RADIOLOGICAL DISPERSAL DEVICES:

AN INITIAL STUDY TO IDENTIFY RADIOACTIVE MATERIALS OF GREATEST CONCERN AND APPROACHES TO THEIR TRACKING, TAGGING, AND DISPOSITION

Report to the
Nuclear Regulatory Commission
and the
Secretary of Energy

May 2003

Prepared by

The DOE/NRC Interagency Working Group on
Radiological Dispersal Devices

Table of Contents

Page No.

Appendices

Figure

Executive Summary

The events of September 11, 2001, heightened the nation's concerns regarding the use of radioactive materials for a malevolent act. In June 2002, the Secretary of Energy and the Chairman of the Nuclear Regulatory Commission (NRC)[1] met to address these concerns and discuss the nation's ability to adequately protect inventories of nuclear materials that could be used in a *radiological dispersal device*[2] (RDD). An attack involving an RDD has been of particular concern because of the widespread use of radioactive materials in the United States and abroad by industry, hospitals, and academic institutions.

At the June meeting, the Secretary of Energy and the NRC Chairman agreed to convene an Interagency Working Group on Radiological Dispersal Devices (hereafter WG) to address these concerns. In the first meeting, the WG identified the following four focus areas for examination: (1) the relative hazards of radioactive materials; (2) the options for establishing a national source *tracking* system; (3) the potential for the use of technological methods for tagging and *monitoring* sources while in use, storage and transit; and (4) actions for facilitating the securing and *final disposition* of unsecured, excess, and unwanted sources.

To identify the radioactive materials of greatest concern, the WG used input from an analysis prepared for this purpose by Sandia National Laboratories.[3] Radioactive materials at facilities *licensed* by the NRC as well as those controlled and managed by the Department of Energy (DOE) were included in the analysis. The radioactive materials contained at nuclear power plants and at licensees within States that have an agreement with NRC to license radioactive materials were not included in the analysis. DOE strategic materials were also not included. The analysis broadly evaluated radioactive materials by applying a systematic approach considering potential dose impacts and attractiveness (quantity and ability to obtain a given material at a given location). A relative rather than an absolute evaluation of materials of concern was provided. The WG assessed the Sandia results and provided additional insights based on expert knowledge and judgment. One of the WG's recommendations is the need to determine, in the near term, any additional protective measures for a subset of radioactive materials under NRC license or DOE control. In efforts to ensure adequate near-term protection, DOE facilities with the highest levels of protection have undergone evaluation of security measures in place. The protection of materials at remaining DOE facilities (e.g., university and research facilities) is being evaluated to determine whether these radioactive materials require movement or additional protection. NRC has required, or will soon require, fuel cycle facilities and irradiator licensees to institute additional protections and has initiated assessments for other licensees.

Recent legislative proposals have included the requirement to improve capabilities for tracking radioactive materials as a means to obtain better knowledge of sources of interest and their locations. The WG recommends pursuing development of a national source tracking system for a subset of the sources based on a *business case*, which defines system requirements and estimates costs. In conjunction with developing the business case, the WG recommends use of interim databases to identify the current location of radioactive materials of concern that can be updated periodically until the national system with recommended attributes can be developed. The WG also assessed the feasibility of using current and developing technologies to tag and monitor radioactive materials so that tracking may be facilitated.

---

[1] Acronyms and abbreviations can be found in Appendix A.

[2] In this report, the first instance of each term defined in Appendix B, "Glossary," is italicized.

[3] *An Initial Study to Identify Materials of Greatest Concern for Use in a Radiological Dispersal Device*, Sandia National Laboratories, November 15, 2002.

These technologies are best used in conjunction with enhanced inspection and inventory processes and are needed to complement the national source tracking system in a comprehensive program of tracking and protection.

Moving materials that are unsecured, excess, or unwanted to secure locations contributes directly to reducing the possibility that these materials can be used for malevolent purposes. The WG evaluated the means available to reuse, recycle, store, or dispose of this material. Associated recommendations address actions to ensure greater availability of disposition mechanisms for possessor and material combinations that lack, or are limited in, disposition options.

