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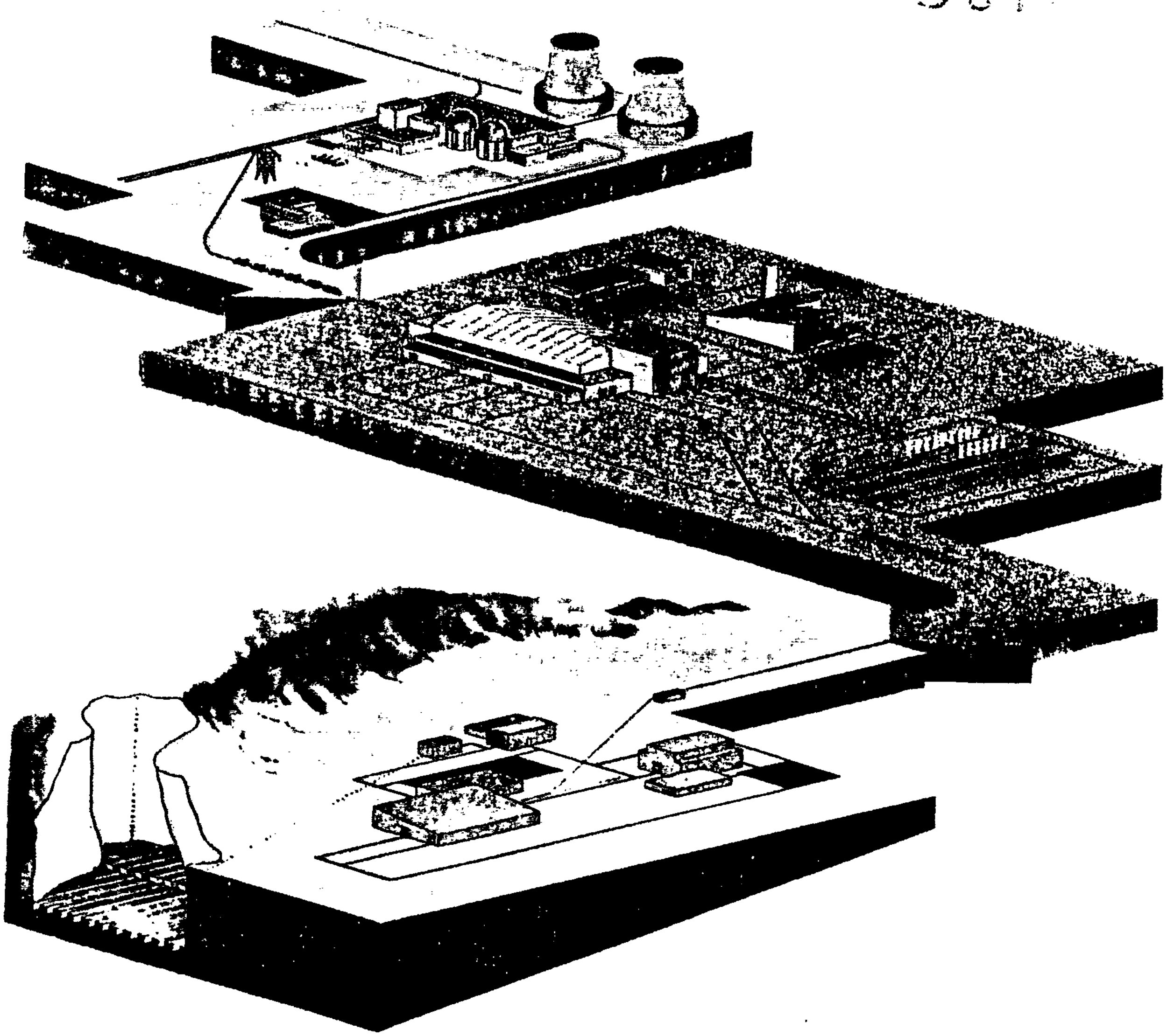
National Security Program Office

WASTE MANAGEMENT SAFEGUARDS PROJECT

HISTORY OF AND RECOMMENDATIONS FOR DEVELOPMENT ACTIVITIES IN SUPPORT OF SAFEGUARDS OF FINAL DISPOSAL OF SPENT FUEL

Bruce W. Moran



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Bruce W. Moran

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EXECUTIVE SUMMARY

Coordinated safeguards assessment and development activities in support of the U.S. Civilian Radioactive Waste Management System (CRWMS) and international safeguards objectives were initiated in Fiscal Year (FY) 1987. Initial technical support activities were performed at the direction of the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM); however, as the priority of support activities changed, direction for the support tasks was transferred to the U.S. Department of State (State), the DOE Office of Arms Control and Nonproliferation (DOE/IS-40), and the U.S. Nuclear Regulatory Commission (NRC). The direction for technical support activities was established at the International Atomic Energy Agency's (IAEA's) advisory group meeting and subsequent consultants' meetings on safeguards related to the final disposal of nuclear material contained in waste and spent fuel. Task directions for the development of international safeguards in support of the final disposal of spent fuel are currently being provided by DOE/IS-40. A summary of safeguards activities performed by the Waste Management Safeguards Project is provided in Table 1.

Although the general impression exists that spent fuel conditioning and repository facilities need low priority for the development of safeguards approaches, conditioning and repository facility construction are now occurring (Table 2). Away-from-reactor dry storage facilities are operating in the United States, Germany, and Canada. The German Pilot Conditioning Facility is under construction and scheduled to begin operations in 1996. Excavation of repository characterization shafts and tunnels of the German and U.S. repository projects is being conducted. The characterization shafts and tunnels (including underground laboratory facilities) will become part of the final repositories if the Gorleben and Yucca Mountain sites are determined to be acceptable.

Systems for design information verification for spent fuel consolidation and conditioning operations are needed immediately. Safeguards approaches for maintaining continuity of knowledge of spent fuel processed at the conditioning facility and for verification of the final disposal package will be needed within three years. Systems for design information verification of the repository facilities will be needed by the end of the decade.

In the reports from the IAEA consultant's meetings, IAEA SP-1 task outlines, and DOE International Safeguards Program plans, tasks have been identified that need to be performed if effective safeguards are to be implemented at the conditioning and repository facilities and if safeguards are to be implemented with minimum impact on CRWMS. These tasks are summarized and correlated in Table 3. Tasks supporting the application of international safeguards in the United States and at the CRWMS facilities should be directed by DOE. Technical assistance in the development of international safeguards approaches and of safeguards technology will be provided by the United States to the IAEA. Tasks requiring the integration of activities being performed by multiple States should be directed by IAEA. All task activities will require maintenance of a dialogue between DOE and IAEA.

Table 1. Waste management safeguards project milestones

		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
DOE	OCRWM			▿ 1	▿ 2							
	IS-40						▿ 4	▿ 7	▿ 8,9	▿ 12	▿ 13,14	▿ 16,17
State Department					▿ 2	▿ 3	▿ 4,5	▿ 7	▿ 10			
NRC/NMSS											▿ 15	
IAEA					▿ 2	▿ 3	▿ 6	▿ 7	▿ 11			

1. Waste Management Safeguards Project initiated.
2. IAEA Advisory Group Meeting on Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel.
3. IAEA Consultants' Meetings on Development of Technical Criteria for Termination of Safeguards for Material Categorized as Measured Discards.
4. United States contribution to IAEA on U.S. program and safeguards relevant to final disposal of spent fuel.
5. Effectiveness assessment of technical criteria for safeguards termination.
6. IAEA SP1 Task Outline Safeguards for Spent Fuel in Conditioning and Repository Facilities (no action).
7. IAEA Consultants' Meeting on Safeguards for Final Disposal of Spent Fuel in Geological Repositories.
8. DOE Waste Management Safeguards Review Group (WMSRG) formed.
9. International Safeguards Program Plan defined.
10. U.S.-Japan Technical Bilaterals on Safeguards Termination.
11. IAEA SP1 Task Outline issued for Safeguards for Final Disposal of Spent Fuel (no action).
12. Assessment of safeguards concerns and approaches for spent fuel acceptance within CRWMS.
13. Assessment of safeguards concerns and approaches for spent fuel transportation within CRWMS.
14. U.S.-German cooperative study program plan for evaluation of safeguards technology for spent fuel disposal.
15. Assessment of Technical Criteria for Termination of Safeguards on Nuclear Material Contained in High-Level Waste.
16. Assessment of safeguards concerns and approaches for spent fuel interim storage facilities within CRWMS.
17. U.S.-German cooperative studies of safeguards technology for spent fuel disposal.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
US			▼ 1				▼ 4																							
Dry Interim Storage Facility																														
US						▼ 2										▼ 10		▼ 12												
GER								▼ 5			▼ 6																			
CAN											▼ 7																			
Conditioning Facility																														
US																▼ 10		▼ 12												
GER												▼ 8				▼ 11														
SWE																		▼ 13								▼ 15				
Repository Facility																														
US													▼ 9																	▼ 18
GER						▼ 3																						▼ 16		
SWE																								▼ 14				▼ 17		

