Establishing a Radioactive-Materials Management Center of Excellence in East Asia

By Ralston W. Barnard[1], Hong Lae Chang[2], and Robert J. Finch[3]

[1] Sandia Staffing Alliance, 6301 Indian School Rd. NE Suite 204, Albuquerque, NM 87110, USA, contractor to Sandia National Laboratories, Albuquerque, New Mexico
[2] Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong, Daejeon, 305-353, Republic of Korea
[3] Sandia National Laboratories, P.O. Box 5800, MS-1373, Albuquerque, New Mexico, 87185, USA*

Introduction

Several East Asian countries have well-developed civilian nuclear programs, and several more countries in the region have expressed interest in developing such programs. Countries that are just embarking on a nuclear-power program have expressed an interest in developing an entire life cycle for the management of nuclear materials used for power generation. Those that currently are generating power from nuclear reactors also have expressed the desire to better manage the nuclear fuel cycle. Management of materials associated with the back end of the nuclear fuel cycle (i.e., high- and low-level radioactive wastes) remains a persistent issue for many programs in East Asia. Safe management of materials at the back end of the nuclear fuel cycle is important for a variety of reasons. Many people view improper storage and disposal of nuclear materials as a safety problem; further, controlled storage is a major component of reducing the risk of improper diversion of radiological materials and enhancing nuclear nonproliferation. Beyond materials generated from nuclear reactor operations, international protocols require the ability to track and confirm the status of low-, intermediate- and high-level nuclear materials for assurances that relevant safeguards agreements are being respected. In addition to civilian nuclear-power programs, more than 60 research reactors currently operate in eleven East Asian countries. Many of these used highly enriched uranium as fuel, which can pose a separate and additional risk for proliferation of materials useful for weapons of mass destruction. Lastly, low- and intermediate-level materials have separate, but similar requirements for proper management.

Unfortunately, management systems and practices for radioactive materials are generally not developed as fully as the power generation systems and capabilities. There exist many university and other higher-education programs in nuclear engineering, however, these generally focus on the technical aspects of reactors and materials management, such as the study of the characteristics of nuclear material from nuclear power plants and research into treatment and disposal of radioactive materials. With growing amounts of radioactive materials likely to accumulate in the region, it is imperative that countries generating such materials have the human and institutional capacities and infrastructure for appropriately managing them. Thus, the need exists for the establishment of additional facilities and courses of instruction so that these skills can be developed. One solution to the need for building capacity is to establish a Radioactive Materials Management Center of Excellence (RMM-CoE) that will serve as a facility for training and building of human-resource capacity and infrastructure. Given the similar nature of the needs for these sorts of disciplines in East Asia, a regional RMM-CoE could

* Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

serve many entities that require development of the same areas of expertise. A regional RMM-CoE will help develop consistent management and operational practices and responses to off-normal situations that will benefit all the nuclear programs in East Asia. Specifically, the goal of the CoE would be to build regional capacity in all aspects of radioactive materials management, including safety, security, and safeguards, nonproliferation strategies, and materials-management practices associated with handling, transporting, storing, and disposing radioactive materials.

An RMM-CoE would address the management needs for various radioactive materials arising from nuclear power generation, as well as other potential sources of low- and intermediate-level wastes (LILW). The RMM-CoE would bolster indigenous capacities for safe and secure disposition of radioactive materials, provide opportunity to consolidate materials in the interest of combating WMD proliferation and terrorism, build human resource capacities to aid in future nuclear energy development and deployment, promote technical cooperation among countries in the region, facilitate regional cooperation and confidence building, and is consistent with objectives of the United States' Next Generation Safeguards Initiative.

Concepts Behind an RMM-CoE

A starting point for defining the scope of an RMM-CoE is to identify the Needs, the Critical System Requirements, and the Major Functional Areas of radioactive materials management. A self-evident statement of the needs of a radioactive materials management system is to ensure that all parties have confidence in the ability of the RMM system to perform its mission with minimal risk to the environment or populations, and to provide assurances of nonproliferation of nuclear materials. The CoE mission must be to ensure that RMM personnel understand that the components of any radioactive-materials management system must perform properly during normal conditions, as well as during all foreseeable off-normal states. Ongoing nuclear-materials management, storage, and disposal programs (such as the DOE's Yucca Mountain Project, Hanford site, Idaho National Laboratory, WIPP, etc.) have established formalisms for evaluating the safety to workers and the general public of designs and operations of radioactive-materials management activities; these formalisms should be a component of a CoE curriculum.

