC-27 project milestones are listed in Table 1.

Table 1. ITC-27 Project Milestones

Date	Milestone
2017	
August 3	Subgroup Instructors Identified
August 8	Subject Matter Expert Lecturers Identified
August 10	Materials sent for IAEA peer review
August 30	Design document approved
October 20	IAEA peer review complete
October 31	Material revisions completed
November 10	Review & Approval and export control
November 15	IAEA instructor's deadline for dry run logistics
November 30	Learning Management System (LMS) development phase
December 22	LMS testing phase
2018	
January 15	IAEA participant information deadline for logistics
January 29	Course dry run with subgroup instructors and IAEA instructors
March 16	Post dry run material edits complete
March 30	Technology loaded
April 13	Printed material complete
April 29 - May 18	Training executed

Course Scope
The course content consisted of 32 modules that included topics necessary to understand how to conduct PPS design and evaluation. An important aspect of ITC-27's training methodology was to ensure that each topic was presented via lecture (hear), and also included demonstrations (see) and hands-on field activities (do), whenever applicable. A final exercise provided participants with the opportunity to apply the design and evaluation knowledge gained during the course. Guest lecturers—both domestic and international—supplemented information from related agency perspectives. A new topic—Unmanned Aerial Systems (UAS)—offered participants a high-level awareness of the types, uses, and capabilities of these systems and how they might be used in both an adversarial and protective capacity.

Since ITC-24, iPads have been used as the electronic platform to reduce the amount of printed course material. For ITC-27, a Learning Management System (LMS) was adopted, which ran on the iPads and enabled course staff to house all course material in one location. The application was simple to use and gave the participants one access point for all activities, including some of the evaluation tools.

ITC-27 continued earlier training methods by utilizing subgroups for the exercises that supplemented the large group lectures. The subgroup structure provided a collaborative learning environment. The small group not only allowed participants many opportunities to ask questions more freely than is possible during a lecture, but also offered an environment in which participants could work through concepts individually, in pairs, or as a team; share insights from their own experience; and network with their fellow subgroup members.

Every participant was assigned to a subgroup, which included 8 to 10 team members and was facilitated by a subgroup instructor. Participants were assigned to subgroups before the course began based on technical and nuclear reactor background and areas of expertise, years of experience, regional diversity, political compatibility, and gender balance. Although the subgroup instructors were primarily from Sandia, ITC-27 also included one subgroup instructor from the Canadian Nuclear Safety Commission.

During the first two weeks of the course, the participants used data for a hypothetical facility, the Lagassi Institute of Medicine and Physics, when working on exercises. The exercises were focused primarily on preventing theft. For the final exercise, participants completed a full evaluation, including identifying upgrades, on one of two different hypothetical facilities, with the focus on sabotage prevention. The first facility, Hypothetical Atomic Research Institute, represented a small research reactor located in an open campus and urban environment. The second hypothetical facility, Lone Pine Power Plant, represented a nuclear power plant. Participants worked through the final exercise over the course of 2-1/2 days. Each subgroup presented its solution to a panel of experts and classmates on the final day of the course.

Course Evaluation
In ITC-27, a Course Evaluator was assigned to manage the evaluation component of the course. Working closely with the core team, Frances Esquibel, the Course Evaluator, led the initiative to update and implement the Course Evaluation Framework, as well as develop a detailed analysis to inform future course planning. The objectives of the revised evaluation framework were to quantify the impact of the training, identify program successes and areas in need of improvement, and provide detailed guidance for future course planning based on participant feedback. The new framework examined course effectiveness holistically by examining a variety of topics of interest to the team including: course content, training activities, classroom technology, subgroup exercises, hosting logistics, and course satisfaction. The evaluation tools included the following:

- Pre- and Post-Tests: The Pre-Test was administered after the introductory module; the Post-Test was administered before the final exercise. The intention was to gather Level 2 Measured Knowledge Increase by including the same 23 questions to gauge how well the participants understood PPS fundamentals. Related to this tool were comprehension questions that were completed at the end of modules directly related to PPS. Three questions were asked per module, one of which was included in the 23 pre-test and post-test questions. This tool was accessed via the LMS.