Table 2. Schedule for construction and operation of spent fuel storage, conditioning, and repository facilities

1. National Waste Policy Act passed; Office of Civilian Radioactive Waste Management established.
2. First U.S. interim dry storage facility (Surry) begins operation.
3. Underground exploration for German repository initiated.
4. National Waste Policy Amendments Act passed; Yucca Mountain designated for assessment for a geologic repository.
5. First German interim dry storage facility licensed.
6. German interim dry storage facility (Ahaus) begins operation.
7. First Canadian interim dry storage facility (Point Lepreau) begins operation.
8. Construction of German Pilot Conditioning Facility initiated.
9. Underground exploration for U.S. repository initiated.
10. Construction of Monitored Retrievable Storage Facility initiated.
11. German Pilot Conditioning Facility begins receiving spent fuel.
12. Monitored Retrievable Storage Facility begins receiving spent fuel.
13. Construction of Swedish small conditioning facility initiated.
14. Underground construction of Swedish small repository initiated.
15. Swedish small conditioning facility begins receiving spent fuel.
16. German repository begins to emplace spent fuel.
17. Swedish small repository begins to emplace spent fuel.
18. U.S. repository begins to emplace spent fuel.

Table 3. Relationship of DOE and IAEA tasks		
DOE	**DOE/IAEA**	**IAEA**
	Interim Storage	
1. Safeguards approach for spent fuel acceptance at CRWMS facilities (completed FY 1993).		
2.a. Safeguards approach for spent fuel transportation between CRWMS facilities (active).		2.b. Development and evaluation of dual, independent C/S systems for transportation and storage (active).
3.a. Safeguards approach for Monitored Retrievable Storage facility.		3.b. Develop DIQ and guidance for storage facilities; develop design information verification procedures (active).
4.a. Develop safeguards systems and equipment for monitoring spent fuel during storage.		4.b. Develop safeguards systems and equipment for monitoring spent fuel during storage.
	5. Acceptability of MRS safeguards approach to IAEA.	
	Spent Fuel Conditioning	
6.a. Safeguards approach for CRWMS spent fuel conditioning facility.		6.b. Develop safeguards approach for conditioning facilities.
7.a. Prepare DIQ for CRWMS conditioning facility.		7.b. Develop DIQ and guidance for conditioning facilities; develop design information verification procedures.
8.a. Develop safeguards systems and equipment for monitoring spent fuel conditioning.		8.b. Develop safeguards systems and equipment for monitoring spent fuel at conditioning facility.
	9. Acceptability of CRWMS conditioning facility safeguards approach to IAEA.	
	Geologic Repository	
10.a. Safeguards approach for CRWMS repository facility.		10.b. Develop safeguards approach for repository facilities.
11.a. Prepare DIQ for CRWMS repository facility.		11.b. Develop DIQ and guidance for repository facilities; develop design information verification activities.
12.a. Develop safeguards systems and equipment for monitoring spent fuel during emplacement.		12.b. Develop safeguards systems and equipment for monitoring spent fuel during emplacement.
		13. Develop safeguards systems and equipment for monitoring spent fuel after repository closure.
	14. Acceptability of CRWMS repository safeguards approach to IAEA.	

1. PROJECT HISTORY

The Waste Management Safeguards Project was initiated in Fiscal Year (FY) 1987 by the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM). Martin Marietta Energy Systems, Inc., (Energy Systems) was tasked by OCRWM to "identify, evaluate, and propose solutions to mitigate impacts on OCRWM conceptual designs resulting from integrating domestic and international safeguards system requirements." Energy Systems was also tasked through OCRWM to support the U.S. government in preparation for and through participation at the International Atomic Energy Agency (IAEA) "Advisory Group Meeting on Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel" held in September 1988. The advisory group meeting recommended that consultants' meetings should be held to separately evaluate safeguards for spent fuel disposal and safeguards termination criteria for nuclear materials designated as measured discards. With respect to spent fuel, the advisory group meeting made the following recommendations:[1]

1. Four stages in the flow of spent fuel from reactors to final disposal exist: (a) reactors and away-from-reactor storage, (b) spent fuel conditioning for disposal, (c) spent fuel positioning in the final repository, and (d) closure of the repository.
2. Spent fuel does not qualify as being practicably irrecoverable at any point before or after placement in a geological formation commonly described as a permanent repository. IAEA should not terminate safeguards on spent fuel.
3. For the stage involving fuel in reactors, away-from-reactor storage, and up to the start of conditioning of spent fuel, spent fuel can be safeguarded using adaptations of existing safeguards measures.
4. The process starting with conditioning of spent fuel and ending with final placement in a permanent repository raises new safeguards problems associated with (a) dismantling and consolidating of the original assemblies, (b) placing the spent fuel in the disposal container, and (c) emplacing the disposal container in the repository. This process would require increased reliance on containment and surveillance (C/S), including other monitoring systems, to assure continuity of knowledge of the flow and inventory of the nuclear material. If the safeguards system fails to provide the assurance required, reestablishing continuity of knowledge by remeasurement may not be possible. Research and development to provide the necessary C/S and monitoring systems should be started with high priority following the necessary system studies and be conducted in consultation with IAEA.
5. Spent fuel can be considered to be virtually inaccessible for physical verification (a) when the particular area, or drift, containing it is backfilled or (b) when all repository operations are completed and the repository is closed.
6. Closed drifts in operating repositories will create unique problems that must be solved by research and development.
7. Technical and legal problems must be resolved before implementing safeguards for a closed repository. Several decades will elapse before a repository is closed; thus, problems associated with closed repositories should be addressed, but with a low priority.

After the advisory group meeting, the waste management safeguards effort focused on development of safeguards termination criteria. This effort was directed and sponsored by the U.S. Department of State (State Department). Energy Systems was tasked to investigate recovery of uranium and plutonium discard materials generated from uranium and plutonium processing facilities, including reprocessing facilities.[2] These tasks were performed in preparation for the IAEA "Consultants' Meetings for Development of Technical Criteria for Termination of Safeguards for Material Categorized as Measured Discards" held in June and October 1989. Follow-up tasking was established to evaluate the effectiveness of the criteria recommended by the consultants' meeting and to develop safeguards termination criteria for conditioned waste.[3,4] Continuation of these tasks to cover other related issues of concern is being directed and sponsored by the U.S. Nuclear Regulatory Commission (NRC).

In FY 1990, the waste management safeguards effort was refocused onto spent fuel in preparation for the IAEA "Consultants' Meeting on Safeguards for Final Disposal of Spent Fuel in Geological Repositories" held in May 1991.[5] This effort was directed and sponsored by the State Department and by the DOE Office of Arms Control and Nonproliferation (IS-40). Energy Systems was tasked to develop and compile information on the U.S. Civilian Radioactive Waste Management System (CRWMS); the design of spent fuel consolidation, conditioning, and geologic repository facilities; and safeguards issues relevant to these facilities.[6] This information was provided by the U.S. government to the IAEA to facilitate their preparations for the consultants' meeting. Energy Systems, Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL), in support of the U.S. government representatives, participated in the consultants' meeting.

During FY 1992, DOE/IS-40, with support from Energy Systems, developed the program plan for "International Safeguards for the Civilian Radioactive Waste Management System."[7] This program plan established the Waste Management Safeguards Review Group (WMSRG) composed of members from DOE/IS-40, DOE/OCRWM, NRC, and Energy Systems. As tasking requires, LANL, SNL, Brookhaven National Laboratory, and the CRWMS managing and operating contractor (TRW Environmental Safety Systems) will be added to WMSRG. During FY 1993, WMSRG oversaw the performance of tasks related to IAEA verification of spent fuel acceptance into CRWMS. During FY 1994, technical support tasks related to international safeguards concerns for spent fuel in transit within CRWMS will be addressed, including development of unattended methods for monitoring spent fuel in dry storage and cooperative assistance with Germany for the development of spent fuel safeguards technologies.