Other needs of a radioactive-materials management system that should be addressed by a CoE are to ensure that the operations of the system do not increase the risk that the theft or misuse of stored radioactive-materials can be used as a constituent for nuclear threats. This need implies the development of systems-analysis and operations-engineering disciplines so that potential customers of a radioactive-materials management system have seamless operations for packaging, transport, and storage of nuclear materials. These same systems- and operations-engineering disciplines can also aid in making management services economically attractive to potential customers, governments, and taxpayers. Lastly, the CoE's overall emphasis can be to make the system acceptable to a broad range of interested parties, including national governments, regulators, international agencies, and interveners. This includes developing sensitivities to governmental policies and public sentiment, and presenting the radioactive-materials management concepts in a way that encourages general agreement and understanding among affected parties.

A CoE can assist in teaching the full spectrum of critical system requirements. In addition to the technical requirements dealing with radioactive-materials management and operations, addressing issues of concern to regulators, interveners, and international overseers are important. Examples of the latter requirements include assurances that all phases of operations are safe, secure, and transparent and sensitive to nonproliferation requirements; preparation of comprehensive threat assessments covering both accidental and intentional off-normal situations; assurances that any storage system or radioactive-materials management system is environmentally sound; and availability of information on the entire radioactive-materials management facilities and operational history in readily analyzable form.

The major functional areas of a radioactive-materials management system encompass characterization, packaging, transportation, storage, monitoring, reporting, technical lifetime and health analyses, disposal, and facility decommissioning. Although some of these topics are part of university nuclear, civil, and environmental engineering curricula, a CoE could focus on the direct application to issues associated with the holistic management of both the nuclear fuel cycle and other radioactive materials. Beyond the technical factors listed above, the human resources and social capabilities are what distinguish the CoE from typical university engineering curricula. As has been emphasized before, the CoE would structure the information to not only cover technical aspects, but also to include consideration of those areas that are needed to satisfy regulators, governmental officials and the public. A few examples of the unique concepts that the CoE could address include

- *Legal and regulatory sensitivities*
  Because nuclear issues can be politically contentious, success in the field requires sensitivity to issues beyond those strictly technical. These include ways to reassure the public and address their concerns about the safety of radioactive-materials management. The needs of governmental and regulatory officials to ensure that infrastructure and management systems are in place must also be addressed. The CoE can help develop an attitude and view of proponents and workers dealing with radioactive-materials management that recognizes the differing opinions and aids communication that can lead to agreement and progress. There are several efforts underway in the US and elsewhere that can be used as resources.

- *Facility operations*
  Facility operations include receipt of radioactive-materials shipments, inspections, identification systems and procedures for storage casks, transfers of material within the facility, periodic inspections and evaluations of stored materials, plans for response to off-normal events, and processes for repatriation of stored material at the conclusion of the terms of storage. This requires the CoE to incorporate operations training into the curriculum.

- *Tracking and security of radioactive-materials movements*
  During transit from originating sites to a radioactive-materials storage facility, all interested parties (e.g., radioactive-materials owners, governmental entities in jurisdictions through which the material is passing, international bodies such as the IAEA, and non-governmental groups) must be able to observe the location, the physical condition, and the security status of the material. This requires the development and understanding of sensors, remote reporting of information, and response tactics as part of a CoE curriculum.

- *Monitoring and performance modeling*

All phases of radioactive-materials management systems must be transparently operated so that interested parties, such as the owners of the material, regulators, international agencies, and interested non-governmental organizations can inspect and analyze the operations on their own schedules. Secondly, as part of the CoE program, the behavior of a radioactive-materials management system (the physical facilities, the operational procedures, the potential environmental effects, responses to off-normal situations, etc.) should be modeled as well as possible to give technical support to the safety case. These modeling exercises are similar to the Probabilistic Risk Assessments and Performance Assessments that are performed for other storage and disposal systems.

