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Nuclear Materials Management in International Spotlight

By John C. Matter
INMM President

Has there ever been a time when our chosen profession has been more in the global spotlight than it is now? Of course the media and public may not be thinking *nuclear materials management*, but we know what is behind many of today's headlines. Unfortunately, most of the current international issues are negative ones surrounding apparently growing nuclear proliferation and challenges to the non-proliferation regime. Perhaps we can agree on a few things: most of us are seeking some form of security, be it individual, group, national, regional, or international. However, there is a great diversity in opinion on how to achieve this, ranging in a loose continuum from many states possessing nuclear weapons through maintaining the *status quo* to future nuclear disarmament. Maybe we can also agree that now more than ever we need new or improved ideas, options, policies, commitments, technical means, and implementation to address our current problems. We cannot succumb to living in the continual presence and fear of weapons of mass death, destruction, and disruption. I am reminded of the adage that a time of great challenge is also a time of great opportunity. Let's do our part and redouble our efforts in nuclear materials management.

One way to stimulate this process is to attend and actively participate in the INMM 44th Annual Meeting, July 13–17, 2003, at the JW Marriott Desert Ridge Resort & Spa in Phoenix, Arizona. I just returned from Technical Program and Executive Committee meetings held there March 11–13. This beautiful resort is brand new and should be comfortable even during the hot desert summer. I expect an outstanding set of papers and livelier-than-ever hallway discussions and *ad hoc* meetings. Charles Pietri and his Technical Program Committee have put together a strong meeting with forty-five sessions (including a poster session) and more than 300 papers. The Opening Plenary Session invited speaker is yet to be confirmed and the Closing Plenary Session will focus on homeland security.

Although the INMM Annual Meeting is the one time each year that the entire INMM community comes together, we also organize, sponsor, and co-sponsor other professional workshops and meetings throughout the year. Please resolve to participate in at least one of the following events:

- Safeguards and Security: A New Era, April 29–May 1, 2003, Oak Ridge, Tennessee (Organized by the INMM Physical Protection and Material Control and Accounting Technical divisions and the Central Region Chapter)
- International Seminar on Interim Storage of Spent Fuel, May 14–16, 2003, Tokyo, Japan (Central Research Institute of Electric Power Industry and INMM Waste Management Technical Division)
- Risk Management…Now More Than Ever (Embedded Topical Meeting), June 1–5, 2003, San Diego, California (American Nuclear Society and INMM)
- Methodologies for Quantitative Assessment of Nuclear Fuel Cycle Technological Proliferation Resistance, June 3–5, 2003, Obninsk, Russia (Institute of Physics and Power Engineering and INMM Obninsk Regional Chapter)
- Safeguards Perspectives for a Future Nuclear Environment, October 14–16, 2003, Como, Italy (European Safeguards Research and Development Association and INMM International Safeguards Division)
- Spent Fuel Management Seminar XXI, January 27–30, 2004, Washington, DC (INMM Waste Management Technical Division)
- The 7th International Conference on Facility Operations-Safeguards Interface, February 29–March 4, 2004, Charleston, South Carolina (American Nuclear Society and INMM Central Chapter)
- 14th International Symposium on the Packaging and Transportation of Radioactive Materials (PATRAM 2004), September 19–24, 2004, Berlin, Germany (Federal Institute for Materials Research and Testing and INMM Packaging and Transportation Technical Division)

One of the keys to our success is good communication. The INMM has several initiatives underway to help our members and colleagues in this process:

- We have recently introduced an electronic newsletter, the *INMM Communicator*. The editor is Sara Pozzi, and I am sure she is interested in your input and feedback. You can contact her at pozzisa@ornl.gov. The newsletter is available to members on the INMM Web site at www.inmm.org.
- We are planning in the future to put on the INMM Web site several presentations that can be used by members for outreach activities. These will include the six technical division subject areas and an overview of INMM.

I am always interested in your ideas and feedback regarding our organization, activities, and benefits. I look forward to hearing from you.

INMM President John C. Matter may be reached by e-mail at jcmatter@ sandia.gov.

Spent Fuel Management Papers Highlight Spring Issue

By Dennis L. Mangan
Technical Editor

This year I participated in the Technical Program Committee meeting for the 44th INMM Annual Meeting, which will be held in Phoenix, Arizona, July 13–17, 2003. The committee, chaired by Charles Pietri, assembled a program that will include forty-five sessions and more than 300 papers. So it appears that the annual meeting should be a great success again. The location, the JW Marriott Desert Ridge Resort & Spa, is extremely pleasant. I recommend you make your plans early.

As I have mentioned before, I wonder what role the INMM can fulfill in combating terrorism, both domestically and internationally. The mission of combating terrorism cuts across each of our technical divisions, making a new technical division dedicated to combating terrorism difficult.

I note that the theme of the Southwest Chapter's annual technical meeting, to be held in Taos, New Mexico, on May 1, is on what role the INMM should play in support of homeland security. A facilitated discussion on this topic is planned. I hope that an ambitious member of the Southwest Chapter will write a throught-provoking paper on this topic for publication in an upcoming issue of the *Journal*.

In this issue we publish five interesting papers. Four were presented at the INMM Waste Management Technical Division's annual Spent Fuel Management Seminar held in Washington in January. Pierre Saverot, secretary of the Waste Management Technical Division and *JNMM* waste management associate editor. The first of these, *Global Perspectives of Spent-Nuclear Fuel and High-Level Waste Management Issues*, by A. Bonne, K. Schneider, and V. Tsyplenkov, of the International Atomic Energy Agency in Vienna, reviews the approaches different countries use to address and implement the issues of the long-term management of SNF and HLW. It certainly is interesting reading. The second paper, *Transportation of Radioactive Waste Study Prospectus*, was prepared by the Board on Radioactive Waste Management (BRWM). This board, part of the National Academies, was established in 1958 to help ensure that public workers and the environment are protected through the appropriate management of all types of radioactive waste, including mixed waste. This paper outlines a study to develop a high-level synthesis of key technical and societal issues for SNF/HLW transport and to identify technical and policy options for addressing these issues and managing transportation risk. This paper is followed by *Radiation Doses to the Public from the Transport of Spent-Nuclear Fuel*, by Ralph Best (JAI Corp.), Steven Maheras and Steven P. Ross (Battelle Memorial Institute), and Ruth Weiner (Sandia National Laboratories). This paper has a lot of interesting information, and seems to be a natural precursor to the study being pursued by the BRWM. The last paper from the Spent Fuel Seminar is by Eileen Supko from the World NuclearTransport Institute. In this paper, *Nuclear Transport: The Impact of International Regulations*, Supko notes a need for harmonized regulations worldwide for the transport of radioactive materials based on the International Atomic Energy Agency's (IAEA's) transport regulations (TS-R-1), the latest version of which was released on January 1, 2002. She also notes that the IAEA process for review of TS-R-1 has moved from a ten-year cycle to a two-year cycle, which depending upon the magnitude of changes incorporated in the review, may make it difficult for countries to keep up with proposed regulations.

The final paper in this issue is a peer-reviewed paper by R. Kouzes, B. Geelhood, R. Hansen, and W. Pitts from Pacific Northwest National Laboratory, *Authentication of Radiation-Measurement Systems for Nonproliferation*. The problem they address here has been around in the arms control and nonproliferation regimes for many years: How can monitoring parties trust the information gleaned from monitoring equipment? This paper discusses many of the issues that need to be addressed to solve this problem.

JNMM *Technical Editor Dennis L. Mangan, of Sandia National Laboratories, may be reached by phone at 505/845-8710 or by e-mail at dlmanga@sandia.gov.*

Letter to the Editor

I welcome the book review by Walter R. Kane of *Megawatts and Megatons: A Turning Point in the Nuclear Age?* that appeared in the winter 2003 issue of *JNMM*.

Readers should be aware that the text appeared in paperback January 2003 from the University of Chicago Press as *Megawatts and Megatons: The Future of Nuclear Power and Nuclear Weapons.*

A few errors have been corrected, and I have added a two-page "Note to the Paperback Edition." Thanks to *JNMM* and Walter Kane for the meaty review.

Sincerely yours,

Richard L. Garwin

Global Perspectives of Spent-Nuclear Fuel and High-Level Waste Management Issues

A. Bonne, K. Schneider, and V. Tsyplenkov
International Atomic Energy Agency, Vienna, Austria

Introduction

The inventories of spent-nuclear fuel (SNF) and high-level waste (HLW) arising from reprocessing are growing and are getting increasing attention from decision-makers and governments in International Atomic Energy Agency (IAEA) member states. Different policies and programs for the long-term management of SNF and HLW are being considered in various countries. The differences likely result from different options related to the nuclear-fuel cycle and institutional conditions (including the legislative frameworks) that exist in those countries.

Global SNF Arising

Today, the amount of spent fuel discharged from commercial power reactors ranges from 10,000 to 11,000 metric tons of heavy metal (tHM) per year. By 2002, a total of about 255,000 tHM of spent fuel had been discharged globally, and about 84,000 tHM of spent fuel was sent to reprocessing. The remaining 171,000 tHM of spent fuel is currently stored. It is projected, based on a medium nuclear-power growth, that the amount of spent fuel stored will increase to 260,000 tHM in 2015 and a total mass discharged from NPPs will be about 395,000 tHM, the balance of 135,000 tHM reprocessed.

Separated plutonium is used in mixed-oxide fuel (MOX) in light-water reactors (LWRs), and thus reducing inventories of plutonium. The amount of MOX fuel for LWRs produced worldwide in 2001 was about 190 tHM and part of that is at present loaded in some thirty-six LWRs. Germany, despite its nuclear phase-out policy, continues reprocessing contracts with France and the UK through 2005, using the resulting plutonium for MOX fuel in German NPPs. The UK stores a small amount of foreign spent MOX fuel, and in France, the amount of MOX fuel entering storage each year from French NPPs is about 100 tHM. Switzerland applies a recycling policy using MOX fuel. Belgium has stopped its recycling policy but uses the formerly recovered plutonium for MOX fuel. All together about 735 tHM of stored spent MOX fuel are stored in spent-fuel pools worldwide. Spent MOX fuel discharge is estimated to amount to about 200 tons per year.

SNF arising and trends of that are not equally distributed among the different regions of the world. An increase in the amount of stored spent fuel is anticipated in Asia due to prospective expanding nuclear power programs in that region (e.g. in China). Also the increase of SNF stored in North America is significant as the major generators in that region (the United States and Canada) are not likely to have a SNF and/or HLW repository fully operational before 2015. It is anticipated that Eastern Europe will have a significant increase in the spent fuel for storeage.

Figure 1. Cumulative worldwide spent fuel arising, reprocessing, and storage, 1990-2015

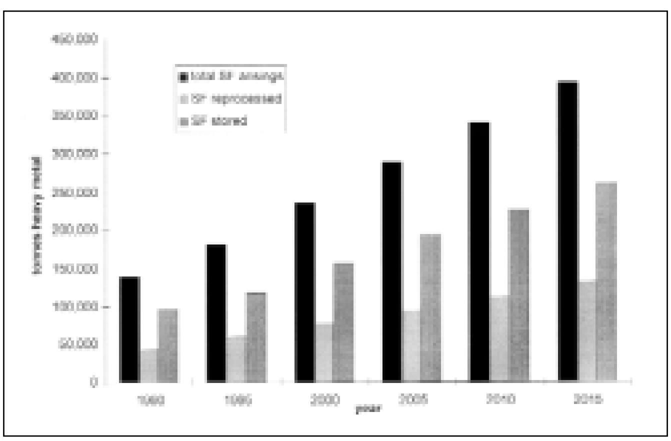
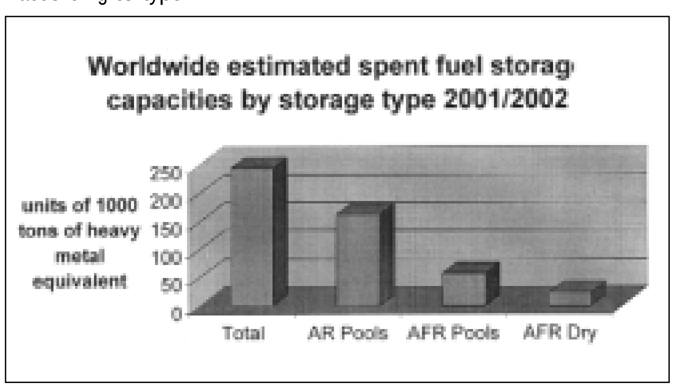


Figure 2. Worldwide estimated spent fuel storage capacities according to type



The current global SNF storage capacity is more than 243,000 tHM, and thus exceeds by about 72,000 metric tons the capacity needed by the end of 2002.

On a worldwide basis, there is no capacity problem. On a national basis, however, a shortage of capacity may occur if storage does not expand. The situation differs from country to country and sometimes even from utility to utility.

The time frame for spent-fuel storage (SFS) has expanded considerably over the last decade, due mainly to pending decisions on final disposal of spent fuel. The time spans considered for SFS allow for continuous technology development, optimization, and innovation. A usual period considered today begins at thirty years on, as in Russia. License applications for forty-fifty years are common, as in Germany. The Netherlands is envisaging 100 years for SFS in an away-from-reactor (AFR) facility to be built. Experience with wet storage amounts to about thirty years, with dry storage in casks to about fifteen years. Wet storage in general is considered not to pose technological problems since it can be easily surveyed and monitored. There are low thermal loads on cladding material and fuel matrix. Corrosion control is usually performed by means of appropriate pool water chemistry and similar measures. AFR dry storage in casks onsite or offsite is increasingly used in most member states (e.g. in the United States, Germany, and possibly Russia).

Burnup credit is under consideration in member states for wet- and dry-storage systems, spent-fuel transport, reprocessing, and final disposal as a means to optimization.