Technical assistance tasks identified by DOE, the IAEA consultants, and the IAEA staff as necessary to support development and application of IAEA safeguards at the CRWMS and international spent fuel management facilities are listed in Appendix A and discussed in the following sections. Current schedules for construction and operation of spent fuel management facilities (i.e., storage, conditioning, and repository) are previously listed in Table 2.

2. CONSULTANTS' MEETING ON FINAL DISPOSAL OF SPENT FUEL

2.1 U.S. Contribution to IAEA[6]

In preparation for the IAEA Consultants' Meeting on Final Disposal of Spent Fuel held in May 1991, IAEA requested that the Member States evaluate the international safeguards aspects of spent fuel conditioning and disposal in a geologic repository. In addition to information describing the U.S. CRWMS program and technologies for spent fuel conditioning and disposal, the United States contributed assessments of the safeguards issues for spent fuel consolidation and for geologic disposal. These assessments were based on CRWMS system designs at the time of the evaluation. Knowledge of proposed system designs in other nations were factored into the assessments. Since the evaluation was completed, system designs have evolved and some have undergone major changes. However, the generic safeguards concerns and approaches remain applicable to the systems. The safeguards assessment of spent fuel consolidation identified the seven potential diversion scenarios shown in Fig. 1.[8]

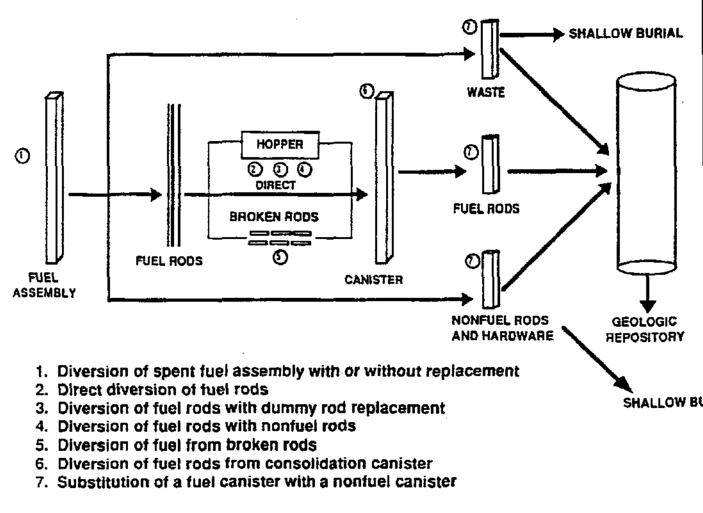

Fig. 1. General spent fuel conditioning facility diversion concerns.

Safeguards approaches were developed to address the safeguards concerns identified for these scenarios. The approaches were developed as a perimeter safeguards system, a pin-tracking and verification safeguards system, and a combined system. The perimeter system is operationally preferred because it would have minimal impacts on the consolidation operations. This system would verify the quantity of spent fuel input to and removed from the consolidation operation and would verify that no fuel left the consolidation process area except in the declared removals. Technologies for implementing this approach were proposed. The pin-tracking system would require process design verification, authentication of operator's process data, and verification of the spent fuel pins as they are removed from the assembly and transferred to the consolidation canister. Technologies for implementing this approach were also proposed.

The safeguards assessment of spent fuel disposal in a geologic repository identified three primary safeguards issues:[9] (1) verifying that declared spent fuel is received, (2) tracking the spent fuel through transfer and repackaging operations, and (3) verifying that spent fuel is not removed from the storage, process, and underground repository areas during active repository operations and after repository closure (Fig. 2). The five major repository operations evaluated were mining, cask receiving and storage, spent fuel repackaging, package emplacement, and repository backfilling and closure. Safeguards issues with the mining operations involved the speed of excavation; the effort required to excavate clandestine paths, workshops, or processing areas; and the difficulty to retrieve emplaced material. Verification of design information for and monitoring of the underground repository was identified as a concern because mining, emplacement, and backfilling may occur simultaneously.

Safeguards approaches were developed to address the safeguards concerns identified through these scenarios. The approaches were developed as perimeter safeguards systems, spent fuel verification safeguards systems, and combined systems. All systems required repository design verification. The perimeter systems are operationally preferred because they would have minimal impacts on the repository operations. These systems would verify (1) spent fuel input to and removed from the repackaging or conditioning facility, (2) spent fuel transferred to the underground repository, and (3) that no fuel left the repackaging and/or conditioning process area or underground repository except in the declared removals. Technology requirements for

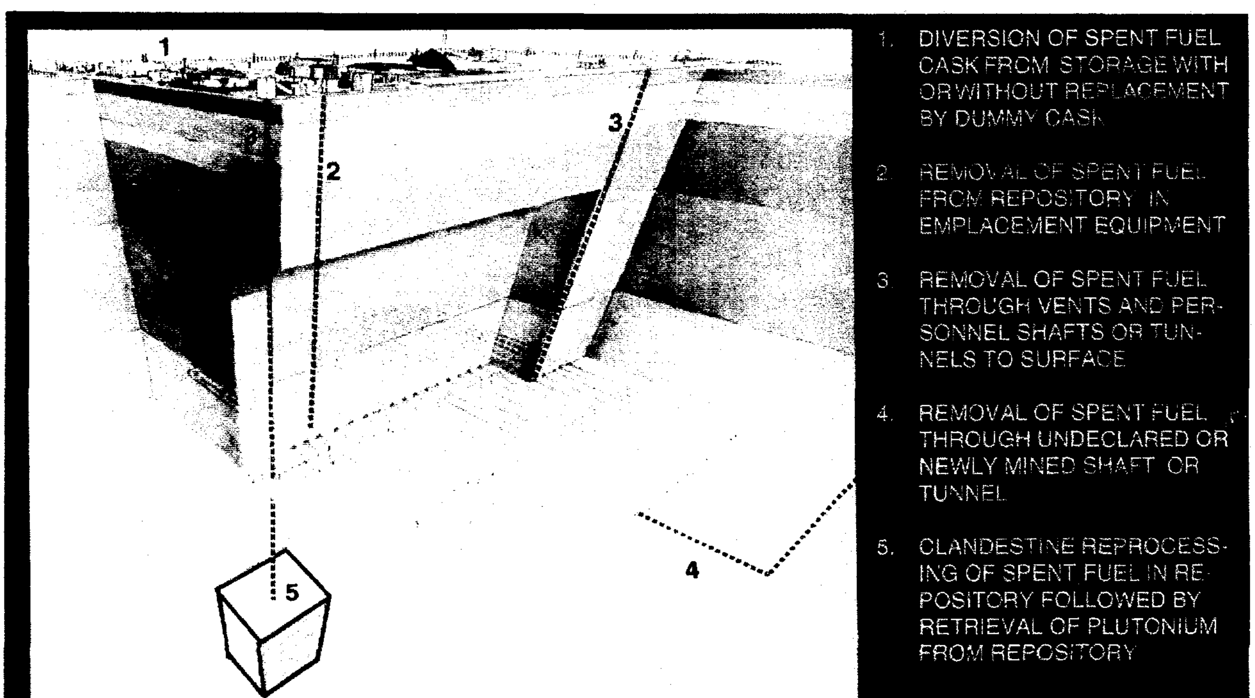

Fig. 2. General spent fuel geologic repository diversion concerns.

implementing these approaches were proposed. The spent fuel verification systems would require (1) authentication of the operator's repackaging and/or conditioning process data, (2) verification of the spent fuel as it is removed from the transport cask and transferred to the disposal cask or canister, (3) verification of the spent fuel's presence in the repository until backfilling occurs, and (4) verification of the integrity of backfilled drifts.