- The Knowledge Increase Survey was administered after the first and second weeks. In this survey, each participant self-reported on knowledge increase. This tool was printed and provided to the participants.

- The Course Activity Survey was administered after the first and second weeks. This survey provided ITC-27 staff with rating data regarding effectiveness of activities. This tool was accessed via the LMS.

- The Course Experience Survey was administered on the final day of the course. This survey was intended to gather Level 1 Measured Reaction to Training, including course satisfaction and relevance. This tool was printed and provided to the participants.

The evaluation framework was designed to gather data on four high-level questions, listed in Table 2; the evaluation tool(s) used to gather that information are also noted.

Table 2. Four Primary Evaluation Topics and Corresponding Evaluation Tool(s)

Question	Pre and Post Tests	Knowledge Increase Survey	Course Activity Survey	Course Experience Survey
1. As a direct result of the training, did we increase awareness, knowledge, and practical application of the principles, concepts, and recommended requirements from NSS-13 for application at participant facilities?	✓	✓		✓
2. Which ITC-27 training components were most/least effective in increasing awareness, knowledge, and practical application of the principles, concepts, and recommended requirements from NSS-13 for application at participant facilities?			✓	✓
3. What were the program successes and the program areas in need of improvement?			✓	✓
4. Did the information collected help us better understand participant background and areas of interest to inform future planning?				✓

The following provides high-level results regarding responses to the questions above. Detailed results of the evaluation data can be found in SAND18-xxxx (Esquibel et al., [in process]).

Question 1 Results: Data indicated that ITC-27 increased awareness, knowledge, and practical application of the principles, concepts, and recommended requirements in NSS-13 for application at participant facilities as a result of the course.

- 88% of participants stated they would be able to apply the information they learned at ITC-27 at their jobs *Always* or *Almost Always*.

- Participants self-reported their knowledge increase as follows:

  o Week 1 average increase: **+38%**

  o Week 2 average increase: **+42%**

- Pre-test class average score: **66%** (Figure 1)**;** post-test class average score: **90%** (Figure 2); class average increase **26.6%**
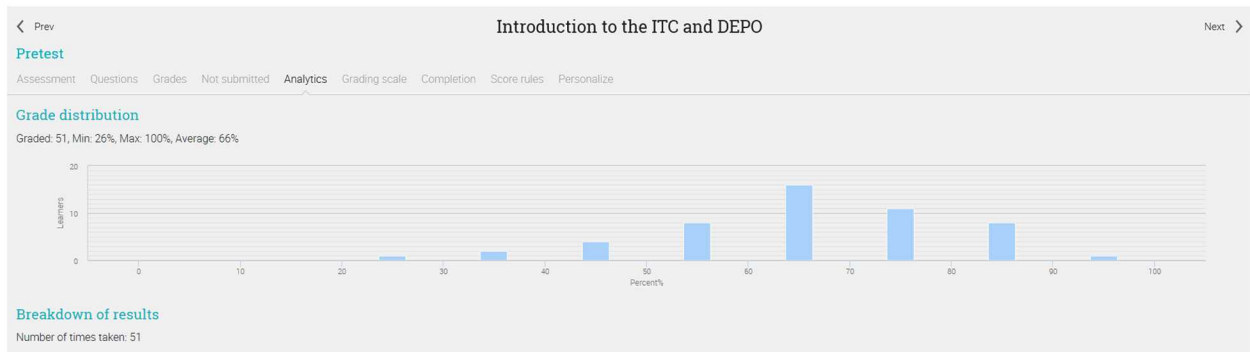