- *Developing a proactive nonproliferation culture*

A nonproliferation culture is one where all concerned (individuals, organizations, and governmental bodies) understand the importance of protecting against the diversion or illicit use of nuclear and radioactive materials. This is best accomplished by establishing an organizational framework that establishes an environment of well-defined responsibilities, clear objectives, and sensitivities to international agreements such as the Nonproliferation Treaty and its additional protocols and declarations. Where a CoE curriculum can help to instill a proactive nonproliferation culture is to influence individual behavior such that attitudes and work practices reflect a rigorous and careful approach, and that transparency of operations is emphasized. The essential features of a nonproliferation culture are sensitivities to several nonproliferation responsibilities, including safeguards requirements, export considerations, and verification requirements.

- *Materials lifetime and degradation studies*

The condition of the physical storage facilities during the period of storage is an important factor in assuring the safety of the storage system. These components include the radioactive-materials, containers, and the storage infrastructure. Degradation of the material contained in casks could result in changes in the thermal, criticality, mechanical, or other properties of the stored material. Such changes could cause problems either during storage or during any transportation activities. Periodic tests of the condition of casks and contained material will help with estimates of storage-system behavior. The CoE should include materials-science studies related to degradation and lifetime-affecting processes as part of the curriculum.

- *Compendium of above items to form a management-systems Knowledge Base*

A Knowledge Base can have great utility in providing information to all interested parties in a transparent and current fashion. It could have two primary functions: to describe the implementation of radioactive-materials management systems, and to contain information about the ongoing operations, contents, and regulatory environment of the systems. The Knowledge Base can contain information on the design, operation, and technologies used in the management of radioactive-materials. It will provide both descriptive information and results of the transparency, safeguards, nonproliferation, and monitoring capabilities of the systems. It will contain information on the techniques and results of tests on the physical condition of the stored materials. The Knowledge Base will also contain the results of performance assessments, probabilistic risk assessments, and projections of the technical condition of the materials at the end of their storage times. Development and implementation of a radioactive-materials Knowledge Base is one of the most important capabilities of an RMM-CoE.

Implementation of an RMM-CoE

A well-designed CoE should consist of two parts: To provide hands-on experience for facility operators, the CoE could be established at an operating materials-management facility; this component would emphasize operational practices, including safety, security and transparency. The other component would be classroom-style education. The CoE could draw on the curricula that universities have developed for areas such as environmental, nonproliferation engineering, nuclear safety practices, and security culture. Any interested East Asian universities or other institutions that already have experience and expertise in materials-management matters could be asked to support other interested candidate institutions that have less experience.

The first step is to ascertain the amount and nature of the demand in East Asia for a broadening of the areas of study related to nuclear engineering, such as nuclear safety, security, and safeguards practices. This will clearly influence the decision to proceed, as well as the emphasis of the focus of the CoE. If a demand and a focus can be established, then a "package" can be prepared for potential CoE hosts to review. The package will set out the basic principles to systematize, standardize and codify materials-management practices and the relationships between nuclear engineering and other related engineering practices. Any discussion with potential organizers of a CoE should emphasize that the Center must include the physical, engineering, and social sciences in its academic scope. The culture of excellence in nuclear programs is as much behavioral as it is technical. Another emphasis is on understanding the meaning and importance of safety rules, as has been emphasized by the US Nuclear Regulatory Commission in its development of guidelines for an effective nuclear safety culture.

Starting the process by defining the needs of potential participants will focus the efforts of the CoE on the most relevant interests. This step can also help to identify the most engaged participants and perhaps a location for the CoE facility. A final partnership for a CoE could therefore include the US, East Asian entities with relevant competence, and the institution hosting the CoE.

Given that considerable amounts of radioactive materials already exist in East Asia, many of the management practices for both LILW and other material types can be coordinated. The capability of the CoE to address the non-technical issues peripheral to the actual radioactive-materials-management operations allows it to encompass all types of radioactive materials.