2.2 Consultants' Recommendations[5]

The IAEA "Consultants' Meeting on Safeguards for Final Disposal of Spent Fuel in Geological Repositories" is stated by the IAEA to be "... only a first attempt by IAEA to define an appropriate safeguards system for the final disposal of spent fuel ..." and to require "... a coordinated effort through joint support programme tasks ...." The consultants' report generalized the operations and design of nuclear power plant storage, away-from-reactor storage, conditioning facility, and final geological repository for the participating countries. Based on these generalized characteristics, the consultants' recommended the following safeguards concepts:

1. For the effective application of safeguards to spent fuel in conditioning and final repository facilities, an unbroken continuity of knowledge of the nuclear material content of the spent fuel (based on operator data and verified by IAEA) is required. The facilities should be thought of as item rebatching facilities, and item accounting would be a practical material accounting approach for these facilities. Rebatching would be performed on an item basis, thus allowing all material to be accounted for. Efforts should be made to minimize broken rods, loose pellets, and powder. Future facilities should be designed in a manner to facilitate item accounting.
2. IAEA should verify operator's declared values by maintaining continuity of knowledge of the nuclear material items. The nuclear material content of the spent fuel is calculated by the operator based on the nuclear material content of the fresh fuel and the irradiation history. Continuity of knowledge will depend on successful application by IAEA of a C/S system and maintenance of item integrity. When rebatching occurs, the safeguards measures should involve design verification in combination with monitoring of all material movements in to and out of the process area supplemented with, if necessary, by monitoring of nuclear material within the process area. The safeguards measures should confirm that the nuclear material in items going in to and out of the process area are accounted for without loss of continuity of knowledge.
3. Consolidation of spent fuel could take place at a reactor's spent fuel storage pool, at a separate facility, or at the conditioning facility. A separate consolidation facility should be safeguarded as an item facility in accordance with the previous items. Introduction of consolidation equipment to a reactor storage pool constitutes a change in facility design requiring that the portion of the pool in which the equipment is located be treated as a separate consolidation facility. The disassembly of fuel assemblies into pins with reassembly of the pins into a close pack configuration in a new package is considered an item rebatching operation.
4. Shipment of spent fuel to an away-from-reactor facility, a consolidation facility, a conditioning facility, or a geological repository will be based on a unique identifiable item and knowledge of the nuclear material content of the spent fuel based on shipper's declared values. Shipments would be covered by C/S measures. Nondestructive assay (NDA) for gross and partial defect tests could be performed on the spent fuel if C/S failed to preserve continuity of knowledge. Accuracy of these measurements may be degraded for consolidated fuel. Various attribute checks may be used to secure continuity of knowledge, but NDA for verification of nuclear material content in sealed casks and canisters would be precluded.

Safeguards for conditioning of spent fuel and for disposal in the geologic repository will use an integrated safeguards verification system (ISVS). An ISVS combines components of monitoring (e.g., radiation and weight among others) and C/S systems into complementary systems that take advantage of the strengths of each. A fundamental assumption of the safeguards approach is that nuclear material becomes "difficult to access" when placed in a disposal container. Thus, sufficient redundancy, diversity, and robustness must be designed into the safeguards system to assure maintenance of continuity of knowledge. This assurance can be provided through verification of container integrity and establishment of characteristics that uniquely identify the container and its contents (e.g., radiation signatures, weight, weld signatures, and heat output, among others). Current capabilities of NDA measurements cannot provide sufficient accuracy to establish a measured material balance. Current NDA procedures are capable of partial defect measurements of single assemblies but not of multiple assemblies. NDA systems should be a part of ISVS.

The safeguards approach for conditioning facilities should include the following features:

1. Received items should be verified by IAEA before shipment and continuity of knowledge preserved by C/S. If verification is not performed before shipment or if continuity of knowledge is not assured, the nuclear material content must be verified on receipt.
2. Traceability of items rebatched from received containers into shipping containers in the process cell is critical. Of crucial importance to the safeguards approach is identification and evaluation of items input to and removed from the rebatching process area. An ISVS should confirm declared process flows by surveillance of all potential diversion paths from the process area. Safeguards verifying inputs to and removals from the process area that are applied external to the process cell are preferred. If the effectiveness of this approach is not guaranteed, application of an ISVS within the process cell or authentication of outputs from operator's systems within the process cell may be required.
3. The nuclear material content of shipped items will be based on operator's data and on the continuity of knowledge maintained by the safeguards systems implemented at the facility. Reactor history and individual fuel assembly identifications will not be important because multiple assemblies will be repackaged into a new sealed container. Verification of nuclear material content should be performed at the exit from the process cell at the level required by IAEA for verification of materials being placed in difficult-to-access storage. This verification should occur as close as practical to the point of packaging of the spent fuel into the final disposal container.

The safeguards approach for geological repositories should include the following features:

1. Safeguards procedures should be based on item integrity, item accounting, and item transfer. Receipts at the repository facility will be verified for item identity and item integrity.
2. To maintain continuity of knowledge, disposal containers received and stored at the repository are safeguarded using an ISVS until transferred underground. An ISVS implemented at repository accesses will record the identity and status of casks and the direction of nuclear material flow.
3. All accesses to the geological repository's underground facility are safeguarded to monitor transfers of nuclear material. Within the underground facility, knowledge of the location of the nuclear material is not important; what is important is knowledge that the material was transferred underground and remains there.
4. Design information regarding the vault design will be verified and periodically reverified to update IAEA knowledge of the underground facility. The open areas of the underground facility will continually change as new emplacement areas are excavated and filled areas are backfilled. Unannounced inspections should be considered.
5. Items emplaced in the geologic repository are safeguarded as nuclear material rebatched into a new container, which is the geologic medium. During the postclosure phase of the repository, site inspections, visual observation of the ground surface, and geophysical techniques to determine the extent of backfill in cavities and to detect other excavations near the repository should be considered.

The following research and development efforts that would assist IAEA in developing effective safeguards for spent fuel disposal were recommended at the consultants' meeting:

1. Develop techniques for identification and assurance of integrity of final disposal containers.
2. Develop techniques for authentication of outputs from operator process and safeguards systems.
3. Establish design and information evaluation requirements for ISVSs and dual independent and redundant C/S systems, then develop and evaluate the systems.
4. Develop NDA fissile assay measurement techniques for fuel rods and spent fuel assemblies.
5. Investigate geophysical techniques to provide information on location and status of spent fuel disposal containers emplaced in a repository.
6. Investigate ISVS safeguards approaches for application to emplaced containers in the underground facility of the geologic repository as a contingency in the event the recommended surface-based approach is not perceived to be capable of achieving the desired level of assurance of nondiversion.
7. Establish a records management system to maintain information on the location, depth, and plan area for each repository and the contained nuclear material inventory for long time periods.
8. Reconsider the safeguards timeliness requirements in developing a safeguards approach for the postclosure phase to incorporate consideration of the long time required to access and retrieve nuclear material inventory from a closed repository.

2.3 Member State Support Tasks

IAEA has issued SP-1 proposed task outlines for multilateral Member State support for safeguards for the final disposal of spent fuel since 1989. Member State support tasks for spent fuel disposal safeguards have been undertaken by Germany in the areas of the application of the Probabilistic Assessment of Safeguards Effectiveness (PASE) system to spent fuel disposal to identify and rank potential vulnerabilities and to evaluate dual independent C/S systems applicable to spent fuel safeguards. The results of these task areas have yet to be reported.

The first general task statement was issued in 1990 in advance of the consultants' meeting. The most recent SP-1 on the subject, *Safeguards for Final Disposal of Spent Fuel* (92/PSS26) was issued December 11, 1992.[10] This SP-1 was initiated to meet in a timely manner the following objectives: (1) identifying safeguards requirements that must be used in the design of the spent fuel management facilities and (2) identifying research and development work required for the effective implementation of safeguards for the final disposal of spent fuel. Interest in supporting the SP-1 has been expressed by the United States, Canada, Germany, and Sweden. The United States has not yet responded to any of the SP-1s issued by IAEA.

To achieve the task objectives specified in SP-1 92/PSS26, IAEA identified the following tasks:

1. Establish design specifications for inventory verification systems for conditioning plants, active and passive operating repositories, and closed repositories through (a) identifying and evaluating diversion routes, (b) evaluating concealment methods, (c) identifying commonalities of diversion paths and detection elements, (d) identifying and evaluating effective safeguards approaches; and (e) identifying the optimum approach.
2. Identify safeguards approaches and technology for verification and reverification of conditioning plant and repository facility design information.
3. Investigate techniques for resource optimization to increase the effectiveness and efficiency of safeguards at spent fuel disposal facilities.
4. Investigate the potential for geophysical techniques to fulfill requirements for verification of the status of backfilled drifts as well as all underground excavations and investigate the use of NDA and C/S for safeguarding emplaced containers.
5. Investigate the use of safety-related design features and safety-related information for safeguards purposes.
6. Develop quality assurance standards for the safeguarding of the final disposal of spent fuel.