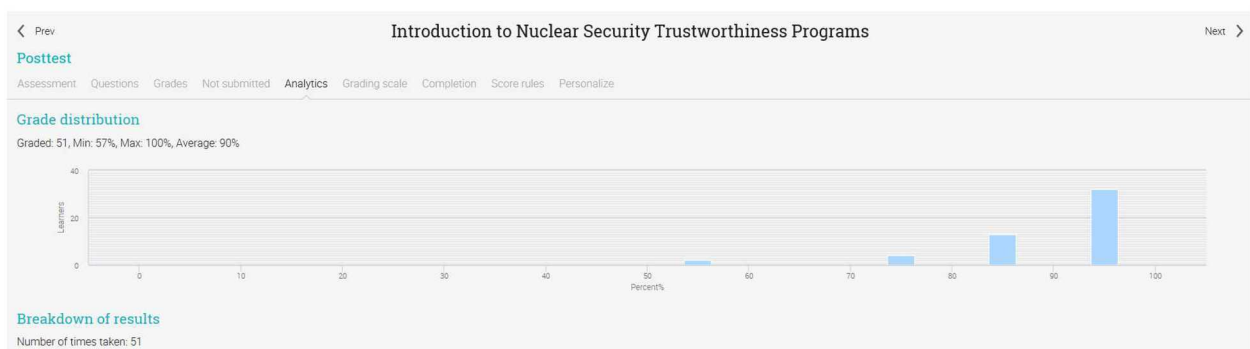**Figure 1. Pre-Test Scores**

Figure 2. Post-Test Scores

Question 2 Results: The participants indicated the following ITC-27 training components were the most/least effective in increasing awareness, knowledge, and practical application of the principles, concepts, and recommended requirements from NSS-13 for application at participant facilities.

- Participants identified classroom exercises as the most beneficial training activity. In addition, accompanying written comments indicated that having a combination of all activities was most important, especially when they built on one another to advance from theoretical knowledge to practice.

- The field exercises were popular and, according to the survey, effective:

  o 70% of participants indicated that hands-on training in the technical area (ISF) greatly enhanced their understanding of course concepts.

  o 70% of participants recommended having more activities outside of the classroom within the technical area (ISF).

- Participants were asked to rate each activity based on how effective it was in preparing them for real world application at their facilities. The following provides a snapshot of the results for weeks 1 and 2.

  o Topics with Highest Scores (indicating lowest priority for revision)

    ▪ Field Exercise: Delay Activity: Delay demonstrations of cutting times, building your own vault, and bolt plate multiplication factor exercise
    ▪ Classroom Lecture: Design Basis Threat
    ▪ Classroom Lecture: Delay
    ▪ Subgroup Exercise: Introduction to Path Analysis Activity: Classroom exercise to understand the purpose of Path Analysis
    ▪ Subgroup Exercise: Tabletop Analysis Activity: Classroom exercise to implement a Tabletop exercise and analyze the results
    ▪ Classroom Lecture: Information Security

  o Topics with Lowest Scores (indicating highest priority for revision)

    ▪ Subgroup Exercise: Alarm Communication and Display Activity: Classroom exercise to recognize effective alarm console configuration.
    ▪ Subgroup Exercise: Introduction to the Hypothetical Facility Activity: Classroom exercise to become familiar with hypothetical facility data handbook identifying targets.
    ▪ Subgroup Exercise: Intrusion Detection Activity: Classroom exercise to determine effective placement for interior and exterior sensors.
    ▪ Classroom Lecture: Introduction to STAGE
    ▪ Classroom Lecture: NMAC
    ▪ Classroom Lecture: Introduction to Trustworthiness

Question 3 Results: Program successes and program areas in need of improvement are listed below.

Program Successes:

- Content: Data indicated that methodologies taught at ITC-27 were perceived as current and relevant for an international audience and the terminology used throughout the course was consistent with NSS-13.

  o 88% of participants felt the methodologies taught at ITC-27 were *Always* or *Almost Always* current and relevant to those in their home country.

  o 84% of participants felt the terminology used throughout the course was *Always* consistent with NSS-13.

- Technology: The implementation of classroom technology was extremely successful during ITC-27.

  o 96% of participants felt using the iPad throughout the course was easy.

  o Only 6% of participants experienced technical difficulties using the iPad throughout the course.

- o Only 7% of participants reported experiencing technical difficulties accessing course materials on the LMS.