Potential Fields of Study for an RMM-CoE

A persistent area of concern for East Asian radioactive-materials management is the issue of interim storage for radioactive materials. Some of the aspects of this problem include the following:

- Evaluating the relative merits of localized (i.e., at-reactor distributed) vs. centralized storage.
- All the aspects of implementation of a dry-storage facility — siting, design, licensing, operations, security, maintenance, decommissioning.
- Optimizing wet vs. dry storage practices and programs.
- Transportation of radioactive materials.

- Ensuring the nonproliferation *bona fides* of an interim storage system.
- Consideration and creation of a Knowledge Base (KB) to support monitoring and transparency of storage operations.

Expanding on these examples, a CoE could develop responses to issues that politicians, government leaders, regulators, international oversight bodies, radioactive-source generators, scientists, and concerned citizens are likely to raise. Thus, CoE graduates would be prepared to answer questions of regulators and politicians regarding topics such as how storage-site proponents would analyze potential accident resistance to events such as floods, earthquakes, tornado missiles, or temperature extremes. Further, a systematic preparation for regulators' questions would include an emergency plan, security program, quality-assurance programs, radiation-protection, and other training programs. To properly evaluate a centralized radioactive-materials storage facility, site-related and transportation questions should be anticipated by the CoE curriculum. Site characteristics ranging from the geology to nearby populations and/or civilian or military facilities should be included in any analysis of a potential site. Transportation issues such as passage near large population centers or industrial facilities, or transportation choke points are examples of preparation that the CoE should offer.

A Probabilistic Risk Assessment (PRA) is a systematic process for examining how engineered systems and human interactions with these systems can respond to various events and processes. A PRA attempts to evaluate the nature and probabilities of various initiating events, and the consequences thereof. The U.S. Nuclear Regulatory Commission employs Probabilistic Risk Assessment as a method to satisfy their mandate that there is no undue risk to the health and safety of the public associated with the operation of nuclear power plants, or other facilities that it licenses. This process is quantitative, in that the probabilities of events with public-health consequences and the magnitudes of those potential health consequences are calculated. The risk of such events is the product of the event probabilities and their consequences. A PRA as an analytical tool includes consideration of the following:

- Identification and delineation of the combinations of events that, if they occur, could lead to an accident (or other undesired event);
- Estimation of the chance of occurrence for each combination; and
- Estimation of the consequences associated with each combination.

Another approach for estimating future system behavior is based on the creation of models for all the components, subsystems, and processes that can occur over time in a radioactive-materials storage system. Scenarios that attempt to weight events by their probability of occurrence are used to describe the possible changes in the environment at the radioactive-materials storage facility. The modeling then uses computer simulations to describe the processes occurring in the entire modeled system over time, and the responses of the components and physical configurations to normal and disruptive scenarios. By modeling numerous possible (and perhaps some very unlikely) scenarios, a predictive estimate of the most likely behavior of the system can be produced. Estimates of the consequences of low-probability scenarios can also be provided.

The culture of nonproliferation, including proper safeguards, verification, and monitoring are additional curriculum areas to be included. This will unify the other disciplines and provide the guiding emphasis for the CoE.

Creation of a radioactive-materials management Knowledge Base (through the application of systems engineering principles) should be a key effort of a CoE. As the KB develops, it will provide a history of and guidance to the analyses and decisions made. It will also document the best practices developed, and provide a record of monitoring, inspections, incidents and responses during management and operations of the systems. The goal is to provide access, through the KB, to information showing that the critical system requirements have been met, that the major functions and technologies have been implemented, and that the operations are conforming to the needs of the interested parties.

Summary

In this paper we have discussed prospects for establishing a regional RMM-CoE, including methods for identifying potential host institutions and partners. Given the depth of technical capability at East Asian centers of higher education, the emphasis of the CoE should be on those aspects of radioactive-materials management peripheral to the core technical knowledge, but vitally important to creating a culture and impression of sensitivity to all aspects of nuclear safety and security. These steps include creating a security culture, developing contingency plans for off-normal events, developing a proactive nonproliferation culture, understanding the importance of risk and other predictive analyses, and creating a compendium of the history and best practices involved in radioactive-materials management.

All these techniques will be useful ways to reassure the public and address their concerns about the safety of radioactive-materials management. The needs of governmental and regulatory officials to ensure that infrastructure and management systems are in place will also be addressed.