As a result of the absence of final repositories, several member states opt for the SNF and/or HLW to be stored on the surface for periods longer than originally anticipated. As a result, there is now discussion of the role of surface storage as an option for the future long-term management of radioactive waste. Some of the different views on this subject were represented at IAEA's International Conference on Issues and Trends in Radioactive Waste Management in December 2002. From the discussions at that conference, it can be concluded that over the long term there is no alternative to disposal because long-term storage requires social stability to maintain institutional control, and this cannot be guaranteed. Nevertheless, although this argument convinces most technical experts, it is evident that some stakeholders are more reassured by the visible evidence of secure surface storage than by disposal underground.

HLW Arising for Specific Countries

Data on the expected waste arising for individual member states are collected by the IAEA on a regular basis. A recent IAEA publication (IAEA-TECDOC-1323) on the institutional framework for long-term management of HLW and SNF provides the most recent information on the anticipated total HLW and SNF arising for twenty member states.[1] Many of the observations formulated in this paper will be drawn from that publication.

Nine countries—Belgium, France, India, Germany, Japan, Netherlands, Russian Federation, Switzerland, and the UK—currently reprocess at least a portion of their SNF, either on their territories or abroad. Switzerland also plans to directly dispose of a part of its SNF. In Germany, SNF generated after January 2005 will be directly disposed of under an agreement reached in 2000 between the German government and major utilities, while SNF generated before 2005 will be reprocessed.

Policies for Disposal

Most member states plan to eventually construct a geological repository where their SNF or HLW will be disposed of, but they are in widely different stages of implementation. Information received from member states indicates that repositories will be constructed within their territories and that the repository capacity will be sufficient to accept the SNF or HLW already generated or expected to be generated by their existing nuclear facilities.

On the other hand, Japan proposes to build a repository that's capacity would be based on economic considerations. Specifically, the Japanese legislation requires that the capacity of its repository be set at the point where the disposal cost per unit of waste would no longer be reduced if additional capacity is added to the repository (i.e. at the limit of economy of scale).

In parallel with efforts to develop their own geological repositories, the member states are keeping in mind that, in certain circumstances, safe and efficient disposal of SNF and HLW might be fostered through agreements among member states to use facilities in one member state for the benefit of other member states, particularly where the waste originates from joint projects.

In most countries, the implementing organization is expected to develop the proposed repository concept and capacity, followed by review and approval by the government. On the other hand, the repository capacity is stipulated by U.S. law, and both the repository capacity and concept are stipulated by Japanese law.

Institutional and Regulatory Frameworks

General

Analysis of the national situations clearly shows that, for the management of SNF and HLW, the principle of separation between policy-making and legislation, regulatory activities, and implementing activities has been established in most countries. The organizational arrangement for radioactive-waste management recently has been or is currently being revised in some countries (e.g. Bulgaria, Canada, and the UK) to better respond to policy considerations on how to handle these issues in the future. Current indications are that the changes in these countries are all likely to go in the direction of a more distinct separation between the three major parties mentioned above.

Oversight bodies, where they exist, have been assigned the task of providing advice to policy-makers and/or the implementing organization on the radioactive-waste management program as a whole, or on separate activities within the program. The attention of such bodies has been directed both toward plans and programs on a strategic level, and toward the implementation aspects of plans and programs. Such oversight bodies may also act as advisors to regulatory authorities.

Financial resource management bodies, where they exist, are a supplement to the basic structure comprising policy-making and regulatory and implementing activities, and are used specifically to deal with long-term financial management issues.

Legislation

The legislative approach in any country is likely to depend completely on conditions that are unique to that country. Different countries have adopted different ways to solve their needs for necessary provisions in laws and regulations in connection with spent fuel and radioactive-waste management. In some countries such provisions are parts of more inclusive legislation (e.g. Sweden) covering most aspects within the nuclear field, or even legislation covering the whole area of environmental protection. In other countries (e.g. France, Japan, Lithuania, and the United States), specific laws and regulations apply to the management of SNF or HLW. Canada is currently considering legislation.

Waste Management Implementing Organizations

Most countries have established separate implementing organizations for the management of SNF and HLW. However, the functions and responsibilities of the implementing organizations vary between countries. In some countries, an implementing organization has been established specifically for the disposal of SNF or HLW (e.g. Finland, Japan, and the United States). In other countries, an implementing organization has been established with a broader responsibility, including such tasks as the long-term storage of SNF pending development of a geological repository, and disposal of long-lived low- and intermediate-level radioactive waste, including future wastes arising from decommissioning of NPPs, along with the disposal of SNF and/or HLW (e.g. Belgium, France, Spain, and Sweden). In the Russian Federation, radioactive-waste disposal tasks are divided among several different organizations that have been nominated by the responsible ministry depending on the task involved.

Three types of implementing organizations in different countries are described in Table I.

The Republic of Korea and the UK have not decided whether or not their implementing organizations will be governmental organizations.

Table 1. Types of Implementing Organizations

Implementing Organizations	
Established	To Be Established
Type 1: *Part of the National or Central Government Administration*	
Germany *(BfS subcontracted to DBE)* United States *(OCRWM)* South Africa *(NECSA)*	
Type 2: *Government owned companies*	
Belgium *(ONDRAF/NIRAS)* Czech Republic *(RAWRA)* France *(ANDRA)* Lithuania *(RATA)* Hungary *(PURAM)* Russian Federation *(Minatom institutions)*	Bulgaria
Type 3: *Private companies (some are partly privately owned)*	
Finland *(Posiva Oy)* Japan *(NUMO)* The Netherlands *(COVRA)* Slovak Republic *(Slovak Electric Plc.)* Spain *(ENRESA)* Sweden *(SKB)* Switzerland *(NAGRA and ZWILAG)*	Canada

Repository Site Selection

Some countries have already sited, or are in the process of siting, geological repositories for the disposal of SNF and HLW. Other countries are expected to initiate similar siting processes in the near future. Although each country is in a different stage or phase of the SNF or HLW management process (even when they have selected similar policies and programs), they are all undertaking a multi-step siting approach.

Most countries are using or planning to use a site-selection process in which several potential candidate sites are initially identified and the number of sites under consideration is reduced as more detailed information is gathered to describe the characteristics of the candidate sites, as described in IAEA Safety Series No.111-G-4.1, *Siting of Geological Disposal Facilities*. This publication describes a process typically consisting of four stages (i.e. conceptual studies and planning, area survey, site characterization, and site confirmation). However, the actual approaches being taken in the member states are not always divided into these four stages, and the definition of the stages varies considerably from country to country. In some countries (e.g. Japan and the United States), the site selection approach is stipulated by law. In other countries (e.g. Finland, Sweden, and Switzerland) the strategies for siting were developed by the implementing organization and reviewed or approved by the government.

In Finland, the Russian Federation,[2] Sweden, and the United States, a repository site or specific candidate site have been specified. Several member states are either planning to use or are already using an underground research laboratory (URL) in the process of site selection.

Disposal Time Schedule

The following points summarize the situation regarding the time schedule:

- Time schedules for disposal are established in Finland, Japan, Russian Federation, Sweden, and the United States.

- Time schedules for disposal will be established within approximately ten years in Belgium, Canada, the Czech Republic, France, Germany, Hungary, the Republic of Korea, Slovak Republic, Spain, and Switzerland.
- In Bulgaria, Lithuania, the Netherlands, South Africa, and the United Kingdom, the schedules for disposal are not established. These countries have decided to extend the SNF and/or HLW disposal planning process for a few decades and to store the material in the meantime.

There are also variations from one member state to another regarding the organization responsible for establishing a schedule. In some countries, the government is responsible for establishing milestones for the disposal program (including by legislation in some cases), while in other countries the schedule is developed by an implementing organization.

Due in part to the fact that all countries are in an early stage of implementing the programs for the long-term management of their SNF and/or HLW, there are considerable differences between countries regarding the schedule for implementing SNF and/or HLW disposal. Emplacement of the waste is expected to begin in 2010 in the earliest case, while some countries have decided to store their SNF and/or HLW until as late as the latter part of the 21st century.

Financing Schemes

Since many of the activities associated with long-term management of SNF and HLW will take place several decades (or more) into the future (possibly after the generators of the waste have gone out of business), it is prudent to collect the financial resources that will be needed for future operations while the waste generators are still in operation. Member states use various financial systems to ensure the long-term availability of financial resources for their geological disposal programs. Funds and reserves are the two most common financing systems. In the former, the financial resources are usually maintained by organizations independent from the waste generators. In the Russian Federation, financing is obtained from the national budget.

The scope of programs for managing SNF and HLW differs from country to country (e.g. some include such activities as decommissioning nuclear facilities, and managing low-level waste, while others do not). Accordingly, the activities covered by the funds vary from country to country, as follows:

- Only SNF and/or HLW disposal (the Czech Republic, Japan, and the United States[3])
- Interim storage and disposal of SNF (Belgium and Finland)
- Decommissioning nuclear power plants and interim storage and disposal of SNF and/or HLW (Hungary, Lithuania, Spain, Sweden, and Switzerland[4])

The annual fees that are widely used to obtain the resources in the funds are generally calculated and determined based on the amount of electricity or waste generated in a certain year (i.e. on the basis of the future liability associated with the waste generated in that year).

In general, two methods are used to collect financial resources: a levy on electricity rates or a contribution from the waste generator (who collected financial resources through electricity rates). The amount of the contribution is generally calculated and determined by agencies of the national governments. In most cases, levies are applied only to income derived from electricity generated at nuclear power plants. However, in Spain, the levy is imposed on income derived from all electricity sales, regardless of the origin of the electricity.

In most countries that have established funds, the government itself, or a high-level organization within the government, is designated as the financial resource management organization. However, there are some exceptions. For example, in Spain the implementing organization manages the funds, and in Japan a nonprofit, third-party body designated by the minister performs this function. In every case, the government is responsible for developing criteria or guidelines for management of the funds.

In the countries where the financial resources are retained internally by the waste generators, the waste generators are responsible for managing these resources. The annual amount deposited to such reserves is determined primarily by the waste generators themselves.

The funds are low risk—funds are deposited in the national account or invested in government bonds or according to a financing strategy established by the competent body. Finland has a unique system in which the waste generators (NPP operators) may borrow up to 75 percent of the accumulated funds.

In addition to collecting funds as waste is generated, any liability associated with managing the waste generated before establishing the financing system must also be covered. The fees for that waste generated have been collected as one-time fees upon establishment of the financing systems (in Finland and Sweden), through a series of payments over time (in Japan and Switzerland), or as a combination of both (in the United States).

Retrievability and Institutional Control

The issue of retrievability is still being discussed in many countries. The requirements for repositories in Germany and Sweden currently do not include provisions mandating retrievability of SNF or HLW. However, these countries are currently considering whether or not to require the retrievability of SNF from repositories. Finland requires that the retrievability of SNF from a geological repository must be ensured. Switzerland and the United States require that the retrievability of SNF and/or HLW disposed of in a geological repository must be maintained for a certain period of time after emplacement. France is conducting a study evaluating disposal options in geological formations, with and without reversibility.

Specification of the institutional controls (including monitoring and required funding) to be applied after repository closure is a task for the future. However, in some countries, the applicable requirements specify that a repository shall be designed to function safely without monitoring.

Disposal Costs

The estimates of the cost of SNF and HLW management vary from country to country, and are difficult to compare. This is mainly due to differences in the elements included in the cost estimates (e.g. research and development, interim storage, transportation, conditioning, and disposal), as well as differences in key assumptions and boundary conditions used for calculating the waste management costs (e.g. the assumed operational lifetime of the nuclear power reactors, period for interim storage and operation of the disposal facility, and the degree of closure and surveillance activities). Some countries include the cost of low- and intermediate-level waste management and the cost for decommissioning of nuclear power reactors in their general cost estimate, while others do not. The price-basis (e.g. year 2000 US $, 1998 CHF) must also be considered for comparing the various cost estimates, as well as the assumptions made regarding inflation and the time value of money. Finally, there are differences in the ways various countries handle the costs of preliminary R&D and the costs of the early stages of developing their long-term HLW/SNF management programs. These costs may or may not be included in the total program cost estimates. For countries with large programs, this could result in a large change in the cost estimate.

At this time, there are basically three types of cost estimates:

- Estimates by countries that primarily include the cost of disposal (the Czech Republic, and Japan) or that plan to reprocess their SNF abroad and therefore only include the cost of interim storage and transportation (Bulgaria)
- Estimates by countries that have broader programs, and thus must include the costs of additional stages of the waste-management process (Finland, Hungary, Lithuania, Slovak Republic, Spain, Sweden, Switzerland, and the United States)
- Estimates by countries that have not yet made a decision on their approach for long-term management of SNF or HLW, but have nevertheless prepared cost estimates based on concepts they have studied (Belgium, Netherlands)

In most member states, the organization responsible for the cost estimates is specified by law. There are two primary approaches followed currently:

- The waste generators (reactor operators) and/or the implementing organizations prepare the cost estimates, which may be reviewed by the government (ministries, regulators, and/or safety authorities). In some cases, government review is supported by reviews by external experts (the Czech Republic, Finland, Hungary, Lithuania, Slovak Republic, Spain, Sweden, and the United States).
- A competent body prepares the cost estimate, which may be submitted to the government for approval, or subjected to an independent review (Bulgaria, Germany, Hungary, Japan, the Netherlands, and Switzerland).

Public Involvement

Each member state dealing with nuclear power recognizes that SNF and waste-management issues require the involvement of the public, and, that to be successful, disposal programs must develop a convincing track record of openness and transparency, particularly in the area of siting repositories. Many member states are conducting public outreach programs to involve the public in the site evaluation and decision-making and to facilitate public understanding and to build public confidence. Efforts are made to communicate with those responsible for news policy in the popular media, such as news editors. Communication with local populations related to nuclear facilities in the area will often be most successfully achieved through respected members of the local society, such as doctors, nurses, and teachers.