- Logistics: ITC Support Staff were the most successful component of hosting logistics during ITC-27 (Figure 3).
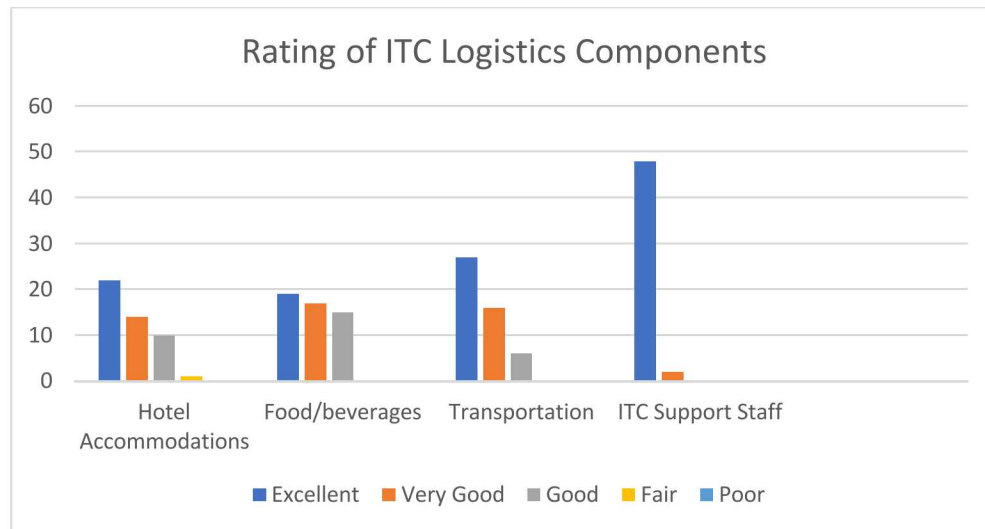

Figure 3. Rating of Hosting Logistics Components

- Course Duration: The majority of participants who provided comments about schedule indicated that the current 3-week duration worked well.
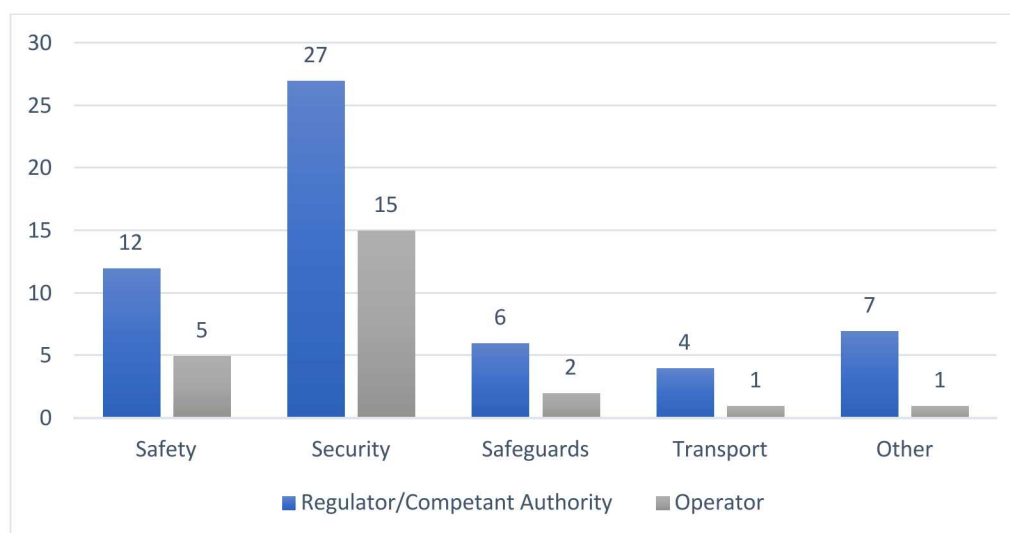
Areas in Need of Improvement

Many participants provided detailed comments when asked how ITC-27 could have been better for them. The following provides a snapshot of key findings.

- Content: Suggestions for exercises were to include more graphics, clarify instructions, and reduce the number of paper-based exercise activities so time can be spent on the most meaningful activities.

- Course Organization: Participants suggested adding more time for exercises, increase time spent in the field, and to consider a revision of week 1 activities; many participants reported via comments that they experienced difficulties with jet lag during the first week.

- Course Materials: 52% of participants indicated it would be helpful to receive course materials prior to the training course (MPVEASI and the Lagassi hypothetical facility data were mentioned specifically). Reasons given were related to preparation, language, comprehension, and time.