While both DOE and NRC have safety and security requirements in place to control radioactive materials and prevent their use for malevolent purposes, there is, in the current environment, clearly a benefit in achieving a higher level of assurance of the adequacy of material control. To that end, the WG provides policy-level recommendations in Section 5.0 (and summarized below) and identifies operational-level recommendations in Appendix H. Taken together, these recommendations represent a comprehensive list of actions that will, when implemented, provide a higher level of protection for radioactive materials. In the policy area, the WG recommends:

- Action levels be used as a basis for applying protective measures in the near term as appropriate for each agency.
- A national RDD protection level be established in coordination with the Department of Homeland Security and other agencies. In the near term, each agency will use the near-term action thresholds to evaluate its facilities to determine if material exceeding the thresholds needs to be better protected.
- A national threat policy that defines threat characteristics that could impact use of radioactive material in an RDD be developed in coordination with the Department of Homeland Security and DOE and NRC continue assessing vulnerabilities of specific facilities or licensees or classes of licensees.
- A national source tracking system be developed to better understand and monitor the location and movement of sources of interest.
- An integrated national response strategy for rapid recovery of unsecured sources be developed in coordination with the Department of Homeland Security. The DOE Offsite Source Recovery Program (OSRP) should continue providing for rapid recovery in the interim, and long-term program management should be clearly defined.
- An integrated national strategy for disposition of unsecured sources be developed. This includes: clearly defining organizational responsibility within DOE for the decision on where to dispose of sources that are *greater-than-Class C,* accelerating recovery of sources by NRC and DOE consistent with this report's findings, and adhering to the Low Level Radioactive Waste Policy Amendments Act (LLRWPAA), including the Federal government establishing greater-than-Class C waste disposal capability (with DOE currently assuming responsibility), securing adequate funding for disposal consistent with ensuring that beneficiaries of the activities that resulted in the generation of greater-than-Class C waste bear all reasonable costs of disposing of such waste, and States conforming to their responsibilities as set out in the LLRWPAA. The LLRWPAA should be reviewed for further enhancements to allow management of radioactive sources in each State to be more effective.
- Coordination and communication with other Federal agencies be enhanced, common technology and data approaches be sought, and efficiencies in modeling and research be achieved.

- Internationally, the United States should continue to coordinate with the International Atomic Energy Agency (IAEA) to finalize the Code of Conduct on the Safety and Security of Radioactive Sources and Categorization of Sources.

1.0 Introduction

The changing face of terrorism has brought greater emphasis to, and concern for, the emergence of unconventional threats facing the global community. Of these, the threat of radiological attack has garnered great interest among the public and decision- and policy-makers. A radiological attack involving the malicious exposure to and dispersal of radioactive materials found in routine commerce has been of particular concern because of the ubiquitous nature of the use of these materials in the industrialized world. Radioactive materials provide critical capabilities in the oil and gas, electrical power, construction, and food industries; are used to treat millions of patients each year in diagnostic and therapeutic procedures; are used in a variety of military applications; and are used in many areas for technology research and development involving academic, government, and private institutions.[4] These materials are as diverse in geographical location as they are in functional use.

The use of radioactive materials in an unconventional attack via some dispersion mechanism, commonly referred to as an RDD or "dirty bomb," is widely recognized to have a greater likelihood of physical and social disruption than of lethal radiological consequences. However, the psychological and economic consequences of dispersal could be high and carry varying levels of risk to public health. The consequences depend not only on the radioactive material involved (its isotopic composition and physical form), but also the dispersal mechanism (explosive or non-explosive) and the environmental conditions under which it is released (e.g., urban, rural, weather). Thus, determining the absolute consequences of any potential dispersal in advance of its occurrence is not possible.

Historically, exposure limits were established for the control and use of radioactive materials based on safety-basis accidents, including inadvertent exposure. However, because of changes in the global threat environment, these same materials/devices must be evaluated for their potential malevolent uses. Obtaining a better understanding of the security risks involving radioactive materials is a necessary component of material protection in recognition of today's environment.