Joint Convention on the Safety of Spent-Fuel Management and on the Safety of Radioactive-Waste Management

The Joint Convention on the Safety of Spent-Fuel Management and on the Safety of Radioactive-Waste Management, the first legal instrument to directly address these issues on a global scale, was opened for signature on September 29, 1997.

The Joint Convention applies to spent fuel and radioactive waste resulting from civilian nuclear reactors and applications, and to spent fuel and radioactive waste from military or defense programs, if and when such materials are permanently transferred to and managed within exclusively civilian programs, or when declared as spent fuel or radioactive waste for the purpose of the convention by the contracting party. The convention also applies to planned and controlled releases into the environment of liquid or gaseous radioactive materials from regulated nuclear facilities.

The obligations of the contracting parties with respect to the safety of spent fuel and radioactive-waste management are based to a large extent on the principles contained in the IAEA Safety Fundamentals document, *The Principles of Radioactive Waste Management*, published in 1995.

The objectives of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive-Waste Management that was adopted after a diplomatic conference in 1997 are:

- To achieve and maintain a high level of safety worldwide through the enhancement of national measures and international cooperation, and
- To ensure that all stages of spent fuel and radioactive waste management include effective defenses against potential haz-

ards to protect individuals, society, and the environment from harmful effects of ionizing radiation, now and in the future

The Joint Convention entered into force in June 2001. A first formal review meeting of the contracting parties will begin on November 3, 2003. One of the obligations for the parties is to report on how they implement the Convention's agreed actions and stipulations. This reporting obligation is an important instrument to build confidence at the international level in the safe and environmentally sound management of radioactive waste.

Conclusion

Governments have a vital role in implementing programs for long-term management of SNF and HLW.

Member states are taking a multi-step approach to developing their programs for long-term management of SNF and HLW.

Member states have legal and regulatory frameworks to govern SNF and HLW management activities, and most have established (or assigned duties to) specific organizations to implement, regulate, and provide oversight of these activities.

Many member states have established funds to ensure that the financial resources needed for long-term management of SNF and HLW are available when needed, and all recognize the need to establish record-keeping systems for after their geological repositories close.

Several countries are reviewing their policies and strategies for long-term HLW/SNF management and plan to develop new institutional frameworks for their use. Other countries have not yet established such policies and strategies.

We can anticipate accelerating activity in dealing with the long-term issue of power reactor spent fuel. Spent fuel continues to accumulate, boosted by ever-increasing capacity factors and license extensions. The increased need for decisions on disposal or prolonged storage is reflected in the recent actions, including:

- The recent U.S. decision to proceed with a spent fuel and high-level waste repository at Yucca Mountain
- Finland's approval, in principle, of a final repository project at Olkiluoto
- The Russian Federation's new law that makes it possible to import spent fuel for indefinite storage or reprocessing
- Canada's Nuclear Fuel Waste Act, which came into force in December 2002, requiring Canada's three nuclear-fuel waste owners to come up with a plan within three years, and
- The proposed directive by the European Commission's Directorate-General for Energy and Transport requiring member states to decide on repository sites by 2008 and to have the sites operational by 2018

The IAEA is giving continuing attention to the collection, analysis, and exchange of information on nuclear power fuel cycle and waste management. To this end, the IAEA, in cooperation with OECD NEA, is organizing the International Conference on Storage of Spent Fuel from Power Reactors in Vienna, Austria, June 2–6, 2003 to review issues and trends in the subject area.

Notes

1. The member states include Belgium, Bulgaria, Canada, the Czech Republic, Finland, France, Germany, Hungary, Japan, Republic of Korea, Lithuania, the Netherlands, Russian Federation, Slovak Republic, South Africa, Spain, Sweden, Switzerland, the United Kingdom and the United States.
2. The Russian Federation has identified the multiple sites.
3. Early in the U.S. program, a small fraction of the program budget (a portion of which was obtained from annual appropriations instead of the Waste Fund) was used for SNF interim storage planning and research and development.
4. The financial resources that will be required for decommissioning are maintained in a separate fund.

Transportation of Radioactive Waste Study Prospectus

The Board on Radioactive Waste Management
Washington, D.C., U.S.A.

Project Summary

This study will develop a high-level synthesis of key technical and societal issues for spent-nuclear fuel and high-level radioactive waste transport and will identify technical and policy options for addressing these issues and managing transportation risks. The principal focus of this study will be on the transportation of spent-nuclear fuel and high-level waste in the United States, but the study will draw on international experiences as well as experiences with transporting other waste types.

Background

The U.S. Department of Energy is leading an effort to develop a monitored geologic repository for the disposal of spent-nuclear fuel (SNF) and high-level radioactive waste (HLW) from commercial and defense nuclear plants. If such a repository is licensed and opened, it could receive SNF and HLW from more than seventy commercial and defense storage sites scattered across the United States. This material would be shipped in heavily shielded containers by rail or truck.

The program to transport SNF and HLW to the repository is planned to last forty years and is estimated to cost $6 billion in current dollars. It will require on the order of 100,000 truck shipments or 20,000 rail shipments, each containing up to millions of curies of radioactivity. Transportation routes may include heavily traveled corridors in the Western and Midwestern United States, many passing through large metropolitan areas, possibly including the city of Las Vegas, Nevada, which is located about 100 miles from Yucca Mountain.

This transportation effort will be unprecedented in magnitude and geographic extent, and there is increasing concern among many parties about potential impacts along likely transportation corridors. Members of the public are concerned about the safety of these shipments, and particularly about the potential for accidents that they believe could release significant quantities of radioactivity. Corridor states and local governments are also concerned about public safety and their ability to provide adequate emergency response should an accident occur. Federal agencies responsible for regulating and shipping SNF and HLW believe that transportation is a low-risk activity, especially compared to other transportation hazards, but they are concerned about public and state and local government acceptance, particularly in view of the growing resistance to recent efforts to transport spent research reactor fuel, defense spent fuel, and transuranic waste within the United States.

U.S. government studies on radioactive materials transport (e.g., NUREG-0170, 1977, NUREG/CR-4829, 1987, and NUREG/CR-6672, 2000) indicate that SNF and HLW can be transported at low risk by truck or rail primarily because transport is done under stringent national and international regulations. SNF and HLW must be transported in certified shipping containers that are designed to withstand severe accidents involving high-speed impacts, drops onto unyielding surfaces, and high-temperature fires. (In the United States, the U.S. Nuclear Regulatory Commission is responsible for certifying commercial shipping containers and continues to study container design and performance characteristics. The U.S. Department of Energy is responsible for certifying its transportation packages using the same requirements established by the U.S. Nuclear Regulatory Commission.) Shipments are made along predetermined routes, and some are tracked in near-real time using GPS. Some types of shipments are also accompanied by security details and trained emergency responders.

Both SNF and HLW have been transported safely within and across national borders for many decades. There have been about 3,000 rail and truck shipments of SNF in the United States since the early 1960s. Of these, four truck shipments were involved in traffic accidents, but none of these resulted in the release of radioactivity. In the rest of the world, there have been about 24,000 shipments by truck, train and ship, again without releases of radioactivity. The higher rate of shipping elsewhere in the world is attributable to the transport of SNF in Japan and Europe for reprocessing.

The gap between expert opinion of waste-transport risks, bolstered by several decades of experience, and public and state and local government perceptions of transport risks may widen if and when the federal government begins to transport SNF and HLW to a geologic repository. There may be several reasons for this perception gap—for example, a lack of public confidence in or understanding of the technical bases for expert opinion; a lack of understanding by federal agencies of the views of state and local governments; a lack of confidence in the federal government's ability to develop and maintain a high-reliability waste transportation program; or perhaps a recognition that expert risk assessments do not account for quality-of-life and pocketbook issues of importance to state and local governments and the public.

Under current schedules, the transport of SNF/HLW to a geologic repository in the United States would not occur until early in the next decade at the earliest. The National Research

Council believes that there is an opportunity to use the intervening time wisely to understand the causes of this perception gap and to take positive steps to address them. The study proposed here would be a first step in this process, and its objective would be to develop a high-level synthesis of the key technical and societal issues and to identify technical and policy options for decision makers in government who are responsible for developing, funding, implementing, and regulating the federal government's SNF and HLW transportation programs.

Project Task Description

The principal task of this study will be to develop a high-level synthesis of key technical and societal issues for SNF and HLW transport and to identify technical and policy options for addressing these issues and managing transportation risk. The principal focus of this study will be on the transportation of SNF and HLW in the United States, but the study will draw on international experiences as well as experiences with transporting other waste types. The study will address the following four questions:

1. What are the principal risks for transporting (including container handling, modal transfers, and conveyance) radioactive waste, and how do they compare with other societal risks? To what extent have these risks been addressed by previous analyses?
2. At present, what are the principal technical concerns for transporting radioactive waste? To what extent have these concerns been addressed, and what additional work is needed?
3. What are likely to be the key technical and societal concerns for radioactive waste transportation in the future, especially over the next two decades?
4. What options are available to address these concerns, for example, options involving changes to planned transportation routes, modes, procedures, or other limitations/restrictions; or options for improving the communication of transportation risks to decision makers and the public?

Work Plan

This twenty-four-month study will be carried out by a committee of twelve experts appointed by the chair of the National Research Council, including two experts from outside of the United States. The committee will meet eight times to gather information, deliberate on the issues, and develop a report. One of these meetings will be organized around a workshop to obtain the views of a wide range of experts, federal, state, and local government representatives, nongovernmental organizations, and other members of the public.

Information needed for this study will be obtained from several sources, including previously published technical studies on transportation risks, waste-package performance, waste inventories, waste-transport procedures, and transport corridors; social science studies that identify and analyze societal concerns for transporting radioactive waste; written records of public hearings held by government agencies to obtain public input on transportation plans and programs; and briefings by subject matter experts, federal, state, and local government representatives, nongovernmental organization representatives, and other interested members of the public.

The committee will issue a consensus report at the conclusion of its study. This report, which will be subject to National Research Council review, will be written primarily for decision-makers in federal, state, and local government, but also for members of the public who have an interest in transportation issues. Funds will be budgeted to allow the National Research Council to distribute 750 copies of this report free of charge to key members of the target audience.

Discussions are currently underway within the National Research Council about ways to make this study more widely accessible to the public, for example, by identifying nontechnical target audiences for this study and preparing a stand-alone product for these audiences based on the committee's final report. We intend to continue these discussions and, to the extent that external resources can be identified from agencies and foundations, to work with the committee to incorporate such activities into this study. The current budget for this project does not include funds to support these add-on activities.

The National Academies Board on Radioactive Waste Management is located in Washington, DC, USA. Its Web site is located at http://www.nas.edu/brwm.

Radiation Doses to the Public from the Transport of Spent-Nuclear Fuel

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Much has been said about the risks to the public from exposure to radiation emanating from shipping casks transporting spent-nuclear fuel, high-level radioactive waste, and other radioactive materials. In public comments, the state of Nevada's Nuclear Waste Project Office (NNWPO) suggested that the regulatory limit of 10 millirem per hour two meters from the side of transport vehicles results in unacceptably high exposures to the public. Robert Halsted, speaking for the NNWPO, presented verbal pictures of radiation exposure to pregnant women in vehicles caught in traffic gridlock next to shipments. At the Waste Management 2002 meeting in Tucson, Arizona, Halsted estimated that a worker at a truck stop where shipments to Yucca Mountain stopped to refuel could receive an annual dose up to 1 rem. Others have suggested there will be environmental justice impacts in minority communities along routes where there will be exposure to radiation from passing shipments. Halsted, again speaking for the NNWPO, called shipments of spent-nuclear fuel and high-level radioactive waste "rolling X-ray machines that you cannot turn off."

When the subject turns to transportation accidents, the state of Nevada and others have called shipments of spent-nuclear fuel "mobile Chernobyls." Nevada commissioned a study that estimated thousands would die if a rail shipment of spent-nuclear fuel were involved in an accident such as the July 2001 accident that occurred in the Baltimore Tunnel in Baltimore, Maryland. Nevada's projections of consequences of radiation doses to the public that could result from sabotage have been even more dramatic.

Several of those commenting on DOE's *Draft Environmental Impact Statement for the Disposal of Spent-nuclear fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 1999) expressed concern regarding contamination of community water reservoirs as the result of an accident. In public comments to the U.S. Nuclear Regulatory Commission (NRC), Halsted stated that if a spent-nuclear fuel assembly dissolved in Nevada's Lake Mead, the resulting levels of radioactivity would exceed the U.S. Environmental Protection Agency's (EPA's) drinking water standards. Others have expressed concern about the use of barges to transport casks on the Great Lakes and the radiological consequences for the lakes if there were an accident. In addition, Nevada has argued that the cost of cleanup following an accident or act of sabotage would be extreme—exceeding $10 billion. Halsted has suggested that accidents with these consequences can be expected to happen. In its report—*A Mountain of Trouble*—Nevada estimated that as many as 350 accidents would occur in transporting spent-nuclear fuel and high-level radioactive waste to Yucca Mountain. The city of North Las Vegas estimated that $5 billion of economic development along the northern Las Vegas Beltway would be lost because of the public's perception of risks from radiation released in transportation accidents that could occur during shipments to Yucca Mountain.

At the same time, the U.S. Department of Energy's (DOE) *Final Environmental Impact Statement for the Disposal of Spent-Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (*YMEIS*) presents an exhaustive analysis of the potential radiological impacts to members of the public from shipments of spent-nuclear fuel from seventy-seven sites to Yucca Mountain. This analysis shows that the total impact on 11 million to 16 million people who live along truck and rail routes that could be used would be small—between two and five latent cancer fatalities over twenty-four years. These impacts fall below the 1-in-1-million threshold used by the EPA to identify environmental issues of concern. In effect, the impacts estimated by the *YMEIS* could not be discerned in the affected population where the annual rate of fatalities from all causes is about 10,000 per 1 million.