Question 4 Results: The information collected helped ITC-27 staff better understand participant background and areas of interest, which informs future planning. Although SNL staff does not determine who attends the training, the Course Experience survey collected demographic data with the intent of gathering insights to assist in future course content planning.

- In response to the question regarding professional background and level of expertise on the Course Experience Survey, most participants categorized their job area as within

Regulatory/Competent Authority (67%), specifically in the area of Security (48%). Safety was also relatively well represented: (23%) (Figure 4).

Note: Some participants chose more than once answer and various combinations, this graph represents a count of each time the category was mentioned.

Figure 4. Category Breakdown among Regulatory/Competent Authority vs. Operator

- The majority (94%) of participants reported having basic, limited, or working level (intermediate) knowledge in the course subject prior to attending ITC-27.

- A total of 21 participants (41%) had between 1 to 5 years of experience; an additional 16 participants (30%) had 5 to 15 years of experience.

- Note: The evaluation results regarding relevance of material to their work (see Question 1) seems to indicate that the course currently meets the experience/knowledge target.

Summary of ITC-27 Successes and Recommendations

Key Successes of ITC-27
1. Successful execution of ITC-27 marked the completion of the largest course in ITC history, with 52 attendees from 40 different countries. Accommodating this many participants while creating an environment in which the participants were free to focus on course learning was a huge accomplishment.

2. Because most participants work for facilities such as nuclear power plants or Category II nuclear material research reactors, a significant change made in ITC-26 and then continued in ITC-27 was to expand the course curriculum to include protection against sabotage of these facility types. About half of the participants come with power plant backgrounds and half with research reactor backgrounds. To reinforce the concept of facility protection, participants are now placed into subgroups based on their nuclear background. This change has also allowed participants to engage in additional technical discussions during their subgroup sessions. More important, in the final exercise—which involves the group applying what they learned to effectively define, design, and evaluate a well-balanced physical

protection system against a sabotage threat—the hypothetical facility for each group matches the group's reactor background.

3. The ITC staff made several incremental changes to the course content for ITC-27. These changes focused primarily on utilizing the ISF at SNL to give participants more hands-on experience at a mock facility. The primary areas that were updated were as follows:

   a. *Delay database module*: In previous ITC courses, the primary focus of performance testing was to test detection systems and response elements. For ITC-27, delay performance testing was introduced to establish a well-balanced performance testing program that addressed all three physical protection elements. For years, participants have asked for delay times for certain barriers, but were unable to receive such data given the sensitivities. In ITC-27, SNL experts created new material that focused on how to collect, record, and build a performance testing database of delay components at any site so participants can take the concept back to their countries to build their own delay database.

   b. *Performance testing field exercises:* ITC staff leveraged existing ITC and other training courses to broaden the performance testing exercises. The primary focus of the performance testing field exercises was to demonstrate how performance testing is conducted in an operating environment. Many countries do not have specific test beds for performance testing and can test only at their operational facilities. ITC staff also developed two new performance tests: one focused on an adversary task timeline related to delay, and the second emphasized response force time motion studies. The testing exercises, which ran simultaneously, allowed all participants to collect, record, and document performance data in an operational environment, promoting enthusiasm and an understanding of physical protection requirements.

   c. *Response force demonstrations*: A Limited Scope Performance Test (LSPT), Alarm Response Assessment Performance Test (ARAPT) and an Enhanced Limited Scope Performance Test (ELSPT) were added as the culmination of the performance testing exercises. These two demonstrations showed participants how diverse types of performance tests can build on each other, as well as demonstrating the different types of data that can be collected from the tests. The LSPT, ARAPT, and ELSPT also exposed the participants to several options that can be utilized based on their specific site's needs.

   d. *Unmanned Aircraft System (UAS) flight and overview demonstration*: UAS is an emerging threat that Member States are addressing in real time. To meet this concern, the ITC staff added a course component that provided participants with a high-level awareness of the types, uses, and capabilities of UASs and how they might be used in both an adversarial and protective strategy capacity.

   e. *Tailored activities:* Activities were tailored to meet the needs of participants from different types of nuclear facility backgrounds and work perspectives. The varied activities, e.g., the use of two different hypothetical facilities for the final exercise, helped to ensure participants could return to their home countries with practical knowledge that could be effectively applied at their country's facilities.