3. WASTE MANAGEMENT SAFEGUARDS REVIEW GROUP[7]

The International Safeguards Program for CRWMS was formed to support the potential application of IAEA safeguards at CRWMS facilities and on CRWMS operations and to ensure that the technologies and approaches necessary to implement effective international safeguards for CRWMS will be available when they are needed. The CRWMS facilities will be eligible for IAEA safeguards and are expected to be among the first spent fuel and high-level waste disposal operations worldwide; thus, they are expected to be selected by IAEA for the application of international safeguards. The mission of WMSRG is to provide management oversight and coordination of activities related to identification and development of safeguards approaches and technology for the effective application of international safeguards to CRWMS.

In FY 1993, Energy Systems was the only DOE contractor providing technical support to WMSRG. In FY 1994, LANL and SNL will also have task responsibilities. Task responsibilities under this project include system studies, policy analysis, and strategies development to provide advanced safeguards concepts for spent fuel and waste management activities. Activities under the project include investigations of advanced safeguards concepts that would enhance the verification techniques and capabilities of international, regional, and bilateral regimes to provide timely detection of loss of spent fuel at nuclear reactors, reprocessing plants, and long-term storage facilities. LANL and SNL have specific responsibilities for participating in international exchanges addressing spent fuel safeguards and for developing and assessing technologies applicable to safeguarding spent fuel storage, conditioning, and repository facilities. Specific responsibilities of Energy Systems under this project are as follows:

1. Participate in international meetings addressing waste and spent fuel management safeguards.
2. Maintain cognizance of DOE/OCRWM programs.
3. Develop and assess waste management safeguards approaches.
4. Provide the technical secretary to WMSRG.
5. Investigate, reevaluate, and establish priority activities for WMSRG for the next two fiscal years.
6. Update the waste management safeguards action plan.

The objective of the CRWMS safeguards studies performed during FY 1993 was to develop and assess safeguards approaches for the acceptance of spent fuel in CRWMS. Tasking and results in this area are shown in Appendix B.[11]

The following safeguards procedures are recommended for IAEA safeguards when spent fuel and high-level waste are accepted into CRWMS:

1. Spent fuel containers received from facilities under active safeguards should be inspected, or verified at the CRWMS facility to confirm identity and integrity in accordance with the IAEA criteria and practices.
2. Spent fuel casks and canisters received from facilities not under active safeguards should be entered into IAEA safeguards on shipper's values without verification of contents. IAEA should verify attributes and integrity of the container and apply item safeguards to the container.
3. High-level waste received from facilities under active safeguards and on which safeguards have been terminated would not be safeguarded at the CRWMS facility. IAEA should be notified of movements of high-level waste in areas containing spent fuel.
4. For high-level waste received from facilities not under active safeguards, IAEA should be requested to terminate safeguards on the wastes in advance of official receipt of the wastes at the CRWMS facility. If accepted for termination of safeguards, the waste would not be safeguarded at the facility.
5. Waste for which safeguards is not terminated should be accepted into the CRWMS facility under the same safeguards procedures as applied to spent fuel containers (items 1 and 2).

If these recommendations are acceptable to IAEA for safeguarding the acceptance of spent fuel in CRWMS, IAEA safeguards would not impact the reactor, storage, and waste facilities that will ship nuclear material to the CRWMS facilities. The procedures should also not change the IAEA safeguards procedures implemented at those facilities selected for the application of active safeguards.

During FY 1993, technical interactions were initiated between SNL and Germany for cooperative support in the development of technologies for safeguarding spent fuel at final disposal facilities. The WMSRG program plan recommends that CRWMS transportation system international safeguards issues be addressed in FY 1994 and that safeguards issues for the Monitored Retrievable Storage (MRS) Facility be addressed in FY 1995. Beginning in FY 1994, LANL will begin work towards developing unattended methods for monitoring spent fuel in dry storage facilities.

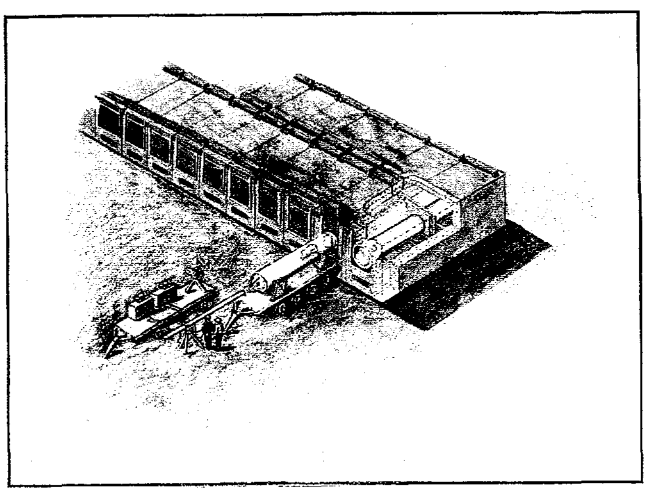

Fig. 3. U.S. modular horizontal dry storage.

4. RECOMMENDATIONS

Although the general impression exists that spent fuel conditioning and repository facilities need low priority for the development of safeguards approaches, conditioning and repository facility construction is now occurring (Table 2). Away-from-reactor dry storage facilities are operating in the United States, Germany, and Canada (Figs. 3 and 4). The German Pilot Conditioning facility is under construction and scheduled to begin operations in 1966 (Fig. 5). Repository characterization shafts and tunnels of the German and U.S. repository

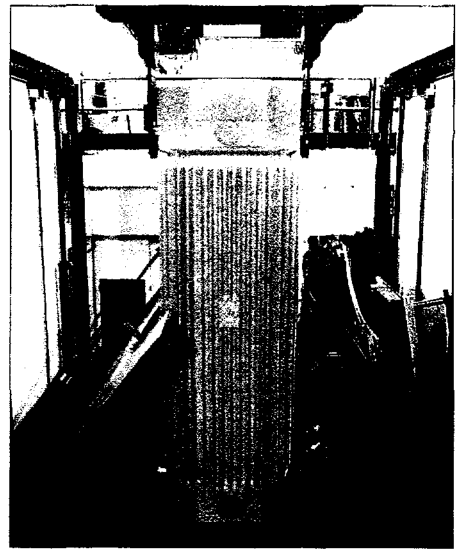

Fig. 4. Castor cask at Gorleben Interim Storage Facility (BLG photo).

project are currently being excavated (Fig. 6). The characterization shafts and tunnels (including underground laboratory facilities) will become part of the final repositories if the Gorleben and Yucca Mountain sites are found to be acceptable.

Systems for design information verification for spent fuel consolidation and conditioning operations are needed immediately. Safeguards approaches for maintaining continuity of knowledge of spent fuel processed at the conditioning facility and for verification of the final disposal package are currently needed. Systems for design information verification of the

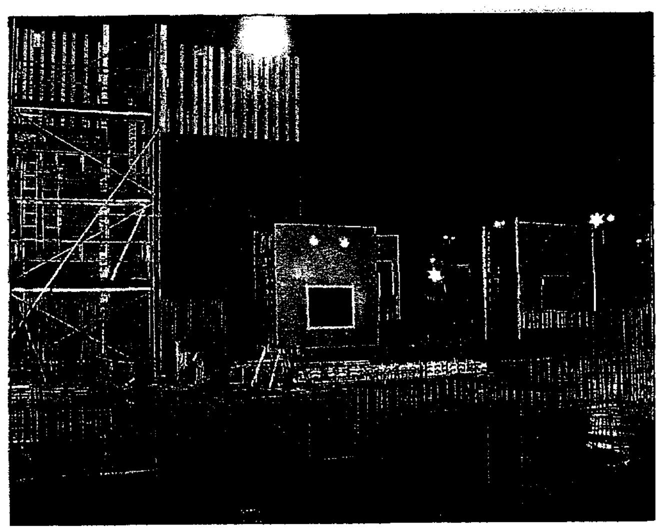

Fig. 5. Installation of shielding windows at Gorleben Pilot Conditioning Facility (GNS photo).