The risks associated with accidents analyzed in the *YMEIS* are far lower than the very low radiological risks from routine transportation. Even when probability is removed from consideration, the *YMEIS* estimated that the consequences of a maximum reasonably foreseeable rail accident occurring in the center of a highly populated metropolitan area would be five latent cancer fatalities in a population of 5 million. In making this estimate, DOE made a number of conservative assumptions, including the assumption that people would not be evacuated from contaminated areas for a year following the accident. It is of interest that the analytical conditions for the maximum reasonably foreseeable accident analyzed are comparable to the most severe conditions reported for the Baltimore Tunnel fire.

Clearly, Nevada and the DOE have drawn substantially and dramatically different conclusions about radiological safety of the public from the same base of information about future shipments to a nuclear waste repository at Yucca Mountain. Thus, it is necessary to look into the source information in an attempt to understand these differences.

Regulatory Requirements

Spent-nuclear fuel or high-level radioactive waste will be shipped in casks certified by the NRC in accordance with the requirements in Title 10, Part 71 of the Code of Federal Regulations. This means that the casks will meet a suite of performance requirements that have been selected to protect public health and safety. It includes requirements limiting radiation dose external to the cask for normal conditions of transport and following accidents. In addition, the cask must include features that prevent the occurrence of nuclear criticality under normal and accident conditions, and it must contain its radioactive material contents when subjected to a sequence of drop, puncture, fire, and immersion accident tests.

In addition, the U.S. Department of Transportation (DOT) regulates shipments of radioactive materials, including spent-nuclear fuel and high-level radioactive waste. These regulations are contained in Title 49 of the federal regulations. The DOT regulations include requirements for selecting highway routes (although routes for shipments of spent-nuclear fuel must also be approved by the NRC); expediting shipments; setting surface contamination limits on shipping casks and vehicles; establishing radiation dose rates external to casks and vehicles; enhancing the safety of rail, truck, and maritime transportation; and using NRC-approved casks. The DOT regulations establish the limit of 10 millirem per hour two meters from the side of a transport vehicle for exclusive-use transport of radioactive materials. Dose rates in normally occupied areas of a transport vehicle cannot exceed 2 millirem per hour unless the vehicle operators' exposures are managed under a radiation protection program.

Dose to Individuals from a Single Shipment During Routine Transportation

Assuming that the dose rate two meters from the side of a shipment is the regulatory limit of 10 millirem per hour, the dose to a person thirty meters (about 100 feet) from the side of a highway or railroad where the shipment passes can be easily calculated. One only needs to know the dimensions of the shipping cask and the speed that it is transported along the road/rails. Assuming a speed of 55 miles per hour, the dose to a person thirty meters from a route from a single passing shipment of commercial nuclear-reactor spent fuel would be about 0.07 microrem. For perspective, this can be compared to the average individual dose in the continental United States of about 41 microrem per hour, or about 0.01 microrem per second, from natural background radiation. Also, assuming that one-half of the dose from the passing shipment is neutron radiation and that a 100-square-centimeter detector/counter having 100 percent efficiency is used, on average 1 neutron would be detected (above background) as the shipment passed. Background neutron radiation resulting from natural environmental processes and sources such as alpha decay of radon gas in the atmosphere, naturally occurring radium in soil, spontaneous fission decay of natural uranium in soil and rock, and cosmic radiation would probably mask the neutron radiation from a passing shipment.

This assumes that the dose rate external to a shipment would be the maximum allowed by regulations and that the shipments would travel at 55 miles per hour. It is unlikely that the dose rate will be the maximum allowed by regulations. One reason is that it will be commonsense practice for shipping facilities to ensure that the dose rate external to shipments is some reasonable margin below the regulatory limit to allow for uncertainties in measurements.

However, shipments could travel at speeds lower than 55 miles per hour, especially rail shipments. Assuming the travel speed is 20 miles per hour and that the dose rate is the maximum allowed by regulations, the dose from a single passing shipment would be about 0.16 microrem to a person 30 meters away—about 2.3 times the dose for a shipment that passed at 55 miles per hour.

For people traveling in vehicles along the same route as a truck shipment, the dose to an individual would be greater than that for people along the roadway. Assuming that personal automobile traffic flows at a speed about five miles per hour faster than the shipment and that a person in a passing automobile traveling in the same direction is an average distance of 2 meters from a shipment when passing occurs, the dose received would be about 6 microrem. People in vehicles passing in the opposite direction would receive much lower doses.

For those who might be locked in traffic gridlock with a shipment vehicle next to (closer than two meters from) the automobile or bus in which they are riding, the *YMEIS* estimates the dose could be as high as 16 millirem. This dose assumes the person would be exposed for one hour with the side of the transport vehicle carrying spent-nuclear fuel less than two feet away. The analysis also assumed that the dose rate external to the transport vehicle would be the maximum allowed by regulations. For perspective, a dose of 16 millirem is approximately the same as the dose one receives from two chest X-rays. It is also about 5 percent of the average annual background radiation dose to individuals in the continental United States and about 7 percent of the average dose from cosmic radiation to a full-term fetus.

Doses from single shipments occur not only to people in traffic with the shipment and to those who live along the shipping route, but also to people who live near places where shipments stop. Rail shipments stop to allow a change of train crews, classification and blocking of rail consists in rail yards, and periodic inspections en route. Truck shipments stop for walkaround inspections, state inspections, rest breaks for drivers, and vehicle refueling. Most stops would occur in rural areas or in areas where there was substantial separation between shipments and nearby communities. For rail classification stops, if general freight service were used, stops could be as long as 48 hours and over weekends and holidays.

The *YMEIS* assumes that rail shipments would stop an average of thirty hours at origin and destination classification rail yards and that the time spent in en-route stops for classification and inspection would be 0.033 hour per kilometer of travel (a rate equivalent to about one classification stop for each 600 miles of travel). The time spent by rail shipments at stops is estimated to exceed the travel time; therefore, the *YMEIS* analysis estimated that a significant fraction of the dose to the public along rail routes would be to persons who live in the vicinity of locations where shipments would stop. If a member of the public stood for thirty hours at a location in a rail yard 200 meters (one-eighth of a mile) from a shipment, and if there were no intervening structure or topography, and if shielding effects of the atmosphere were discounted, the total dose to the individual would be about 90 microrem. Again, this assumes the dose rate external to the rail car is the maximum allowed by regulations. Assuming the linear no-threshold hypothesis correlation of the risk of suffering a fatal latent cancer (a rate of 0.0005 latent cancers per rem of dose to a population), a dose of 90 microrem would increase the probability of the exposed individual suffering a fatal cancer from about 23 percent to about 23.000005 percent.

For truck shipments, the dose to members of the public at truck stops is a significant fraction of the total dose that would occur along the shipment route. A 1996 study of truck stop times conducted by Sandia National Laboratories[4] collected observations of the numbers of people near trucks at stops and the time required for a stop. Based on this study, the average stop time for

Table 1. Dose from a single truck or rail shipment of spent-nuclear fuel, high-level radioactive waste, or other exclusive-use shipments of radioactive material

Individual	Transportation condition	Dose[1,,2]
Person 30 meters from route	55 mph passing	0.00000007 rem (0.07 μrem) probability of LCF 3.5×10^{-11}
	20 mph passing	0.00000016 rem (0.16 μrem) probability of LCF 8×10^{-11}
Person in automobile	5 mph passing traffic	0.000006 rem (6 μrem) probability of LCF 3×10^{-9}
	Stopped 1 hr in traffic gridlock	0.016 rem (16 millirem) probability of LCF 8×10^{-6}
Person living near rail classification yard	Shipment stopped for 30 hours @ 200 meters	0.000090 rem (90 μrem) probability of LCF 4.5×10^{-8}
Person fueling auto at truck stop	10-minute stop @ 10 meters	0.0001 to 0.0004 rem (100-400 μrem) probability of LCF 5×10^{-8} to 2×10^{-7}
Truck stop worker	19-minute stop @ 20 meters[3]	0.000050 rem (50 μrem) probability of LCF 2.5×10^{-8}
Airline passenger exposed to elevated levels of cosmic radiation	Round trip from New York to Los Angeles	0.007 rem (7 millirem) probability of LCF 3.5×10^{-6}
Average individual in United States exposed to all sources of background radiation	1-second exposure to natural background radiation	0.00000001 rem (0.01 μrem) probability of LCF 5×10^{-12}
	1-hour exposure	0.000041 rem (41 μrem) probability of LCF 2×10^{-8}
	1-year exposure	0.36 rem (360 millirem) probability of LCF 1.8×10^{-4}
	Lifetime exposure to natural background radiation (70 years)	25 rem probability of LCF 1.3×10^{-2} (1.3%)

1. Assumes dose rate external to shipment equals regulatory limit of 10 millirem per hour two meters from vehicle side.
2. LCF estimates based on linear no-threshold model with a factor of 0.0005 LCFs per rem of exposure to a population.
3. Stop time for truck stop worker dose based on average of observations by Griego et al. 1996.

trucks was about nineteen minutes, with the longest observed time being forty-nine minutes. Because there is a continuous flux of people at a truck stop, the Sandia study reported observations of the average number of people at specified distances from a truck during the time the truck was at the stop. Based on the reported data, there are on average six people at an average distance of sixteen meters from a truck when it is stopped. Assuming that an individual in this group is fueling an automobile for ten minutes while a spent-nuclear fuel shipment is ten meters away, the dose received by the individual would be between 100 and 400 microrem. The dose to a truck stop worker twenty meters away from a shipment that stopped for nineteen minutes would be about 50 microrem. These estimates assume that there are no intervening structures or vehicles that would provide shielding and that the dose rate external to the shipment would be the maximum allowed by regulations.

Table 1 summarizes doses to members of the public that could occur in the course of routine transportation of spent-nuclear fuel, high-level radioactive waste, or other exclusive-use shipments of radioactive materials. For perspective, the table also lists doses from other radiation sources to which the public is routinely exposed.

Dose from an Accident

In 2000, Sandia National Laboratories and the NRC published a reanalysis of the performance of shipping casks in severe transportation accidents.[6] The report concluded that casks used to transport commercial spent-nuclear fuel that were designed, manufactured, and operated in accordance with NRC regulations in Title 10, Part 71 would survive more than 99.99 percent of all accidents without releasing their contents. In addition, the report presented estimates of cask performance under a series of severe accident conditions (categories of accidents) that would be expected to occur less than once in 10,000 accidents. The severe accident conditions were categorized according to ranges of effective speeds of impact and cask body temperatures following exposure to fire. The estimates of releases were coupled with estimates of the likelihood of occurrence for each of eighteen categories of severe truck and twenty categories of severe rail accidents.

In a recent report released to the press, Nevada presented data, based on DOE analyses, that suggests that releases, particularly of radiocesium, would be dramatically greater than estimates presented[6] for equivalent accidents. However, on close examination, the argument for using the observed fraction of total radiocesium leached from broken-up spent fuel rods as a basis to escalate the amount of the isotope that would be volatilized from ruptured cladding is flawed. The report claims to use DOE data as its basis for estimating that as much as 9 percent of total radiocesium could be deposited in fuel rod gaps and compares this to the estimate of 0.3 percent used in the Modal Study.[3] These two sets of values are then used to escalate the cesium release fraction by a factor of 30 for severe transportation accidents that involve fire. What is ignored is the fact that the amount of radiocesium released in a fire accident is not the total radiocesium present. Rather, it is the material that is in vapor phase in fuel rod gaps and plenums carried out by gases being released through rod ruptures. The vapor pressure of cesium is so low that, following initial blowdown release, evolution of volatile cesium from rods would be exceedingly slow and would not contribute measurably to total releases from a cask.

The analysis of the risks of exposure to releases resulting from transportation accidents presented in the *YMEIS* used (1) the data presented by Sprung,[6] (2) accident rates in each state shipments would cross,[5] (3) the distance shipments would travel, and (4) the estimated number of shipments that would be made to Yucca Mountain. The analysis estimated that there could be as many as sixty-seven truck accidents in the course of about 50,000 truck shipments or eight rail-car accidents in the course of about 10,000 rail-cask shipments. These estimates were for respective scenarios wherein shipments of 70,000 metric tons of heavy metal (tHM) of spent-nuclear fuel and high-level radioactive waste to Yucca Mountain would be made mostly by truck or mostly by rail. Based on these results and on the probability of a transportation accident that would be severe enough to cause a release of radioactive materials, the likelihood of an accident that would have any release would be about 0.007 over 50,000 truck shipments and 0.00008 for 10,000 rail shipments.

For accidents where there could be releases, as would be expected, the amount of gases, volatile radionuclides (including cesium), particulates, and crud released increases as the combined fire and impact forces increase. However, based on truck and rail accident statistics, the probability of an accident occurring decreases dramatically as the severity of accident conditions increases. Because the estimated risks of releasing radioactive materials from casks in accidents are so low, the DOE does not expect that any of the projected accidents would be severe enough to release radioactive materials. In fact, the risk of release is so low that the risk of dose to populations living near locations of accidents in which shipping casks would be undamaged (99.99 percent of accidents) from normal radiation external to a cask while it is being recovered is comparable to the radiological risk of releases. Even so, the dose to an individual living thirty meters from the accident scene where an undamaged cask was being recovered would be small—about 100 microrem.

Because it is useful to understand the magnitude of consequences that could result from the most severe accidents that can be reasonably foreseen, the analysis in the *YMEIS* evaluated so-called maximum reasonably foreseeable transportation accidents. Such accidents are defined by the DOE as accidents that would have a probability of occurring more often than once in 10 million years. To identify the maximum reasonably foreseeable accident, the *YMEIS* analysis evaluated the consequences of all of the severe accidents identified by Sandia,[6] then selected the accident that would have an annual probability of occurring greater than 0.0000001 (1×10^{-7}) and that would lead to the greatest consequences. In selecting this accident, the analysis considered the probability that it would occur in highly populated urbanized areas and under weather conditions that would lead to the greatest consequences. The most severe accidents that satisfy all of these conditions for both truck and rail shipments were those involving long-duration fires, such as the Baltimore Tunnel fire.