The widespread presence of radioactive materials in commerce and the myriad of possible deployment environments and mechanisms for RDDs present many challenges to understanding which radionuclides pose the greatest hazard. In order to focus attention and resources on those radioactive materials that pose the greatest risk to public health and safety, it is important to understand the potential consequences from their use considering potential threat scenarios. There have been several studies of RDD issues over the years. However, it is necessary to consider systematically and jointly the present state of material usage and availability to develop a broad understanding of the relative hazard of material classes that will provide a current basis for decisions. In addition, DOE and NRC recognize the need to evaluate options for tracking more significant radioactive source materials to provide appropriate agencies with the information necessary to verify authorized material possession and shipments. Obtaining needed

[4]The Atomic Energy Act of 1954 promoted the peaceful uses of nuclear energy through private enterprise and to implement President Eisenhower's Atoms for Peace Program. The Act allowed the Atomic Energy Commission to license private companies to use nuclear materials, including those in sealed source devices. The Energy Reorganization Act of 1974 redirected these efforts by separating the Atomic Energy Commission into the DOE and the NRC. These agencies have instituted numerous regulations to control the storage, transport, and use of nuclear materials by licensees, and to protect the health of workers and the public.

information can be facilitated through use of tagging and monitoring technologies. Recently Congressional legislation has been proposed for the establishment of such a national tracking system. Further, both DOE and NRC acknowledge the need to ensure that excess, unsecured, and unwanted sources are secured in a timely fashion.

In response to these new threats, the Secretary of Energy and the NRC Chairman held a joint meeting in June 2002 to address issues surrounding security of radioactive material. As a result of their discussions, an Interagency Working Group on Radiological Dispersal Devices (hereafter WG) was convened to proactively address the vulnerabilities, protection, and control of sealed sources and other radioactive materials that pose potential hazards from malevolent use. The WG was tasked to identify the range of materials that could potentially be used in RDDs, make recommendations that contribute to improved control of these materials, and identify gaps in current policies or approaches. To address the protection and control of radioactive material, the WG focused on four areas as discussed in Section 2.0. The WG established subgroups corresponding to each of the priority focus areas, with membership from both DOE and NRC to provide organizational perspectives on each issue. Appendix C contains the WG's Charter including WG membership and subgroup membership.

2.0 Scope

This report addresses four broad areas corresponding to the WG focus areas: (1) radioactive materials of greatest concern; (2) tracking and inventorying radioactive sources; (3) tagging and monitoring radioactive sources; and (4) dispositioning unsecured radioactive sources.

Radioactive Materials of Greatest Concern: To assess the hazards of materials, a systematic analysis was applied to broadly assess radioactive materials to determine those of greatest concern for use in an RDD.[5] The intent of the analysis was to provide a relative indication of materials of concern, rather than an absolute ranking, and to provide a basis on which initial judgments can be made regarding necessary actions. The initial analysis was supplemented by further analysis and expert knowledge and judgment. The scope of consideration included materials under NRC license and DOE control in the United States, excluding strategic nuclear materials and radioactive material in nuclear power plants, radioactive waste, and spent fuel. Due to time constraints and available data, the hazards analysis also did not consider materials in transit.

Tracking and Inventorying Radioactive Sources: Options for providing a national source tracking system were examined by: describing potential system capabilities and uses for its information, discussing the system in the context of a comprehensive view of source control, assessing existing systems as possible avenues for providing the system, discussing the probable benefits and challenges of implementing this system, and noting areas that require further consideration. The primary purpose of the system would be to enhance the accountability for these sources by having an accurate listing of all sources by location.

Tagging and Monitoring Radioactive Sources: A summary analysis of classes of technologies that may be useful to enhance tracking and monitoring of radioactive materials presently found in commercial and governmental activities in the United States was prepared. Clearly, policy decisions regarding the breadth and depth of material tracking and monitoring that will be required will illuminate technology requirements. Therefore, this analysis was restricted to an examination of technology classes that are available or under development, rather than specific systems.

[5] The WG did not explicitly consider materials for use in an *improvised nuclear device*. Those materials with potential use as a *radiation exposure device* are included to the extent discussed in Section 3.1.

Dispositioning Unsecured Radioactive Sources: Issues and concerns related to recovery, storage, and disposition of unsecured, excess, and unwanted (both *greater-than-Class-C [GTCC] radioactive waste* and non-GTCC radioactive waste) sources are generally described, including current processes and capabilities to recover sources, options associated with source recovery, and the framework necessary to continually capture such sources. The analysis considered sources regulated or controlled by NRC, DOE, Agreement States, and non-Agreement States, and international recovery of sources, including Department of Defense recovery of sources, with potential return to the United States. The analysis included radioactive sources containing byproduct, source, special nuclear, and *naturally-occurring and accelerator-produced radioactive material* (NARM) and identified major gaps or weaknesses in the ability to disposition these sources. The resulting information could be used as a road map for current disposition activities and as a starting point for more detailed evaluation of gaps and weaknesses.