Bucket in Gorleben shaft 1

Drilling unit in Gorleben shaft 1

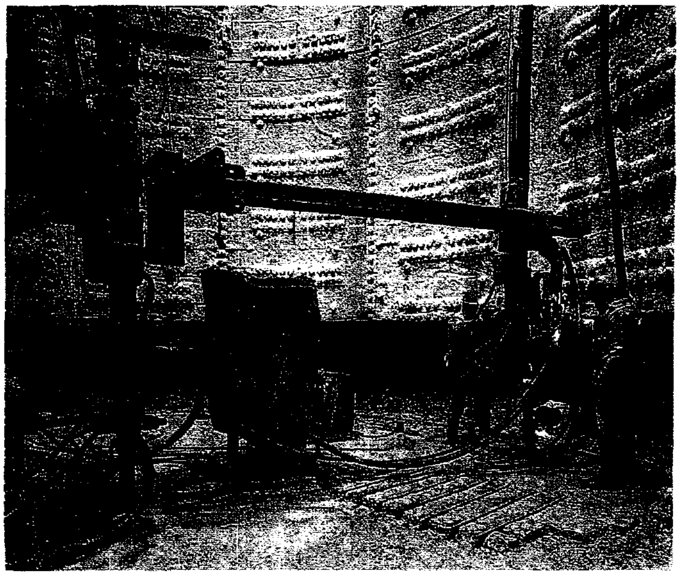

Fig. 6. Excavation of Gorleben shaft 1 (DBE photos).

repository facilities will be needed during this decade.

4.1 Identified Safeguards Tasks

DOE and IAEA have identified tasks that need to be performed if effective safeguards are to be implemented at the conditioning and repository facilities and if safeguards are to be implemented with minimum impact on CRWMS. These tasks are listed in Appendix A.

For effective international safeguards that meet the safeguards system development objectives identified at the consultants' meeting, the following sequence of activities need to be accomplished.

1. Evaluate the generic diversion paths identified at the consultants' meeting against the proposed facility designs. The proposed designs may make the paths considered more or less credible. (The Germans have initiated the use of PASE for their repository facility but not apparently for their conditioning facility.) A multinational technical investigation of proposed facility designs needs to be performed to identify credible diversion paths that must be safeguarded. These paths cannot be developed from intimate knowledge of just one facility design because the credible paths for each facility design may be different.
2. Identify specific diversion paths. Once credible diversion paths have been identified, the paths must be described in detail to permit identification of detection points that may be used in developing the safeguards approaches.
3. Evaluate generic safeguards approaches versus the specific diversion paths. For the conditioning and repository facilities at least two safeguards approaches were identified (i.e., perimeter and process), with the perimeter approach (because of lower facility impacts) being favored. The technical effectiveness of the perimeter approach was questioned and must be determined. A multinational technical evaluation of the potential detection points and safeguards applicable to those detection points needs to be performed to determine the political and technical acceptability of using the detection points and the potential for technical success in applying safeguards at each usable detection point.
4. Identify specific safeguards approaches and system design requirements. Safeguards applications for identified detection points need to be identified to minimize the number of detection points that must be used in the safeguards approach and to minimize the safeguards effort and technical requirements. These approaches must consider IAEA use of authenticated safety, process, and safeguards

equipment of the facility in addition to use of independent IAEA safeguards equipment. The detection capabilities and vulnerabilities of each potential system must be identified and system design requirements established.

5. Determine research and development requirements for the safeguards system. When the safeguards approaches are established, existing safeguards systems may be determined not to be capable of meeting the system design requirements. Research and development programs will need to be identified to (a) upgrade technology to meet the requirements, (b) combine the capability of multiple technologies to establish new systems, or (c) develop new technologies.
6. Develop design information questionnaire (DIQ) form and guidance. Because the conditioning and repository facilities are new facilities that have not previously been safeguarded by IAEA, design information questionnaire forms and guidance will need to be developed to ensure that IAEA obtains the necessary information from each facility to effectively verify the facility operations and to develop facility-specific safeguards approaches.
7. Develop design information verification procedures and requirements. The conditioning and repository facilities will present new challenges for design information verification. The conditioning facility will be an active physical process with many operational flexibilities. The repository will be a facility whose design is continually changing as new drifts are excavated and filled drifts are backfilled.
8. Determine research and development requirements for the design information verification system. When the design information verification system approaches are established, existing technologies may be determined not to be capable of meeting the system design requirements. Research and development programs will need to be identified to upgrade technology to meet the requirements, to combine the capability of multiple technologies to establish new systems, or to develop new technologies.
9. Develop design requirements for ISVS, C/S, NDA, geophysical techniques, cask verification, information processing, and recordkeeping systems required to implement the safeguards approaches.
10. Develop and evaluate new safeguards techniques.
11. Implement safeguards approaches.

The sequence of activities is applicable to both the consolidation and repository facilities. The activities associated with the conditioning facilities need to be performed first because one conditioning facility is being constructed and other conditioning facilities may begin operations within this decade. Activities for repositories may be addressed with lower priority but should be addressed within this decade. Tasks supporting the application of international safeguards in the United States and at the CRWMS facilities should be directed by DOE. Technical assistance in the development of international safeguards approaches and of safeguards technology will be provided to the IAEA by the United States. Tasks requiring the integration of activities being performed by multiple States should be directed by IAEA. All task activities will require maintenance of a dialogue between DOE and IAEA.

4.2 Member State Support Tasks

The IAEA SP-1/proposed task outline titled *Safeguards for Final Disposal of Spent Fuel* begins to lay out a development program for identifying and developing a safeguards approach for spent fuel conditioning and repository facilities. Subtask 1 (Design Specification) of the SP-1 examines the credible diversion paths, evaluates candidate safeguards approaches, and recommends system design criteria. Subtask 2 (Design Information Verification System) uses the diversion path data from Subtask 1, evaluates candidate design information verification approaches, and recommends system design criteria. Subtask 4 (Geophysical Techniques and ISVS) uses the results from Subtasks 1 and 2 and begins to establish design criteria for technology to be used in the identified safeguards approaches identified for repository facilities.

The SP-1 task outline needs to be extended to evaluate the other technologies that may be required for the identified safeguards approaches, especially those related to conditioning facility safeguards. The following technologies identified in the consultants' meeting recommendations (in addition to geophysical techniques and ISVS for verifying underground repository activities) need to be developed: (1) NDA fissile assay measurement systems for spent fuel; (2) ISVS and dual, independent C/S systems for conditioning and repository surface facilities; (3) authentication technology for verification of outputs from the facility operator's process, safety, and safeguards systems; (4) technology to identify and assure the integrity of final disposal canisters; and (5) a perpetual records system for disposed fuel. The ISVS developed for the repository accesses will need to be able to automatically separate casks containing spent fuel from casks containing high-level waste. Particular attention needs to be paid to development of ISVSs for spent fuel consolidation activities. The consultants' meeting also recommended that revised safeguards timeliness criteria for spent fuel in closed repository facilities be established. Development of design information questionnaires needs to be addressed to ensure that IAEA obtains the information it needs for development and implementation of effective safeguards.

Subtask 1 was partially addressed by the consultants' meeting, by the Member State contributions to the meeting, and by Member State support tasks. The consultants' meeting recommendations provide a framework for the development of a safeguards approach; however, the recommendations do not assure that all credible diversion strategies for each State's conditioning and repository facility designs have been evaluated or that optimal safeguards approaches were identified. The Member State contributions and technical support assessments have been provided to IAEA based on the State's knowledge of its own facilities. Effort needs to be provided under Subtask 1 to assess the identified diversion strategies versus multiple State systems and to develop candidate safeguards approaches that address the credible diversion paths. The diversion paths and potential safeguards approaches need to be described and evaluated more comprehensively and in greater detail.

SP-1 Subtasks 3, 5, and 6 are not mandatory for accomplishment of the IAEA's objectives. Subtask 5 could be incorporated into Subtask 1. The use of authenticated safety data should be evaluated for use in development of the IAEA safeguards approaches. The technical support requested in Subtasks 3 and 6 should be developed from the global international safeguards perspective and then applied to safeguarding conditioning and repository facilities. A quality assurance system should be established and applied to all IAEA safeguards activities. From this IAEA-wide system, quality assurance programs should be developed that identify the requirements and inspection procedures specific to the spent fuel conditioning and repository facilities. Developing quality assurance programs individually for every safeguards approach without a central system will result in programs that cannot be effectively implemented.