For the conditions analyzed, and assuming that evacuation and other remedial measures would not be taken for at least one year following the accident, the analysis of a maximum reasonably foreseeable rail accident estimated the exposed population would receive a dose of about 10,000 person-rem, resulting in an estimated five latent cancer fatalities. The analysis estimated that the fifty-year committed dose to a maximally exposed individual would be about 29 rem. A dose of 29 rem would increase an individual's risk of a latent fatal cancer, the rate for fatal cancers from all causes, from about 23 percent to about 24.5 percent. For an accident involving a truck cask, the results were about one-ninth those for the rail cask accident; as might be expected, this roughly correlates to the ratio of the contents of the two kinds of casks.

Accidents with greater consequences are analyzed in the *YMEIS*. But, the next most likely rail and truck accidents that also have greater consequences are estimated to be 100 times less likely to occur than the already very unlikely maximum reasonably foreseeable accidents.

The *YMEIS* also considered the potential for severe accidents involving transportation of spent-nuclear fuel in casks transported by barges. Because the total annual distance traveled by barges for shipments from reactor sites to nearby railheads would be limited, accidents that could lead to release of radioactive materials would not to be reasonably foreseeable. Nonetheless, the *YMEIS* concluded that even if radioactive materials were released in a barge accident, the dose to members of the public would be much less than for accidents where radioactive materials were released to the atmosphere. In response to public comments, the DOE observed that spent-nuclear fuel is a solid ceramic clad in a corrosion-resistant metal tube and that it cannot be easily dispersed into the environment. Further, spent-nuclear fuel, which has been exposed to the high-temperature water environment of a nuclear reactor followed by years of storage in a water pool, does not dissolve in water and therefore could not be readily dispersed from a shipping cask into waters used by the public for recreation and drinking.

In considering the maximum reasonably foreseeable accidents, Nevada has argued that DOE should assume that the spent fuel being shipped has been discharged from the reactor for five years. In contrast, based on an analysis of the expected stream of spent fuel that would be delivered from reactor sites, the DOE analysis assumed the fuel would be fifteen years old. In reality, because five-year cooled fuel would constitute only a small fraction of the fuel shipped to Yucca Mountain, the annual probability of severe accidents involving this fuel would be less than 1 in 10 million. Also, even if considered in the analysis, the capacity of shipping casks would be less if carrying five-year cooled fuel than the capacity would be for casks carrying the assumed fifteen-year cooled fuel. Thus, the increase in radionuclide content of five-year cooled fuel would be offset by the reduction in cask capacity to accommodate this fuel. In effect, the assumptions suggested by Nevada would not lead to results that differed significantly from those estimated by the DOE.

In comments to the DOE, Nevada and others expressed concern for the safety of emergency response personnel who are first to arrive at the scene of an accident. As a consequence, in the *YMEIS*, the DOE estimates the radiological risks to emergency personnel who are first on the scene of an accident. Because there is a very small likelihood that the contents of a cask would be released in an accident, the expected dose to a first responder who follows the DOT's *North American Emergency Response Guidebook* (published by the American Trucking Association) would be small. The guidebook recommends that responders:

- Assess the accident scene and report the information immediately to a radiation authority
- Approach an accident from upwind
- Stay clear of all spills, vapors, fumes, and smoke
- Remove injured people from the scene
- Isolate a potential spill or leak area twenty-five to fifty meters in all directions
- Keep unauthorized people away from the area
- Move a safe distance upwind from the accident scene until additional assistance arrives

The analysis in the *YMEIS* considered that responders could receive a dose as high as 2.6 millirem at accidents in which a cask's shielding was not damaged. A dose of 2.6 millirem is approximately equal to the average dose from natural background radiation received by individuals in the continental United States in 2.5 days. In the case of maximum reasonably foreseeable severe accidents where impact forces or fire could lead to loss of lead shielding in a rail cask, the analysis in the *YMEIS* estimated that a first responder unaware of a cask's reduced shielding could receive a dose as high as 0.83 rem. Such conditions are very unlikely, having a frequency of occurring of about 1 in 1 million years. A dose of 0.83 rem would lead to an increased risk of an individual in the United States suffering a fatal cancer from about 23 percent from all causes to about 23.04 percent.

Table 2 summarizes the estimates of doses to populations and individuals that could result from accidents involving shipments of spent-nuclear fuel to individuals. The table also presents estimates of the risk of latent cancer fatalities from the received doses. For perspective, the table presents estimates of the number of individuals who could be killed in traffic accidents involving the shipments.

Table 2. Dose to individuals from accidents in transporting spent-nuclear fuel

Accident	Transport mode	Number or frequency	Individual or population	Dose and dose risk
All accidents—no release expected	Truck	67 per 50,000 shipments—about three per year if most shipments to Yucca Mountain are by truck	General public within 80 kilometers of route—about 11 million live within 800 meters of route	~0.5 person-rem for 50,000 shipments probability of LCF 2.5 x 10^{-4}
	Rail	8 rail car accidents per 10,000 shipments—about 1 every 3 years if most shipments to Yucca Mountain are by rail	General public within 80 kilometers of route—about 16 million live within 800 meters of route	~1 person rem for 10,000 railcar shipments probability of LCF 5 x 10^{-4}
Accidents without release	Truck or rail	One accident	Individual 30 meters from accident scene	0.0001 rem (100 μrem) probability of LCF 5 x 10^{-8}
			First responder	2.6 millirem probability of LCF 1.3 x 10^{-6}
Accidents with release, including loss of shielding accidents	Truck	0.007 for 50,000 shipments to Yucca Mountain	General public within 80 kilometers	~0.1 person-rem for 50,000 shipments probability of LCF 5 x 10^{-5}
	Rail	0.0008 for 10,000 shipments to Yucca Mountain	General public within 80 kilometers	~0.8 person-rem for 10,000 shipments probability of LCF 4 x 10^{-4}
Maximum reasonably foreseeable accident	Truck	~1.4 per 10^{10} cross-country truck shipments	General public within 80 kilometers in large metropolitan area	~1,000 person rem probability of LCF 0.5
			Maximally exposed individual member of the general public	3 rem probability of LCF 1.5 x 10^{-3}
			First responder	2.6 millirem probability of LCF 1.3 x 10^{-6}
	Rail	6 per 10^{10} cross-country rail shipments	General public within 80 kilometers in large metropolitan area	~10,000 person rem probability of 5 LCFs
			Maximally exposed individual member of the general public	29 rem probability of LCF 1.5 x 10^{-2}
			First responder	0.83 rem probability of LCF 4 x 10^{-4}
Traffic accident	Truck	67 per 50,000 shipments—about 3 per year if most shipments to Yucca Mountain are by truck	Member of general public or transportation worker	4.5 fatalities from causes not related to radiological characteristics of the cargo
	Rail	8 rail car accidents per 10,000 shipments—about 1 every 3 years if most shipments to Yucca Mountain are by rail		2.5 fatalities from causes not related to radiological characteristics of the cargo

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Nuclear Transport: The Impact of International Regulations

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The International Regulatory Regime for Transport

The transport of radioactive materials is subject to a strict regulatory regime to ensure safety and security. The international standards developed at the International Atomic Energy Agency (IAEA) are reflected in the standards and regulations of the modal bodies such as the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO); regional regimes such as the European agreements for transport of dangerous goods via road, rail, and inland waterways in Europe; and the regulatory regimes of the IAEA member states.

The World Nuclear Transport Institute (WNTI) was founded in 1998 by the Federation of Electric Power Companies of Japan (FEPCO), COGEMA of France, and British Nuclear Fuels Ltd. (BNFL) of the United Kingdom to represent the collective interests of industries involved in or reliant on the safe, efficient, and reliable transport of radioactive materials. Based in London, with regional offices in Washington and Tokyo, WNTI has grown to thirty-eight members worldwide representing such sectors as major utilities, fuel-cycle companies, fabricators, transport companies, and package producers. WNTI's ability to represent the collective interests of its members is enhanced by the global span of its membership and the diversity of transport concerns it represents. WNTI offers a forum for members to share information, ideas, and concerns. It acts as a catalyst to stimulate the development of consolidated industry positions before international regulatory bodies. WNTI provides the nuclear transport industry, and those who rely on transport, with the collective eyes, ears, and voice in the key intergovernmental organizations that are so important.

On the basis of its nongovernmental organization (NGO) status, WNTI has a continuing exchange with the IAEA and the IMO. WNTI has consultative status with the United Nations Committee of Experts on the Transport of Dangerous Goods and is a liaison member of the appropriate International Standards Organization (ISO) committee. Industry, through WNTI, is represented at the key meetings where implementation and review of the regulations are discussed.

The Importance of Harmonized Regulations

The IAEA transport safety regulations, from which the international transport safety regime flows, are based on the philosophy that radioactive materials being transported should be packaged adequately to provide protection against the hazards of the material under all conditions of transport, including foreseeable accidents. The bottom line of regulation is safety and security. But safety and security are not based solely on the wording of the regulatory provisions. Safety and security are also assured to the extent that there is clarity within the regulations; to the extent that there is consistency and uniformity in their interpretations and their application around the world; and to the extent that they provide for efficient operation. This is not always the case. Different schedules for the introduction of changes to modal and national regulations, and different transition periods from one set of regulations to another, can cause confusion, introduce further complexity, and delay transports. On January 1, 2002, the latest version of the IAEA transport regulations–TS-R-1–was in force in the international and modal regulations. Not all countries were able to adjust their national regulations to implement TS-R-1 provisions by that time. In the United States, for example, revision of U.S. Nuclear Regulatory Commission (NRC) and U.S. Department of Transportation (DOT) regulations to harmonize with TS-R-1 will be finalized in 2003.

Consistent interpretation and application of international regulations is important to the safe, efficient, and secure movement of radioactive materials. Consistency and predictability in regulations assist in ensuring compliance, help to avoid confusion among all those involved in the transport chain, avoid any perception that differing applications of the regulations in different jurisdictions are somehow more or less stringent than others, and focus resources on safety considerations and compliance. The impact of differing approaches is significant at a time when there is increased pressure for new design reviews and foreign validations.

Differing interpretations of regulations exist in a number of areas. For example, the desired sequence of performance tests may differ among authorities from one jurisdiction to another. To illustrate, for Type B(U) and Type B(M) packages, tests to demonstrate the ability to withstand accident conditions of transport typically include two drop tests: a puncture test, which is a one-meter drop of the package onto a bar of a circular section fifteen centimeters in diameter; and a nine-meter drop test which is a drop of the package onto a flat, unyielding surface. The IAEA standards prescribe that these tests must be performed in the order that leads to the maximum damage. However, at least one national jurisdiction specifies that the nine-meter drop test must be performed first, and the one-meter puncture test second. Should the applicant and the national authority with regulations based directly on the IAEA regulations agree that performing the puncture test before the nine-meter drop is the most damaging sequence, what happens if the applicant requires the package to be validated by a national authority that takes a different view? This is a case in which differing interpretation of the IAEA regulations can lead to increased work on the part of an applicant requiring package validation in multiple countries.

The IAEA process for review of TS-R-1 has moved from a ten-year review cycle to the current two-year review cycle with potentially significant consequences for transport. So we find ourselves in a situation today where TS-R-1 is still in the process of being implemented in a number of jurisdictions; the first two-year review cycle for TS-R-1 has just concluded; and a new review cycle has begun. If regulations were to change so substantially every two years as to require a whole new edition of the transport safety regulations, it is not at all clear that national regulations worldwide could keep up with the pace of the changes. Will a two-year review cycle allow sufficient time for public consultations and for the necessary regulatory procedures prior to incorporation of the changes into national regulations? Will a two-year review cycle allow adequate time for industry to make necessary modifications where required by new regulation, to train staff in new requirements, and, where necessary, to modify operational procedures? No one benefits from a smorgasbord of regulations of varying vintages.

The result of the recently review of TS-R-1 is that the altered TS-R-1 will appear as an amended edition (1996, as amended) rather than a new revised edition. This recognizes that the changes were not of such magnitude to require a whole new edition with the necessary accompanying process of substantial regulatory change around the world. It is also noteworthy that the current review cycle for TS-R-1 that began this year has been characterized as one of review rather than revision.

The transport of radioactive materials relies on the accessibility of approved packages, and the IAEA member states have recognized the need to authorize existing package designs over a reasonable period of time. The system should allow packagings that are properly maintained and continue to meet their original design bases to safely continue in use to the end of their useful design lives. Differing approval processes and differing interpretations of regulatory provisions can impact the availability of suitable packagings for multinational shipments. Evaluation of existing design review and validation processes by industry and by national competent authorities may be helpful to determine how increased efficiencies can be built into the current system. For example, safety analysis reports that are more standardized internationally would be helpful.

Impact of Changes to TS-R-1 on Spent-Fuel Transport in United States

How might the harmonization of U.S. transport safety standards with IAEA standards affect spent-fuel transport in the United States? One example is evident from the proposed revisions to the U.S. regulations that are under consideration, *"Compatibility With IAEA Transportation Safety Standards (TS-R-1) and Other Transportation Safety Amendments,"* Federal Register, April 30, 2002 (Volume 67, No. 83). Historically, the IAEA, DOT, and NRC regulations have included transitional arrangements or grandfathering provisions when the regulations are revised. The purpose of grandfathering is to minimize the impact on existing package designs.

The primary grandfathering provisions proposed for U.S. safety regulations include the following:

Packages approved under NRC standards that are compatible with the provisions of the 1967 edition of Safety Series No. 6 may no longer be fabricated, but may be used for a three-year period after adoption of a final rule. Under TS-R-1, these packages can no longer be used.