4. The new Learning Management System (LMS) enabled course staff to house all course material in one location and administer core components of the new course evaluation. The

application was simple to use and gave the participants one access point for all activities on the course iPads.

5. Implementation of the new Course Evaluation Framework increased the utility of collecting participant feedback throughout the course. The framework is much more robust than any ITC has utilized before, and has already proved to be a valuable source of quantifiable data to help guide future course planning. By providing a highly structured data summary, the team was better equipped to assess course effectiveness holistically, identify areas in need of improvement and—for the first time during an ITC—measure participant learning as a direct result of training.

6. The IAEA provided three NSS guidance documents to the participants. Course feedback indicated that all participants greatly appreciated receiving these documents. Having these documents in hand allowed them to gain a better understanding of the content of the guidance documents and also see how closely tied the ITC course materials are to the documents.

7. Note: The integration of material and updates between the ITC and RTC (Regional Training Course) has been a great benefit for all training material. Lessons learned from both activities have been applied across the various training materials in an ongoing effort over the past year. Lessons learned from both courses will continually be applied to PPS courses and other workshops that support IAEA and bilateral engagement efforts.

Key Lessons and Recommendations for ITC-28 Improvements
1. Note: IAEA is proposing to conduct ITC-28 beginning the last week of October 2019 (October 28 through November 15). The proposed dates will reduce scheduling conflicts with other IAEA training courses.

2. Because of high demand from international participants to attend the ITC, the IAEA has requested that ITC staff explore the possibility of including a larger number of participants, increasing subgroups from 6 to 8. This increase would affect scheduling, especially for hands-on exercises, and also require two additional subgroup instructors.

3. Building on the introduction of the first international subgroup instructor (Canada) into ITC-27—he was tremendously received well and his experience added international dimensions to the course—international subgroup instructors should also be invited for ITC-28. International experts as subgroup instructors not only bring their experience into the course but also build capacity so the IAEA can call on them for the Regional Training Courses (RTC), which are conducted around the world.

4. With the addition of new exercises and a greater focus on integrating technology demonstrations and hands-on exercises into the ISF during ITC-27, revising the course schedule for ITC-28 will be necessary to provide a better balance of time to complete all exercises. Feedback provided by the participants through the Course Experience Survey indicated a preference towards activities performed in the field, especially when paired with the module and classroom exercises in the Hear-See-Do approach. To effectively apply this feedback, the ITC staff recommends reviewing the overall course schedule to ensure the flow of the course is appropriate and that field and classroom material are balanced, creating an exceptional environment for participant learning.

5. Based on qualitative feedback derived from the Course Experience Survey regarding course exercises, the ITC staff recommends a thorough review of all exercises for ease of use and applicability to needs in participant home countries. Currently, some exercises have objectives that no longer supplement learning objectives from the presentations; other exercises are too time-consuming, especially when participants are asked to study long passages of English text. In addition, the exercises should allow time for discussions within each subgroup of best practices, lessons learned, and issues that participants have witnessed at their own facilities. All exercises should be reviewed and updated so that the content reflects the needs of the ITC audience, meets the topic's scope and timeline, and most importantly, allows time for fruitful discussions among participants.

6. Recommendations for course content additions or modifications:

    a. The Nuclear Material Accountancy and Control (NMAC) presentation and exercises need to be revised so that they apply to Category II nuclear material research reactors and power reactors. Most participant experience is with these reactor types. Matching the NMAC content to their needs will help the participants to better understand how to apply these concepts at their own facilities.

    b. The hypothetical Nuclear Burst Reactor (NBR) facility of Lagassi has not been used in the course since ITC-25. It would be helpful to replace this hypothetical facility. One option would be to use a mock facility that protects radiological sources, as many countries protect both types of assets (nuclear material and radiological sources) at their own facilities. Another option would be to replace the NBR with mock Category I nuclear material.