The IAEA's consideration of artificial intelligence and advanced computer logic systems to address resource optimization (Subtask 3) should be praised. Automation of the resource optimization approach will permit more consistent and timely evaluation of diversion scenarios and selection of safeguards techniques. However, the accuracy of the automated system is highly dependent on the programmer's understanding of the manual resource optimization approach used for actual facilities. Use of artificial intelligence systems to automate evaluation processes requires that the evaluation process being modeled is well characterized. Rules-based and fuzzy logic systems require modeling the thought processes of an expert analyst. Neural networks require training the system through providing necessary data inputs and acknowledging correct decisions made by the system. Because PASE is still an evolving analytical tool, few expert analysts in the use of PASE currently exist. Use of automated systems based on processes that are not well-known can result in unrecognized logic system failures. In addition, the design of the spent fuel management facilities continues to evolve, thus preventing the development of models using actual facility operations. In the absence of operating facilities, the automated evaluation system outputs cannot be performance tested to verify their accuracy.

Appendix A

IDENTIFIED TASK ACTIVITIES TO SUPPORT SAFEGUARDS FOR FINAL DISPOSAL OF SPENT FUEL

Appendix A

IDENTIFIED TASK ACTIVITIES TO SUPPORT SAFEGUARDS FOR FINAL DISPOSAL OF SPENT FUEL

	Task	DOE	Consultants	SP-1
Spent Fuel Acceptance				
1	Assess and categorize potential verification measurement points prior to packaging at reactor (completed FY 1993).	✓		
2	Assess applicable partial and gross defect measurement techniques that could be used prior to spent fuel packaging at a reactor (completed FY 1993).	✓		
3	Assess techniques to verify loading of transportation cask at a reactor (completed FY 1993).	✓		
4	Summarize technologies available in the time frame needed for accepting spent fuel into CRWMS (completed FY 1993).	✓		
5	Assess issues associated with receipt of defense high-level waste (HLW) in the CRWMS (completed FY 1993).	✓		
6	Determine IAEA need to verify nuclear material content of spent fuel and HLW items received from a not safeguarded facility (completed FY 1993).	✓		
7	Assess IAEA rights to verify spent fuel entering the CRWMS at a reactor not selected for routine IAEA inspections (completed FY 1993).	✓		
Spent Fuel Transportation				
8	Determine potential means of spent fuel removal from a transportation cask (active).	✓		
9	Determine cask attributes that would uniquely identify a loaded transportation cask (active).	✓		
10	Assess surveillance and monitoring technologies to detect removal of spent fuel from cask (active).	✓		
11	Assess need for transportation cask tracking capabilities (active).	✓		
12	Determine cask design features that would facilitate implementation of international safeguards (active).	✓		
13	Develop and evaluate international safeguards approach for CRWMS transportation system (active).	✓		
14	Determine requirements for multiple independent and redundant surveillance and monitoring systems for transportation casks (active).	✓		✓ (Ger.)

	Task	DOE	Consultants	SP-1
	Spent Fuel Acceptance			
15	Establish design and information evaluation requirements for multiple independent and redundant C/S systems for spent fuel transportation (active).	✓		✓ (Ger.)
16	Develop and test multiple independent and redundant C/S systems for spent fuel transportation casks (active).	✓		✓ (Ger.)
	Spent fuel dry storage facilities			
17	Determine nuclear material and other material flows at dry storage facility.	✓		
18	Determine potential diversion paths for dry storage facility.	✓		
19	Develop and assess the IAEA safeguards approach for dry storage facility.	✓		
20	Determine material control and accountability (MC&A) structure required to support IAEA safeguards at dry storage facility.	✓		
21	Determine data, records, and reports generated by the facility that would be verified by IAEA.	✓		
22	Determine IAEA reporting requirements for the facility and develop information transfer interfaces.	✓		
23	Determine IAEA safeguards activities and technology for verification and reverification of design information for storage facilities.	✓		✓
24	Develop DIQ for dry storage facility.	✓		
25	Determine IAEA inventory verification activities for dry storage facility.	✓		
26	Determine cask storage attributes that would verify the integrity of the storage casks.	✓		
27	Determine storage cask attributes that would uniquely identify a loaded storage cask.	✓		
28	Determine surveillance and monitoring systems to detect spent fuel removal from stored casks.	✓		
29	Determine cask design features that would facilitate implementation of international safeguards.	✓		
30	Determine multiple independent and redundant surveillance and monitoring systems for cask storage operations (active).	✓		✓ (Ger.)
31	Establish design and information evaluation requirements for multiple independent and redundant C/S systems for spent fuel storage (active).	✓		✓ (Ger.)

	Task	DOE	Consultants	SP-1
	Spent Fuel Acceptance			
32	Develop and test multiple independent and redundant C/S systems for spent fuel storage (active).	✓		✓ (Ger.)
	Spent Fuel Conditioning Facility			
33	Determine nuclear material and other material flows at conditioning facility.	✓		
34	Identify and evaluate diversion routes for conditioning facility.	✓		✓
35	Evaluate diversion concealment methods for conditioning facility.	✓		✓
36	Identify commonalities of diversion paths and detection elements for conditioning facility.	✓		✓
37	Identify optimum effective safeguards approaches for conditioning facility.	✓		✓
38	Investigate techniques for resource optimization to increase the effectiveness and efficiency of safeguards at spent fuel conditioning facility.			✓
39	Determine MC&A structure required to support IAEA safeguards at conditioning facility.	✓		
40	Determine data, records, and reports generated by the facility that would be verified by IAEA.	✓		
41	Determine IAEA reporting requirements for conditioning facility and develop information transfer interfaces.	✓		
42	Determine procedures for the IAEA to conduct physical inventory verifications.	✓		
43	Determine IAEA safeguards activities and technology for verification and reverification of design information for conditioning facilities.	✓		✓
44	Develop DIQ form and guidance for conditioning facilities.	✓		
45	Develop DIQ for conditioning facilities.	✓		
46	Determine systems to verify the identity and integrity of received casks.	✓		
47	Determine potential verification measurement points for received spent fuel casks.	✓		
48	Determine partial defect measurement techniques that could be used to verify characteristics of received spent fuel.	✓		
49	Determine systems for monitoring the movement of spent fuel and packages to and from the repackaging/consolidation process area.	✓	✓	

	Task	DOE	Consultants	SP-1
	Spent Fuel Acceptance			
50	Determine safeguards systems to verify transfer process for spent fuel items between casks/canisters.	✓	✓	
51	Determine process cell perimeter safeguards systems to verify the nondiversion of spent fuel during transfer operations.	✓	✓	
52	Develop NDA fissile assay measurement techniques for fuel rods and spent fuel assemblies.	✓	✓	
53	Determine systems to confirm the contents of casks/canisters before shipment to the repository.	✓		
54	Determine operator process, safety, and safeguards monitoring systems that could be used to provide safeguards information.	✓		✓
55	Develop techniques for authentication of outputs from operator and IAEA monitoring and safeguards systems.	✓	✓	
56	Establish design and information evaluation requirements for integrated safeguards verification systems and multiple independent and redundant surveillance and monitoring systems.	✓	✓	
57	Develop quality assurance standards for conditioning facility safeguards systems.			✓
58	Develop and test safeguards systems for the conditioning facility.	✓	✓	
	Final Repository Facility			
59	Determine nuclear material and other material flows at repository.	✓		
60	Identify and evaluate diversion routes for repository facility.	✓		✓
61	Evaluate diversion concealment methods for repository facility.	✓		✓
62	Identify commonalities of diversion paths and detection elements for repository facility.	✓		✓
63	Identify optimum effective safeguards approaches for repository facility.	✓		✓
64	Investigate techniques for resource optimization to increase the effectiveness and efficiency of safeguards at repository facility.			✓
65	Determine MC&A structure required to support IAEA safeguards at repository.	✓		
66	Determine data, records, and reports generated by the facility that would be verified by IAEA.	✓		
67	Determine IAEA reporting requirements for repository facility and develop information transfer interfaces.	✓		
68	Develop procedures for IAEA to conduct physical inventory verifications at surface facilities.	✓		