Each of the subgroups completed a report focusing on its defined scope. These reports are listed as references in Section 6.0.

3.0 Issues and Discussion

3.1 Identifying Radioactive Materials of Greatest Concern

The WG enlisted Sandia National Laboratories (Sandia) to develop a computational methodology to systematically evaluate radioactive materials for RDD concerns. The computational methodology used by Sandia, as discussed in its report, "An Initial Study to Identify Materials of Greatest Concern for Use in a Radiological Dispersal Device," combines insights about relative dose impacts (the Material Index) and relative attractiveness for access (the Attractiveness Index). The Material Index includes consideration of the potential dispersion of these materials. The Attractiveness Index includes the quantity of each material possessed at each location or by each facility, the number of locations with such quantity, and the material protection. The combination of these two factors yields a *Hazard Index*, which is an expression of relative concern.[6] Because of time constraints, the computational methodology was based on information already available. A qualitative metric of a high Hazard Index was assigned to a material/location that had high in both the Material and Attractiveness indices or high in one index and medium in the other. A medium Hazard Index was assigned for situations of high-low or medium-medium pairs. A Hazard Index of low, or very low, was assigned to all other situations.

The purpose of the Sandia analysis was to systematically and broadly analyze radioactive materials, by applying a common methodological approach, to determine those of greatest concern for use in an RDD. The intent of the analysis, as a first step in review, was to provide a relative, rather than absolute, indication of materials of concern and to provide a defensible basis upon which initial judgments can be made by each agency and other Federal and State entities. Initial assumptions shaped the assessment and its results. Consistent with its intent to provide relative results, the assessment does not provide insights on what specific protective measures are warranted in relation to specific facilities, licensees, or classes of licensee. Subsequent specific actions will be determined by each agency based, in part, on assessments of vulnerabilities associated with specific classes and uses of radioactive materials.

Over 85,000 radioactive material records from NRC and DOE databases were screened against the DOE Category 3 facility threshold, as defined in DOE Standard 1027-92 and LA-12891-MS. This screening eliminated from further consideration materials that did not meet minimum dose impact criteria. Of the

[6] The IAEA in its Categorization of Radiation Sources, dated December 2000, endorses an approach to assessing the threat posed by radioactive sources that accounts for factors beyond radioactivity content. One such example as used by Sandia is the level of physical protection afforded various uses of the material.

approximately 49,000 records representing 240 isotopes in the DOE Nonactinide Isotope and Sealed Source (NISS) database, 3800 records remained after the initial screening. Of the approximately 37,000 records in the NRC Licensing Tracking System (LTS) database, 2900 records remained after screening. The Category 3 facility threshold values define the amount of material, in suitable form, that is capable of delivering a dose of 10 rem, based on the contribution from direct exposure and inhalation, to a person located 30 meters from the point of dispersal for a 24-hour period of exposure and a longer time period of ingestion. This dose level would not produce short-term health effects in any exposed person, although it could theoretically increase the long-term risk of cancer. Radioactive material in sufficient quantity to produce that dose level would also produce contamination in the surrounding areas and disrupt society by denying access to contaminated areas. Therefore, the Category 3 values make reasonable screening thresholds to focus further analysis on those materials representing the largest potential consequences. While the focus was broad in its inclusion of radioactive materials, the assessment did not analyze all DOE and NRC materials; specifically, reactor materials, radioactive waste, spent fuel, and DOE strategic material were not included. Likewise, Agreement State material was not included.[7] The analysis did not make direct assumptions about the consequences desired by those who would use an RDD, but defaulted to a radiological basis to discern materials of concern from health and contamination impacts. As such, psychological and economic consequences were not addressed explicitly. Limitations in the availability of certain quantifiable data prevented some potentially important considerations from being included in the analysis, such as consideration of remediation efforts in the wake of an RDD. Also, certain materials in the available data could not be considered due to lack of specificity. The analysis did not consider encapsulation, self-protection of sources, or materials in transit. These data and analysis limitations were important to the development of the WG's recommendations for further action.