    c. The Hypothetical Atomic Research Institute (HARI) used in ITC-26 and ITC-27 has the same reactor configuration as HARI in the SHAPASH hypothetical facility. However, the ITC HARI uses a different building type and physical protection system. Discussions should be pursued regarding whether to use one HARI type for consistency with other IAEA training courses or maintain two different HARI facility types to meet different learning objectives. The ITC will continue to use the HARI facility from ITC-27 until a decision has been made.

    d. In response to the high volume of interest about cyber security, it would be helpful to introduce a hands-on cyber exercise on operational and security systems at the ISF. Such an exercise would reinforce key learning objectives from the existing Information Security presentation. Although the advantages of including such an exercise are apparent, it will require careful planning to ensure participant understanding while also remaining within classification and export control parameters.

    e. Adding topics such as nuclear security program management, emergency management, nuclear security self-assessments, and safety culture was brought up by many participants. Presentations may be added to the course to cover these topics predicated on finding time in the course schedule. Creating a hands-on demonstration on how criticality safety and radiation detection can be used to

complement the security components may be an effective way to demonstrate the safety and security interface.

7. With improvements in course content, classroom and field exercises, the 2-week dry run will continue to be an important component to ensure success. The dry run not only provides a chance to polish new material but also serves as a training opportunity for the subgroup instructors, allowing them to become familiar with course content and gain experience in subgroup facilitation. International experts also attend the dry run, gaining an understanding of the curriculum and the use of subgroups.

8. Beginning in ITC-24, the course materials were transferred to an electronic platform to reduce the amount of printed material. At that time, iPads were considered the best technology for class use. Over the past several ITCs, the iPads have been used to significant effect; the ITC-27 evaluation indicated that the participants found electronic delivery of course materials to be easy to use. However, significant improvements to tablet technology have been made over the past six years, and the iPads purchased in 2012 have become obsolete and are no longer the best platform to utilize expected course technology growth. The ITC staff recommends evaluating and purchasing new tablets for participant use for ITC-28, ensuring that all course materials can continue to be presented effectively through the most appropriate technology available.

9. Suggestions for providing training materials prior to course based on feedback from Course Experience Survey:
   a. Participants requested that some training materials be provided to them before the class starts so they can be better prepared. The Hypothetical Facility Handbooks are training materials that can be provided ahead of time. Doing so should allow students to spend less time reading during the classroom exercises and more time on achieving exercise objectives and engaging in participant discussions.

   b. Consider using Distance Learning as a learning launching pad for ITC. Participants would be able to access the existing ITC website to take required presentations prior to the course. Presentations to be considered for Distance Learning are NSS-13, Risk and Regulatory Requirements, Design Basis Threat, and MPVEASI Tool Use. The Distance Learning could free up time in the three-week schedule for other relevant topics or more hands-on exercises.

10. Consider modifying the ITC supplemental text to reflect the training curriculum format in the RTC training package. Much good work was performed in revising the course materials when the group integrated the existing ITC supplemental text into RTC course material. A needs analysis is required to understand the level of effort and cost to adopt the RTC curriculum model.

11. The ITC logistics team received both verbal and written feedback through the Course Experience Survey that the hotel accommodations, though satisfactory, could have been better. We recommend evaluating other available lodging options in the Albuquerque Uptown area to see whether there is a better fit for participants.

Project Personnel

Name	Position	Agency
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Arvydas Stadalnikas	Senior Nuclear Security Officer	IAEA
Gregory Baum	Course Director, Subject Matter Expert	SNL
Sondra Spence	Course Coordinator	SNL
Janet Chapman	Instructional Designer, Technical Writer	SNL
Michael Kline	Logistics Team	SNL
Stephanie Kelly	Logistics Team	SNL
Carla Sanchez	Logistics Team	SNL
Valine Griego	Logistics Team	SNL
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Nathan Foust	Project Financials	SNL
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David Lee	Subgroup Instructor	SNL
Steven Horowitz	Subgroup Instructor	SNL
Matthew Erdman	Subgroup Instructor	SNL
Robert Bruneau	Subgroup Instructor	SNL

Work Breakdown Structure
HQ WBS: 21.1.1.10

Working Documents and Reference Material
All files are posted to the project SharePoint site.
- Project Charter
- Design Document
- Project Schedule
- Cost Estimate
- Course Materials