Packages approved under NRC standards that are compatible with the provisions of the 1973 or 1973 (as amended) editions of Safety Series No. 6 may no longer be fabricated. However, the proposed rule would not impose any restrictions on the use of these packagings.

Packages approved under NRC standards that are compatible with the provisions of the 1985 or 1985 (as amended 1990) editions of Safety Series No. 6, and designated as "-85" in the identification number, may not be fabricated after December 31, 2006, but may continue to be used.

Package designs approved under any pre-1996 IAEA standards (i.e., packages with a "-85" or earlier identification number) may be resubmitted to the NRC for review against the current standards. If the package design described in the resubmitted application meets the current standards, the NRC may issue a new certificate of compliance (COC) for that package design with a "-96" designation.

Under the ten-year IAEA review cycle, package designs could be manufactured for two revision cycles or for approximately twenty years. With the two-year revision cycle, it is not yet clear what the allowable manufacturing period will be; clearly a four-year allowable manufacturing period would be impractical. According to NRC's April 30, 2002, Federal Register notice, this issue is under review by the IAEA. In the interim, NRC has proposed that it will specify in existing 10 CFR 71.13 when packages can no longer be manufactured or used, rather than using a two-revision cycle approach.

All of the transport cask designs certified by NRC over the past several years as part of dual-purpose storage and transport systems are "-85" packages. This means that transport casks manufactured before December 2006 could be used beyond that date under a valid COC, but no new packages could be manufactured. Depending upon the schedule for procurement and manufacture of a cask fleet by the U.S. Department of Energy (DOE) for transport of spent fuel to a repository, this could present an obstacle in package procurement since all packages fabricated after

December 31, 2006, would have to fully meet TS-R-1 requirements. This would mean that cask designs would have be resubmitted to the NRC for review against the new standards in order for these packages to be manufactured for inclusion in the DOE cask fleet. It will be vitally important for DOE to factor this into its cask procurement process.

Summary

Implementation and revision of international transport safety standards and harmonization of U.S. regulations with these international standards raise many issues of importance to industry. As the DOE begins its planning process for transport of spent fuel from nuclear power plants to a repository, it is important to take the full measure of any potential implications of international transport regulations and their ongoing review. In addition, the international experience of the industry in the transport of radioactive materials, particularly spent-fuel transports, can provide important insights and experience in the development of a U.S. transport program.

Authentication of Radiation-Measurement Systems for Nonproliferation

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Abstract

Radiation-measurement systems are central to the affirmation of compliance with a variety of agreements related to arms control and nonproliferation. *Authentication* is the process by which the monitoring party gains appropriate confidence that the information reported by a monitoring system accurately reflects the true state of the monitored item. Authentication employs a set of tools to provide evidence that a system performs its required and defined tasks. These tools include functional testing using trusted unclassified calibration sources, evaluation of documentation including the software, evaluation of hardware, random selection of hardware and software, and use of tamper-indicating devices.

Procedures for carrying out authentication are central to the successful implementation of the complex process of authenticating systems throughout their life cycle. These can be divided into the elements of design, fabrication, installation, and operations. In this paper, we focus on U.S. authentication requirements. Radiation-measurement systems are now being specified that are the subject of U.S. authentication activities. We introduce the concept of authentication-assurance levels (AALs) to measure the effectiveness of authentication.

Introduction

The end of the Cold War resulted in unprecedented arms control agreements and initiatives between the United States and former Soviet Union countries to reduce the number of nuclear weapons and to safeguard the dismantled fissile materials. Following the breakup of the Soviet Union, the U.S. Congress enacted the Cooperative Threat Reduction (CTR) Program (originally called the Nunn-Lugar Initiative) to assist former Soviet Union countries in enhancing the safety, security, control, accounting, and centralization of nuclear weapons and fissile materials. The Defense Threat Reduction Agency (DTRA) is charged with administering the objectives of the CTR Program, including the safeguarding of fissile materials via the Fissile Material Control Program.

Bilateral nonproliferation and arms-control agreements and negotiations held between the United States and the Russian Federation are leading to the disposition of nuclear-weapons material and the deactivation and decommissioning of production and processing facilities. A new population of material that originated from nuclear weapons programs is being stored. This will place new requirements on information security and authentication beyond those traditionally considered. The material in question has classified characteristics, which results in measurement data that is classified, and thus requires a barrier to prevent the monitor from gaining sensitive information. The desirability of this material is greater than material that has been previously placed under international safeguards. The plutonium and highly enriched uranium (HEU) from these efforts ultimately will be processed into reactor fuel or disposed of by other means. The International Atomic Energy Agency (IAEA) is also involved in this effort through trilateral discussions and possibly separate agreements between the United States and the IAEA, and Russia and the IAEA.[1] Such agreements involving weapons states generally involve some level of transparency, where a monitoring party enters a host-party facility and confirms that the conditions of the agreement are being satisfied to some level of confidence. Because of the possible classified nature of the information, new constraints are placed upon monitoring measurement systems, and both the host and the monitor must work harder to gain a baseline of trust.

A number of radiation-measurement systems are under discussion and development for possible use in future confidence building activities or for possible affirmation of compliance with nonproliferation and arms-control regimes. Authentication, vulnerability assessment, certification, attestation, and demonstration of operational functionality are all required for a viable measurement system. This paper will discuss the technical basis of authentication from a U.S. perspective applied to bilateral discussions, and will introduce a new methodology for potentially measuring the effectiveness of authentication.

Definition of Related Terms

Authentication is the process by which the monitoring party gains appropriate confidence that the information reported by a monitoring system accurately reflects the true state of the monitored item. A joint authentication task force of U.S. Department of Energy and Department of Defense has developed an unpublished report on procedures and requirements for authentication of systems, from which the above definition, and some of those that follow, have been extracted.[2] Information in this article is consistent with the deliberations of that task force. The use of appropriate confidence in this U.S. definition of authentication implies a weighing of consequences in determining the cost and effort associated with gaining confidence in a specific regime, which will need to be determined on a case-by-case basis. The need for determining the appropriate authentication activity for a regime has motivated the definition of the AALs discussed in this paper.

It should be noted that the definitions of terms vary somewhat between various technical communities, which can lead to some confusion. In the U.S. usage, authentication is the activity applied to equipment to assure correct results and data are obtained, while the IAEA typically applies authentication to the verification of data validity and vulnerability assessment to the equipment assurance.[3, 4, 5] In the end, all parties generally share a common interest in the protection of the host's classified information and in the monitoring party's desire for correct results.

Vulnerability assessment is the set of procedures, typically used by the host party, to identify potential threats to its operation of a facility or a measurement system and to establish that a system adequately protects sensitive or classified information. Monitoring party concerns of system vulnerability are an aspect of authentication. From the monitor's point of view, a vulnerability assessment could involve a review of the authentication process to determine if compliance can be adequately confirmed.

Because of a requirement to protect any classified information of the host party, many of the measurement systems developed for nonproliferation and arms-control utilize an *information barrier* (IB) to prevent the monitoring party from observing such classified information. An IB consists of technology and procedures that prevent the release of host-country classified information to a monitoring party during a joint inspection of a sensitive item, while promoting assurance of an accurate assessment of host-country declarations regarding the item.[2, 6, 7] The IB blocks the monitor from access to any classified information, while converting the classified information into an unclassified result confirming whether the measured material conforms to the host's declaration to meet pre-agreed criteria. Authentication carefully explores that data processing by involving a combination of detailed examination of systems and documentation, functional testing, and analysis of the security function for systems. Authentication may be applied independently of whether or not a system incorporates an IB. The presence of an IB complicates the process of building trust.

IB-protected systems may operate in *open* and in *secure* (or *closed)* modes, where open mode provides access to details of unclassified data for the purpose of functional and other testing, while secure mode is used with classified data, and provides only simple pass/fail/error types of output information with minimal input capability.

Certification includes all processes required for the host to allow operation of a system within its facility. Certification includes the process by which a host party assures itself that a monitoring system (which may have an integrated IB) will not divulge any sensitive information about a monitored item to a monitoring party. We include the Russian Federation attestation process as part of certification.

When measuring classified items, the information extracted and presented is necessarily limited. Measurement systems can be categorized as *attribute-measurement* systems or as *templating* systems. An *attribute* is a specific physics-related quantity, such as the ratio of two isotopes as determined from a gamma-ray spectrum. The system that takes a measurement and analyzes the data to produce an attribute value must include physics knowledge of the observation. On the other hand, a templating system can be implemented to compare measurements, such as parts of gamma-ray spectra, between an unknown item and a known item. The templating system may just state that the two items are similar without any physics-based analysis of the data. Attribute measurement systems are typically specific instantiations of radiation-measurement systems that are being developed in the United States and the Russian Federation for possible use in future verification or confidence-building activities.

Attribute or template measurement systems have two basic requirements: protection of classified information during and after measurements; and credible performance of the system for the measurement. Part of a solution for the requirement to protect the host party's classified information leads to the concept of *host supply.* Under the host-supply scenario, the host party would supply the system to be used by the monitor in a host facility in order to provide paramount protection for any host-classified information. Host-supply means that the host has the last private, unsupervised access to a system before use, whether it is built by the host party, the monitoring party, or a third party.[6, 7] The crucial authentication issues for the monitor, then, are that a measurement system correctly measures the agreed-upon attributes or template, and that there are no hidden features in the system to pass erroneous information.

In August 2000, the Fissile Material Transparency Technology Demonstration at Los Alamos National Laboratory, showed that an IB-protected attribute-measurement system can make the type of measurements required for nonproliferation without compromising classified information.[8]

Authentication is specific to each regime where it is applied. We consider here the specific application of U.S. authentication under potential bilateral agreement for transparency.[9]

Authentication Basics

A monitoring system must be designed from the start to facilitate the authentication process. Thus, the design task becomes much more difficult than merely designing a functional system. An information barrier, if present, further complicates the authentication process. Designing for authentication is especially important in a resource-limited regime, where the potential gain from an expedient design decision must be balanced against the cost of the additional authentication effort it may produce. The authentication process involves searching for both inadvertent exploitable design or implementation flaws leading to incorrect results, and deliberate covert features designed into the system for some advantage (often called a *hidden switch*). It is important to realize that authentication goes well beyond normal functional testing, since such testing will not necessarily reveal a hidden switch. The authentication effort can be viewed as gaining a detailed step-by-step knowledge regarding all the data processing occurring within the automated measurement system. Emphasis is placed on complete documentation as a means of reducing the cost associated with reverse engineering the system to acquire knowledge regarding all the data processing.

Authentication can be described by a set of high-level guidelines. The basic tenets of authentication are that systems: 1) are designed for correct operation; 2) are assembled as designed; 3) function as designed; and 4) do not contain hidden features that allow the passing of material inconsistent with accepted declaration. Authentication of systems by a monitoring party involves a collection of tools and methods and is operationally realized through:

- The measurement of unclassified radiation reference sources
- Complete documentation for all hardware and software
- Surveillance plus tamper-indicating devices placed on system components and enclosures
- Random selection of system hardware and software modules for examination
- Thorough private testing of duplicate systems and components in monitoring party facilities

Authentication can be facilitated by following a set of reasonable, basic guidelines when a system is being specified and designed (including those below).

- Documentation should be complete for all aspects of system hardware and software.
- Hardware components should be simple and without extraneous functionality.
- Hardware components should be laid out for easy physical examination.
- Physical enclosures and shielding should provide a two-way information barrier to prevent both disclosure of information and remote-control signals.
- Identical and modular hardware components should be used across a system.
- Hardware and software components should be selected on the basis of availability and share-ability of complete documentation.
- Operating systems should be minimal or nonexistent.
- Software should be transparent and well-documented.
- Software should be simple, concise, and without extraneous functionality.
- Unused hardware should be rendered inoperable.

System components should be the most basic possible for the measurement task, and contain only the required functionality. Since the cost and difficulty of authentication rises with included functionality and the interaction between system components, extraneous functionality is extremely expensive.

Life Cycle of a Measurement System

Procedures for carrying out authentication are central to the successful implementation of the complex process of authenticating systems. The procedures must allow for the varying requirements of authentication throughout the life cycle of a system, which can be divided into the following elements with respect to authentication:

Design

It is essential that systems be designed with the requirements of authentication in mind. Authentication requirements will significantly impact hardware and software design criteria and may impact the overall cost. The need for a complete understanding of the system functionality has the most impact on authentication costs because components that are not fully documented must be reverse engineered or otherwise shown to contain no covert features. Thus, components must be selected based on factors such as completeness of documentation and ease of examination. In some cases, nonoptimized performance may have to be accepted to meet the programmatic authentication goals. For example, an older generation of processor might be preferred for simplicity over a newer, more powerful one with a wide array of unnecessary features. Hardware and software design criteria and procurement decisions can greatly influence the available options and costs for authentication. Thus, the authentication and design teams should work together during the design phase. The quality of the overall design must be judged in terms of facilitating authentication and being robust behind an information barrier. Facility design and facility monitoring system design decisions can likewise impact the ability to authenticate systems.

Fabrication

Authentication of a system requires that the procurement, fabrication, assembly, and testing proceed in a manner that has been agreed to by all parties. Authentication activities during fabrication may include monitoring the actual fabrication practices onsite, reviewing documentation for compliance, subassembly testing, or random destructive or nondestructive testing of components, and an exhaustive review of all software (source code, compiled/executable, and embedded). It may be necessary to transport a system to a host facility after the system has been authenticated. In this case, the equipment might be sealed, stored, and subsequently transported in a mutually agreeable manner for installation at the host facility in order to maintain continuity-of-knowledge of the security of the system.