The methodology presented here for identifying radioactive materials of greatest concern provides a flexible and scalable tool that lends itself to varying inputs or realigning analytical boundaries to broaden or narrow the number of radioactive materials of greatest concern depending upon the interest of the user. For example, the attributes of portability and convertibility were eliminated during the development, but can be evaluated at a later date. The results were intended for initial use by the other subgroups of the RDD WG to guide their assessments related to a system to track sources, technological methods to monitor sources, and source disposition. This supported the WG goal of an integrated RDD analysis effort with integrated recommendations. The results can be used to define the source tracking system population and future tracking priorities, define the prioritized set of radioactive materials which may benefit from enhanced tagging and monitoring based upon the hazard involved, and determine recovery and disposition priorities and evaluate the potential impact of accelerated recovery for those sources determined to be at risk. Additionally, the scalable methodology allows each agency to use specific threshold values, threat characteristics, and applicable threat scenarios, as appropriate to that agency and its materials. The results of the report, when combined with expert knowledge and judgment, are intended to focus and prioritize decisions for next steps regarding further analysis and research, resources, and policy.

Based on review of the Sandia results on dose impacts and attractiveness and as supplemented by consideration of direct radiation hazards, the WG identified those radioactive materials of greatest concern, which should be given first priority for consideration of increased security measures. Certain materials may require no further assessment because of their low relative hazard index and consideration of other factors. For instance, the Sandia analysis indicates that many radioactive materials would not be useful in an RDD because of their low radiological toxicity, short half-lives, low dispersibility, and/or low

---

[7] The Agreement States and NRC have similar types of licensees, and the amounts of material that they license them to possess are also similar. Note that States license NARM, which falls outside of NRC jurisdiction.

quantities. Examples are short-lived medical isotopes such as technicium-99m; luminous exit signs containing tritium, which has a low toxicity; most measuring instruments and gauges, which generally contain small quantities of material; and uranium-238, which has low dispersibility and low radiotoxicity. Assumptions used in the plume dispersal models also impact results.

The proposed NRC thresholds were determined based on consideration of WG determinations, including the Sandia report, by a group of NRC staff and Agreement State representatives. In arriving at the recommended near-term action thresholds, the NRC/Agreement State group considered contamination from dispersal and direct radiation. A contamination threshold that could deliver doses of 2 rem/year over 0.5 square kilometers to occupants was used. This 2 rem/year threshold corresponds to the Environmental Protection Agency (EPA) Protective Action Guideline (PAG) for re-entry into a contaminated area and continues to emphasize radiation overexposure potential while also considering extensive contamination consequences given the area proposed. For direct radiation, a dose-rate threshold of 25 rem/hour at 1 meter was used, based on the scenario where a person was unknowingly exposed to a concealed source for 8 hours at 1 meter (receiving a total dose of 200 rem). Obviously, there is a significant subjective aspect to choosing thresholds, and others could be selected. However, the material quantities associated with the recommended levels are largely in the same range as the levels of materials involved in actual major incidents that have occurred over the last 30 years. For example, Ir-192 sources in the 50–100 curie range have caused direct radiation fatalities, and Am-241 sources in the 10 curie range have caused significant contamination incidents. However, differences exist in the strontium-90 and californium-252 values (factors of 10 and 30, respectively) that are being investigated at this time.

In contrast, DOE has an established radiological sabotage methodology, which is part of its draft Design Basis Threat Policy. The methodology establishes a graded scale of protection based on the potential risk to the public, employees, and environment from malevolent acts, such as radiological sabotage. The malevolent acts include the postulated actions a terrorist might take to achieve the greatest possible result. Nuclear materials are evaluated through a vulnerability assessment process, including plume modeling, to ascertain the potential risk to the health and safety of the public, employees and environment. Based on the potential exposures, appropriate safeguards and security measures and programs are implemented. The DOE threshold values are based on those health effects that have been determined to result from a specific exposure or dose to the bone marrow, gastrointestinal tract, lung, or whole body. The lowest amount of material necessary to achieve one of the threshold values is taken as the bounding condition. In practice, this equates to calculating the potential dose for each organ and taking the maximum consequence as the bounding case and greatest possible consequence. The bounding case is used to determine the level of safeguards and security measures and programs that must be implemented.

The near-term protective measures NRC is considering include ensuring that materials are stored within a secure area, necessary access is determined and controlled, background checks are employed as appropriate, various graded schemes of intrusion detection and assessment are in place, local law enforcement response can be provided, and transfers to other authorized users are verified. In determining what additional near-term protective measures might be appropriate, a graded approach considering the materials, quantities, and measures already in place would be one option. In the near term, each agency will use the action thresholds to evaluate its facilities to determine if material exceeding the thresholds needs to be better protected. Until a national RDD protection level is defined, each agency will continue to utilize its respective approaches to evaluate protection levels.