	Task	DOE	Consultants	SP-1
	Spent Fuel Acceptance			
69	Determine IAEA safeguards activities and technology for verification and reverification of design information for repository facility.	✓		✓
70	Develop DIQ form and guidance for repository facility.	✓		
71	Develop DIQ for repository.	✓		
72	Establish a perpetual records management system to maintain information on the location, depth, and plan area for each repository and the contained nuclear material.		✓	
73	Determine systems to verify the identity and integrity of received final disposal casks.	✓	✓	
74	Determine potential verification measurement points for received spent fuel in casks.	✓		
75	Determine partial defects measurement techniques that could be used to verify characteristics of received spent fuel.	✓		
76	Determine systems to confirm the contents of casks before transfer underground.	✓		
77	Determine cask design features that would facilitate implementation of international safeguards.	✓		
78	Determine systems to verify the transfer of disposal casks underground.	✓	✓	
79	Determine monitoring systems to detect the removal of nuclear material through vents and men and material shafts.	✓	✓	
80	Determine monitoring systems to detect the removal of nuclear material through tuff and waste ramps.	✓	✓	
81	Determine monitoring systems to detect undisclosed mining.	✓	✓	
82	Determine monitoring systems to detect undisclosed shafts and tunnels.	✓	✓	
83	Determine systems to verify continued presence of emplaced spent fuel.	✓	✓	
84	Determine systems to monitor the integrity of a backfilled and sealed repository.	✓	✓	
85	Investigate geophysical techniques to provide information on location and status of spent fuel disposal containers emplaced in the repository.	✓	✓	✓
86	Investigate safeguards systems and approaches for application to emplaced containers in the underground repository facility.	✓	✓	

	Task	DOE	Consultants	SP-1
	Spent Fuel Acceptance			
87	Determine operator process, safety, and safeguards monitoring systems that could be used to provide safeguards information.	✓		✓
88	Develop techniques for authentication of outputs from operator process and safeguards systems.	✓	✓	
89	Establish design and information evaluation requirements for integrated safeguards verification systems and multiple independent and redundant surveillance and containments systems.	✓	✓	
90	Develop quality assurance standards for the safeguarding of the final disposal of spent fuel.			✓
91	Develop and test integrated safeguards verification systems and geophysical techniques for the repository facility.	✓	✓	
92	Reconsider safeguards timeliness requirements for diversion of spent fuel from a closed repository.		✓	

Appendix B

RESULTS OF FISCAL YEAR 1993 SAFEGUARDS ASSESSMENTS

Appendix B

RESULTS OF FISCAL YEAR 1993 SAFEGUARDS ASSESSMENTS

Task Number	Task	Findings
1	Review IAEA criteria and current practices for verifying spent fuel in storage and shipments.	IAEA has established safeguards criteria for verification of spent fuel in difficult-to-access storage, closed containers, and accessible storage. All three criteria categories may be applicable to spent fuel within CRWMS. Spent fuel placed in difficult-to-access storage is verified (at the partial defects level) before storage and maintained under dual, independent C/S; spent fuel in closed containers is verified by NDA at a level to assure that the contained items are present; accessible spent fuel is verified through verification of C/S systems and/or verification of spent fuel item count and gross attributes. IAEA safeguards practice for safeguarding spent fuel storage has been implemented in the following facilities: (a) La Hague, France, (accessible spent fuel in water storage received from reactors not under active safeguards); (b) Sellafield, Great Britain, (spent fuel in sealed canisters); (c) Ahaus, Germany, (monitored retrievable storage of spent fuel in transport/storage casks); and (d) Point Lepreau, Canada, (spent fuel in vertical concrete storage casks). Facility-specific systems were implemented to meet the safeguards criteria at each facility.
2	Review NRC requirements for verifying spent fuel transfers.	For transfers of spent fuel and spent fuel in storage, NRC requires nuclear material control and accountability based on item accounting. Verification of item identity, item integrity (e.g., tamper-indicating seals verification), and item count are required; confirmatory measurements on the spent fuel are not required.
3	Review DOE/OCRWM spent fuel acceptance criteria for verifying spent fuel transfers.	During the spent fuel acceptance process, DOE/OCRWM will accept operator's records for fuel irradiation and will retain the right to verify fuel physical characteristics (to verify that the fuel is "standard fuel") and fuel identification numbers. To take advantage of burnup credit during cask loadings, DOE/OCRWM may also verify fuel burnup during cask loading at the reactor facility. Burnup verification would be performed using NDA techniques.

Task Number	Task	Findings
4	Review spent fuel storage, transfer, and shipping procedures at U.S. nuclear power stations.	Spent fuel storage, transfer, and shipping procedures were reviewed at the Oconee Nuclear Power Plant, South Carolina (wet handling in storage pool for modular horizontal storage, Fig. 3) and at the Idaho National Engineering Laboratory (dry handling in hot cell for vertical storage casks). Discussions confirmed that verification measurements are not performed on received, stored, or shipped spent fuel. If verification measurements were required, measurements would need to be performed during dry transfer of the spent fuel from the transport cask to the storage cask (Idaho) or performed at the spent fuel interim staging location used during loading of the storage canister (Oconee).
5	Determine potential verification measurement points applicable to spent fuel shipments from a reactor.	Verification measurement techniques have been developed that would be capable of verifying spent fuel at the gross, partial, and bias defect measurement levels. The following techniques have been developed (a) enhanced Cherenkov-glow device (gross defect), (b) gross neutron counting (gross defect), (c) gross gamma-ray counting and gamma-ray spectroscopy (gross defect), (d) gamma-neutron fork detector (partial defect), (e) gamma-ray tomography (partial defect), (f) active neutron measurement (bias defect), and (g) lead slowing-down time spectrometer (bias defect). Only the enhanced Cherenkov-glow device and the fork detector are routinely implemented by IAEA. Facility-specific systems using gamma-ray and neutron systems have been implemented at a few facilities.
6	Review potential verification measurement techniques for spent fuel and techniques for verifying loading of a cask and determining the technique's availability.	Cask loading verification techniques have been developed in support of IAEA. The following techniques have been developed, however only manual and camera surveillance have been implemented: (a) manual surveillance, (b) camera surveillance, (c) laser surveillance system (LASSY), (d) crane monitoring, (e) automatic spent fuel identification number reader, and (f) integrated safeguards verification systems. ISVSs include detectors for radioactivity and direction of movement in addition to the above components.
7	Assess issues associated with receipt of conditioned high-level waste.	IAEA personnel stated that high-level wastes on which safeguards have been terminated that are also disposed at the repository should not be an issue if they do not affect the safeguards implementation. However, high-level wastes will have similar radiation signatures as spent fuel and will be transported into the repository in similar shielding casks. Thus the high-level waste may not be distinguishable from spent fuel. A technology needs to be developed to provide automated separation of spent fuel from high-level wastes.

Task Number	Task	Findings
8	Determine IAEA rights to verify spent fuel at eligible, but unselected, U.S. facilities.	IAEA personnel stated that IAEA could only verify nuclear material at a U.S. facility not selected for the application of safeguards under the invitation of the U.S. government. However, before negotiation of a safeguards approach for the CRWMS facilities, IAEA would not want to preclude any potential safeguards approaches or activities.
9	Determine the safeguards vulnerabilities associated with not verifying spent fuel received from a safeguarded and an unsafeguarded facility.	Verification of transfers of safeguarded nuclear material must be verified to provide assurance of the quantities of nuclear material removed from and added to inventories and to provide assurance that no material was diverted during transport. Verification of receipts of unsafeguarded material in CRWMS does not have a technical justification because no motivation for diversion of the spent fuel under safeguards exists that did not exist when the material was not under safeguards. If diversion of spent fuel to the weapons program occurred, it would be expected to occur before the material was transferred under safeguards. Verification of the spent fuel could be performed when (if) the container was rebatched.

ACRONYMS AND INITIALISMS

CRWMS	U.S. Civilian Radioactive Waste Management System
C/S	containment and surveillance
DIQ	design information questionnaire
DOE	Department of Energy
FY	Fiscal Year
HLW	high-level waste
IAEA	International Atomic Energy Agency
ISVS	integrated safeguards verification system
LANL	Los Alamos National Laboratory
LASSY	laser surveillance system
MC&A	material control and accountability
MRS	Monitored Retrievable Storage
NDA	nondestructive assay
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
PASE	Probabilistic Assessment of Safeguards Effectiveness
SNL	Sandia National Laboratory
WMSRG	Waste Management Safeguards Review Group

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