Installation

Installation for systems requiring authentication must be documented by detailed installation and test procedures. Appropriate physical control or oversight of the system must be maintained during this phase, unless authentication occurs after installation. For example, installation activities likely to be observed by the monitoring party include equipment installation, software installation, calibration, and testing. Functional testing will be performed as part of the acceptance testing process for a system during the installation phase. Functional testing is limited to determining if the system is improperly designed, erroneously fabricated, or broken. Functional testing cannot reveal a selectively triggered hidden feature designed to subvert a measurement.

Operations

Once a facility becomes operational, access may be limited for the monitoring party. Some systems may only be used intermittently; in this case, periodic re-authentication before each use may be required. For example, the monitor must be assured that any software controlling the system has not been swapped between monitoring visits. Other systems may be in continuous use and re-authentication would by necessity be accomplished by means that do not hinder operations. Whether systems operate in monitor-attended or unattended mode will also impact what authentication measures are required. For any complex system, some amount of maintenance, upgrade and repair is expected. Re-authentication may be required following such events. Procedures will be required to assure that equipment (e.g., systems, spares, and sources) left in a stored condition between monitoring party onsite visits, has remained in a protected state. If the equipment has not remained in a protected state, some level of re-authentication will be required.

Approaches to Authentication

Some authentication activities will be common across the life cycle elements discussed above, while others will be unique to one aspect of the life cycle. The outcome of authentication is a level of confidence that accurate and reliable information is provided to the monitoring party, and that irregularities are detected. The monitoring party requires the ability to authenticate the correct operation of a system under a variety of conditions spanning a range of operational and off-normal scenarios. Authentication utilizes a set of tools and approaches, explained below, to provide evidence that a system performs its required tasks.

Functional Testing Using Trusted Unclassified Calibration Sources

Radiation sources, including sources similar to the stored items, play an important role in verifying the correct functioning of an IB-protected system. The monitor will independently validate these unclassified radiation sources on a separate system where access to the raw data can occur. Artificial sources of data, such as a recorded pulse train from a similar system or a mathematical model of the system, can be a valuable cross-reference means of validating physical sources and of functionally testing a system over a broader range of source values. An additional feature of an artificial data source is that it may, in principle, be used to transfer a calibration point between identical measurement systems.

Evaluation of Data

The quality of the data provided by an automated-measurement system must be validated. Depending upon the complexity of the system, this may be a simple task or this could be a very time-consuming and difficult task. The monitor will gain considerable confidence in an information barrier protected system by confirming the correctness of the numeric measurement results. During open-mode testing, the level of confidence increases with the amount of monitor access to the data (e.g., ability to remove raw data on media, ability to examine raw data on the system, ability to view intermediate results, and ability to view numeric results and error estimates). Private measurements with a duplicate system where the monitor can gain complete access to data from sources provide the most confidence in data quality. The validation of the data displayed, stored, or removed is possibly semi-independent of the authentication of the software and hardware that has been used, since it may also depend on the data source (e.g., radiation source or video picture). Data must be protected from tampering throughout its life cycle.

Evaluation of Documentation

Examination of hardware, software, operations, and maintenance documentation, and a comparison to the as-built system can be an important authentication tool. Examination of documentation can also help define sensitive design points for targeted authentication efforts.

Evaluation of Software

Software exists at several levels in systems (e.g., firmware, embedded software, operating systems, acquisition software, and analysis software). A detailed examination of all software, including source code, is central to authentication. A necessary component of the software evaluation is rebuilding a duplicate executable code from the provided source codes using the same compilers, build instructions, and associated software tools originally used to produce the executable code. In addition, all the software and firmware installed in the system must be shown identical to the examined and rebuilt code. Without proven equivalency of source code and installed executable code, detailed examination does not create assurance. A means for determining changes in the agreed upon software should be incorporated in the design and examination procedures. All software must be available in machine-readable source code form, and be fully documented. An alternate means of precluding tampering with commercial software that has a significant mass market might be independently obtaining a duplicate copy through an anonymous buy and comparing it to resident code.

Evaluation of Hardware

A variety of hardware makes up a system (e.g. detectors, computers, power supplies, and data acquisition boards). An examination of these components is central to authentication. The ability to photograph components down to board level during onsite monitoring visits provides assurance that the system remains unmodified. Comparisons of these photographs to those in the documentation and those of the duplicate system build assurance. Visual examination and comparison of the hardware onsite is valuable, but not as effective as photography. Private examination of hardware in the duplicate system is a very powerful confidence builder. Signals can be traced and measurements made on the duplicate system that are not possible during a brief period of joint examination before use. However, authentication is facilitated by the ability to make some electrical measurements during joint examination.

Random Selection of Hardware and Software

Random selection of hardware and software components or complete systems is a powerful authentication tool. Any party attempting to subvert any particular module must do so with the knowledge that the monitor will potentially be carefully examining a randomly selected module during private inspection at a monitor's facility. Random selection consumes spare modules and requires a sufficient initial procurement. Random selection will be one of the tools used during onsite authentication efforts. Several random-selection schemes are possible. A large number of duplicate components or systems can be procured or built. The monitoring party can then select from these components or systems for use during equipment assembly or operation. At the same time the monitoring party can also select specific components or systems to be shipped offsite for further private examination. Any remaining components or systems would be placed in secure storage for use in future random selection schemes. At installation, a random selection scheme could select a complete system to be installed in the facility and a duplicate complete system for private examination. During subsequent monitoring visits, the monitor could select a module for replacement under a random selection scheme where the monitor selects one module from storage as the replacement and another for private examination. A variation would allow the monitor to privately examine the replaced module when appropriate. Random selection can be used on less expensive individual software-bearing components before each use to confirm the controlling software in the system is unchanged. If a system repair is required, a replacement could be randomly selected by the monitor from the spares pool, and another for private examination.

Usage of Tamper Indicating Devices

Tags, seals, and other tamper-indicating devices (TIDs) are important verifications of the physical integrity of systems. TIDs provide some assurance of continuity-of-knowledge of a system and its components, which means traceability through time of the secure state of the system. TIDs are of great importance for equipment that operates in an unattended mode, i.e., when the monitoring party is not present. Unique TIDs can be a useful means of identifying components subject to a random selection scheme and a means of ensuring that modules or software-bearing components have not been swapped out.

Use of Surveillance

To increase the level of confidence that systems are not modified or altered by the host party, surveillance systems are routinely used to augment the protection that TIDs provide. Defeating an enclosure sealed with a TID that is viewed by a video surveillance system, for example, requires the generation and simultaneous application of two separate tampering strategies.

Use of Procedures

Documented procedures must be provided for all aspects of authentication and for any other onsite activities that affect the reliability of a system to provide accurate information. Formal procedures, for example, clarify the respective roles of the host and monitor during random selection.

Authentication-Assurance Levels

One of the important topics of discussion for a transparency regime is how much authentication activity is sufficient to provide the appropriate amount of confidence for the monitoring party. This need to determine the appropriate level of authentication activity has led to the definition of the AALs to provide a means to measure the degree of confidence gained from a collection of activities.

The information-technology community has defined a standard called the Common Criteria,[10] which defines a set of evaluation-assurance levels (EALs), a set of criteria for evaluating information-technology security. The EAL concept can be extended to define levels of authentication, and the associated procedures to reach these levels, with regard to a target of evaluation (TOE), which in this case is a radiation measurement system. Evaluation has been the traditional means of gaining assurance, and is the basis of the Common Criteria approach. Evaluation techniques can include, but are not limited to:

- Analysis and checking of processes and procedures
- Checking that processes and procedures are being applied
- Analysis of the correspondence between toe design representations
- Analysis of the toe design representation against the requirements

- Verification of proofs
- Analysis of guidance documents
- Analysis of functional tests developed and the results provided
- Independent functional testing
- Analysis for vulnerabilities (including flaw hypothesis)
- Penetration testing

The EALs provide an increasing scale that balances the level of assurance obtained with the cost and feasibility of acquiring that degree of assurance. There are seven hierarchically ordered EALs:

- EAL1—functionally tested
- EAL2—structurally tested
- EAL3—methodically tested and checked
- EAL4—methodically designed, tested, and reviewed
- EAL5—semi-formally designed and tested
- EAL6 – semi-formally verified design and tested
- EAL7—formally verified design and tested

EAL1 is the entry level, summarized as a simple performance test. Up to EAL4, increasing rigor and detail are introduced, but without introducing significantly specialized security-engineering techniques. EAL1-EAL4 can generally be retrofitted to pre-existing products and systems.

PNNL has developed a definition of AALs based upon the EAL concept.[11, 12] The definition of AALs will allow for quantifying the authentication level reached for a given system and allow decisions to be made about tradeoffs of authentication procedures and the desired level of authentication. The IAEA has also prepared an evaluation standard based upon the Common Criteria, and has defined the analogous vulnerability-assessment levels (VALs).[13]

The AALs as defined range in value from 0-4, with 4 being the level that provides the most confidence that a system meets its security objectives.

To obtain a high level of authentication assurance, the authenticating authority must identify all required assurance components before the development of a system to be authenticated and provide them to the developer to assist in designing the necessary authentication features into the system. If developers are to produce systems that are expected to be authenticated at AAL4, significant improvements in automated system development practice will be required. System development life cycle and quality standards similar to Integrated for Systems Engineering/Software Engineering/Integrated Product and Process Development, ISO12207, and ISO15288 should be adopted or developed at the national level.

The AALs provide an increasing scale that balances the level of assurance obtained with the cost and feasibility of acquiring that degree of assurance. They are ordered hierarchically inasmuch as each higher AAL represents more assurance than all lower AALs. The increase in assurance from level to level is accomplished by increasing the rigor, scope, and depth of assurance components, and from the addition of new requirements.

The five defined AALs and their correspondence to the EALs are as follows.

AAL0 (unauthenticated)	~EAL1 & EAL2 functionally and structurally tested
AAL1 (minimally authenticated)	~EAL 3 methodically tested and checked
AAL2 (limited authentication)	~EAL 4 methodically designed, tested and reviewed
AAL3 (critical authentication)	~EAL 5 semi-formally designed and tested
AAL4 (optimal authentication)	~EAL 6 verified design and tested

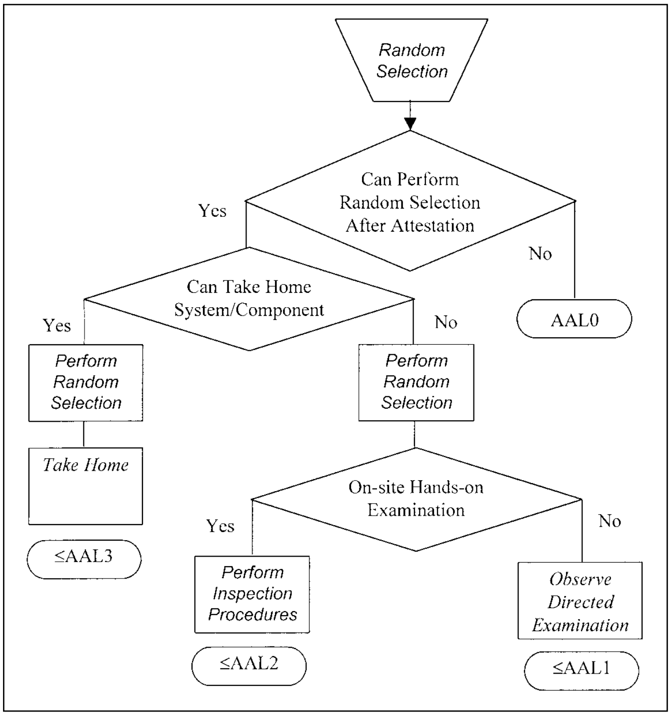
No AAL equivalent has been defined for EAL7 because, we believe, this level of rigor in formal design is not obtainable in a nonproliferation arena. Higher AAL values could be defined if such scenarios became possible.

For example, consider what AAL2 means. AAL2 (limited authentication) is applicable in those circumstances where developers or users require a moderate level of independently assured security and are prepared to incur additional security-specific engineering costs. AAL2 requires the cooperation of the developer in terms of the delivery of design information and test results. AAL2 requires additional components from each of the defined Security Assurance Requirements except guidance documents. Authentication analysis is supported by the low-level design of the modules of the TOA, covert channel analysis and a subset of implementation of the TOA security functions. Development controls are supported by a lifecycle model, identification of tools, and partially automated configuration management.

The AALs give a standard against which a specific authentication regimen can be measured and provide a basis for the comparison of activities to help determine the appropriate level of authentication required for a monitoring system in a specific regime. PNNL is applying this AAL-ranking approach to authentication efforts for transparency. One manner in which this can be done is to design a fault tree that reveals the possible AAL values that can be obtained from various decisions made about authentication activities. Figure 1 shows such a possible fault tree for authentication decisions made related to a random selection process. As decisions are made about what actions monitors can take, the tree leads to a conclusion about the maximum assurance level that can be reached through that set of procedures. A combination of such trees can be used to lead to an overall assurance level obtained from a set of defined procedures.

This example shows that random selection must be performed after attestation, which is the final host information security evaluation. After this point, there would be no private access by either party to the monitoring equipment, only joint access. Lacking this right to random selection after attestation would lead to AAL0 for this process. The ability for the monitor to take equipment for detailed examination leads to a higher AAL. Lacking this, hands-on access to the randomly selected equipment onsite provides higher assurance than only directing some host activity.

Figure 1. A possible decision tree for random selection. The tree is applied to a specific scenario, such as the random selection of a complete system at a site acceptance test, or the random selection of components during a normal monitoring visits. It is assumed that random selection will be performed.

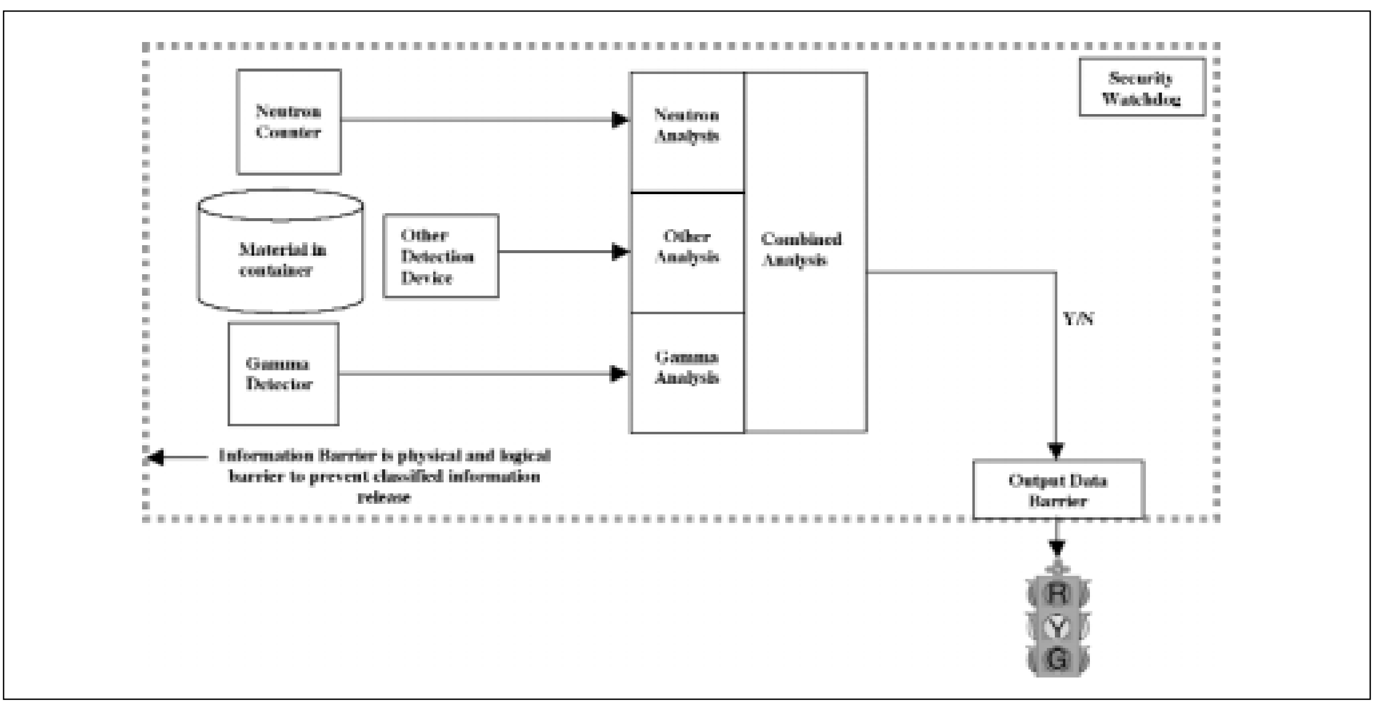


Authentication of Example Radiation Measurement Equipment

Figure 2 shows a generic radiation measurement layout as an example of the type of attribute-measurement system being considered for use to confirm compliance with nonproliferation agreements. This generic system consists of a high-purity germanium detector (HPGe) for gamma-ray measurements plus a neutron-detector system. The HPGe could potentially determine such attributes as the presence of plutonium or highly enriched uranium, the isotopic ratio of ^{240}Pu to ^{239}Pu or uranium enrichment, and the presence of plutonium metal (absence of oxide or other compounds). The neutron-detector system may range in complexity from a single neutron detector, a neutron coincidence counter, or a neutron-multiplicity counter (NMC). An NMC consists of dozens of ^{3}He detectors in a large moderating enclosure capable of measuring several parameters about the observed item when combined with the HPGe results.[14] These parameters could include the mass of plutonium, neutron production from impurities and the matrix material, and the neutron multiplication.

An item to be measured will be enclosed in a container that is placed near the detectors. The data are collected with a simple data-acquisition system that in this example includes an IB. The IB is a physical and logical barrier that protects the host's classified information from disclosure to the monitor. The IB includes procedures as well as hardware and software. The IB is also designed to prevent the input of an external signal into the measurement system, reducing the likelihood that a hidden switch

Figure 2. A generic schematic of a radiation-measurement system for attribute determination in an arms-control application. The information barrier includes both procedures and technology to prevent the release of host-party sensitive information.



may be successfully used to subvert the measurement system. The presence of the IB means that monitors will not be able to observe the actual data from the detector system when it is measuring a sensitive item. Instead, only pass or fail lights will indicate that the system has passed or failed the observed item with respect to the negotiated attributes for the material. There may also be error indicators. The IB would include a security watchdog to shut down the system and purge all data if a problem arises such as opening of the system when a sensitive item is present. The presence of the IB, and the resulting lack of detailed information about the data collected, increases the requirement for system authentication, and adds substantially to the problems of building a robust radiation measurement system.

PNNL has established an authentication laboratory for testing radiation-measurement systems with large quantities of plutonium oxide in a dedicated laboratory at the plutonium finishing plant located at the Hanford site in Washington State. This facility is designed for measurements required to clarify physics issues related to attributes,[15] and testing analysis and measurement equipment such as that which may be used in bilateral monitoring situations. Such equipment testing is required for developing the methods and procedures that will be used for onsite authentication of host-developed instruments, should that be negotiated. In addition, if equipment is brought back to the United States following random selection at a host facility, the authentication laboratory will be available for detailed examination for authentication of any host-supplied equipment.

The initial authentication of a monitoring system would take place during installation and acceptance at a facility. Assemblies would be sealed with TIDs. Photographic records could be produced. Random selection of components and/or systems could also be made at this time. Some items randomly selected could be shipped back to the United States for detailed examination. Functional testing with radiation sources and electronic signals could be performed to exercise the system attributes. Once a system was authenticated, some means would be used to provide confidence regarding the security of the system between U.S. monitor visits. When a U.S. monitor arrives during a scheduled visit of the facility, the system would possibly undergo some routine authentication activities to assure that the system was still operating reliably.

Summary

Authentication is a necessary aspect of the implementation of systems for the assurance of compliance with nonproliferation and arms-control agreements. It is a necessary component of a regime in which measurements must be made on classified or sensitive items and materials. A consistent basis for this authentication activity has been developed by the United States technical community and applied to bilateral activity. Efforts to apply authentication to radiation-measurement systems are now being implemented.

Acknowledgements

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First New Nuclear Engineering Programs in 20 Years Open at South Carolina Universities

The first new nuclear engineering university programs in the United States in more than twenty years were formed at two South Carolina schools in fall 2002. These nuclear reactor-oriented programs, were approved by the South Carolina Commission on Higher Education last fall.

South Carolina State University (SCSU) in Orangeburg, South Carolina, is now offering an undergraduate program, while the University of South Carolina (USC) in Columbia, South Carolina, has a graduate program in nuclear engineering.

Both programs respond to state and national needs for nuclear engineering graduates. South Carolina has seven operating nuclear-power reactors, a commercial fuel fabrication facility, a low-level waste disposal facility, and the U.S. Energy Department's Savannah River Site.

Since 2000, the U.S. Department of Energy has provided more than $600,000 to South Carolina State University, assisting the university's transition from an engineering technology-based program to a nuclear engineering program. DOE's support has included funds for two junior faculty and scholarships for twelve to fourteen students each year.

SCSU's new undergraduate nuclear engineering program will be offered in partnership with the University of Wisconsin. Students accepted into the program will complete their degree requirements at both SCSU and the University of Wisconsin. While the majority of courses can be completed at the South Carolina campus, students will need to round out their education with reactor physics courses and other courses that take advantage of the availability of a research reactor at Wisconsin's Madison campus. Eleven students are currently enrolled in the program at SCSU and the university hopes to enroll about thirty students for the upcoming school year.

The University of South Carolina's nuclear engineering graduate program will offer a master of science, master of engineering, and doctor of philosophy degrees, with research expected to be developed in the general areas of reactor design, reactor safety, material applications, and other applications. Fifteen students are currently enrolled in introductory nuclear engineering graduate courses at USC and the university anticipates about thirty students enrolled in graduate studies for the upcoming year.

Sandia and Cray Inc. Form Partnership for Supercomputer Supporting Stockpile Stewardship Program

The U.S. Department of Energy's National Nuclear Security Administration (NNSA), Sandia National Laboratories, and Cray Inc. have signed a contract for a multi-year project, valued at approximately $90 million, to develop and deliver a massively parallel processing supercomputer for the Advanced Simulation and Computing program (ASCI).

Named Red Storm, the supercomputer represents another step forward toward meeting the science-based simulation requirements of the U.S. DOE's Stockpile Stewardship Program, to assess and certify the safety, security, and reliability of the nation's nuclear deterrent.

With a theoretical peak performance of 40 trillion operations per second, Red Storm is expected to be operational in fiscal year 2004. NNSA's ASCI program partners with U.S. computer manufacturers to accelerate the development of the larger, faster computer systems and software needed for the demanding stewardship simulations.

NNSA Implements Reorganization

The Department of Energy's National Nuclear Security Administration (NNSA) in December 2002 moved to a new organizational structure that eliminates a layer of management and sets the agency on a course to achieve a 20 percent reduction in federal personnel by the end of fiscal year 2004.

While the entire organizational structure is changing, the NNSA field organization will see the most dramatic change. Under the previous structure, the site offices that oversaw NNSA's contractor operations reported to headquarters through three operations offices in Oakland, California, Las Vegas, Nevada, and Albuquerque, New Mexico. Beginning in December, all site offices began to report directly to the NNSA administrator through the principal deputy. The operations office system will be eliminated.

Overall, about 20 percent will be trimmed from NNSA's federal workforce at headquarters and in the field by the end of FY '04, with headquarters taking a 30 percent cut. The reduction will be accomplished through managed attrition. Security forces and the Navy Nuclear Propulsion program will not be affected by the staff reductions.

DOE/NNSA Cites Los Alamos National Laboratory for Price Anderson Violations

The University of California, the contractor for Los Alamos National Laboratory, has been issued a Preliminary Notice of Violation by the U.S. Department of Energy's (DOE) National Nuclear Security Administration (NNSA) for violations of nuclear safety rules and procedures involving the storage of nuclear waste materials.

The violations did not result in actual harm to workers or the public. DOE/NNSA took this action because the violations could have led to the continued storage of transuranic (TRU) waste without analyzing all of the hazards, development of required safety controls to protect workers and the public, and proper authorization by the DOE/NNSA. TRU waste contains radioactive material in a form and quantity that, if not properly controlled, may cause harm to workers or the public.

The DOE/NNSA also took this action because the TRU waste storage conditions were in violation of nuclear safety rules for a period of several years and the contractor failed to promptly identify and correct the conditions. The DOE/

NNSA considered this a significant failure of the laboratory's self-assessment and corrective action management processes.

Additional details on this and other enforcement actions are available on the Internet at http://www.eh.doe.gov/enforce.

U.S. to Join Negotiations on Major International Fusion Project

The United States will join the negotiations for the construction and operation of ITER, a major international magnetic fusion research project, U.S. Secretary of Energy Spencer Abraham announced in January. The ITER project's mission is to demonstrate the scientific and technological feasibility of fusion energy.

ITER will provide 500 megawatts of fusion power for 500 seconds or longer during each individual fusion experiment. ITER will demonstrate essential fusion energy technologies in a system that integrates physics and technology and will test key elements required to use fusion as a practical energy source. ITER will be the first fusion device to produce a burning plasma and to operate at a high power level for such long duration experiments. The fusion power produced in the ITER plasma will be ten times greater than the external power added to the plasma.

Canada, the European Union, Japan, and the Russian Federation are the current members of the collaboration who have been negotiating ITER construction and operation since last year. China has recently joined the negotiations as well. Candidate sites in Canada, the European Union, and Japan have been offered, one of which will be selected during the negotiation and governmental decision-making process.

The U.S. proposes to provide a number of hardware components for ITER construction, to be involved in the project construction management and to participate in the ITER scientific research and technology development. The nature and details of the U.S. participation and contributions would be determined during the negotiations. DOE's Office of Science, which has extensive experience in large, international programs, will lead U.S. negotiations on ITER.

The construction cost for ITER, including buildings, hardware, installation and personnel, is estimated to be about $5 billion in constant 2002 dollars. However, the parties will provide most of the components as "in kind" contributions. The U.S. share of the construction cost is expected to be about 10 percent of the total. ITER could begin construction in 2006 and be operational in 2014. Fusion research would last for up to twenty years.

Centers of Excellence to Get $110 million

The National Nuclear Security Administration has renewed contracts worth $110 million with five universities for its Academic Strategic Alliance Program's Centers of Excellence. The five recipients and their centers have signed contracts for $22 million dollars each over five years, exercising the renewal options of previous five-year contracts.

The five university-based Centers of Excellence were chosen competitively in 1997 from among almost fifty proposals to create complex computer-based simulations in support of NNSA's Stockpile Stewardship Program. The centers are the California Institute of Technology, Center for Simulating the Dynamic Response of Materials; Stanford University, Center for Integrated Turbulence Simulations; University of Chicago, Center for Astrophysical Thermonuclear Flashes; University of Illinois Urbana-Champaign, Center for Simulation of Advanced Rockets; and the University of Utah, Center for the Simulation of Accidental Fires and Explosions.

The renewal proposals were subjected to an intense and extensive peer review by subject matter experts. The decision to extend the original five-year program for a final five years was based on the accomplishments and quality of the ongoing work as determined by peer review and its value to national security in the Stockpile Stewardship Program.

NNSA is funding the contracts to:

- Solve science and engineering problems of national importance through the use of large-scale, multidisciplinary modeling and simulation
- Enhance overall supercomputer effort by engaging academic experts in computer science, computational mathematics, and simulations of science and engineering
- Leverage relevant research in the academic community, including basic science, high-performance computing systems, and computational environments
- Strengthen education and research in areas critical to national security
- Strengthen ties among NNSA's weapons laboratories and participating U.S. universities.

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