3.2 Tracking and Inventorying Radioactive Sources

There is broad U.S. Government and international interest in tracking radioactive sources to improve accountability and control. Currently, there is no single U.S. source of information to verify the authorized users, locations, quantities and movement of these materials. Separate, non-standard systems at NRC and in the Agreement States track licensees and the maximum amounts of materials they are authorized to possess but do not record actual sources or their movements. At DOE, multiple systems at separate locations provide some source tracking capabilities. The WG examined options for providing a national source tracking system by (1) describing potential system capabilities and considering potential uses for its information, (2) discussing the system in the context of a comprehensive view of source control, (3) assessing existing systems as possible avenues for providing the system, (4) highlighting the probable benefits and challenges of implementing the system, and (5) noting areas that require further consideration as development and implementation of a national source tracking system proceeds. The following sections address each topic.

System Capabilities and Information Uses

A national source tracking system should provide a "cradle-to-grave" account of the origins of each source (manufacture, *recycling*, or import) and would record how, by whom, when, and where it has been transported, used, and eventually disposed of or exported. This standardized, centralized information, if reported reliably, would help NRC and DOE:

- Monitor the location and use of radioactive sources.
- Detect and act on discrepancies.
- Conduct inspections and investigations.
- Communicate radioactive source information to other government agencies.
- Respond in the event of an emergency.
- Verify legitimate ownership and use of radioactive sources.
- Further analyze hazards attributable to the possession and use of radioactive materials.

Initially, a national source tracking system would account for sources containing the materials and near-term actionable quantities. This initial deployment would affect approximately 2000 NRC and Agreement State nuclear materials licensees, as well as a number of DOE sites. The system would:

- Record information about NRC licensees, Agreement State licensees, and DOE facilities.
- Record data on materials of greatest concern possessed by or in transit to these licensees. Sources or materials in containers would be identified in the system by a unique identifier.
- Record where each source is currently located—whether in a licensee's inventory or in transit, including import and export.
- Provide the means to capture information about recovered sources and their disposition.
- Provide the means to verify imports and recipients of sources from foreign vendors.
- Track sources throughout the country, regardless of which regulatory body (DOE, NRC, or an Agreement State) has jurisdiction.

To be accurate, this system would need to capture information about the creation, storage, shipping, receipt, and disposal of a source as close to "real time" as possible. Having commercial licensees and DOE facilities use a secure, Internet-based interface to a *database system* is a likely way to provide this capability; it would use a public network to which many licensees already have access,[8] and it would be faster, more accurate, and less labor-intensive than having licensees complete forms to be mailed and entered into the system centrally.

The WG envisions this system resembling the Federal Express or United Postal Service tracking systems, which are available online, and which allow authorized users to locate and track the movements of their materials. This easy-to-use system would help commercial licensees and DOE facilities manage their own inventories and shipments, as well as fulfill reporting requirements to regulatory agencies. The system would be aided by bar coding or other tagging technologies (see Section 3.3) for input, making the job of maintaining an inventory easier, less time-consuming, and less prone to error.

Some of the main users and transactions of the national source tracking system include:

- **Manufacturers** would record new source creation, new source shipment, and spent source receipt.
- **Licensees and facilities** who use the sources would record source receipt, shipments to a vendor or disposal facility, expected importation of sources, export to a foreign recipient, and storage-in-transit.
- **Disposal facilities** would record source receipt, disposal, or other long-term disposition.
- **All licensees and facilities** would perform periodic physical inventories, report loss or theft, and be able to view and maintain their own information.
- **Other government agencies** would use the system to validate imports or transfers.
- **NRC and DOE** would use the system to monitor the location and use of radioactive sources, detect and act on discrepancies, aid in inspections and investigations, communicate radioactive source information with other government agencies, respond in the event of an emergency, and further analyze hazards attributable to the possession and use of radioactive materials.

Appendix D presents an illustration of the interrelationships of a recommended national source tracking system.

Comprehensive View of Source Control

The national source tracking system should be developed as part of a comprehensive radioactive source control program, because information capture can only be one aspect of protecting radioactive sources from malevolent use. A comprehensive program would integrate the national source tracking system with potentially heightened requirements for materials licensing, local accountability and physical source protection, and government on-site inspection. This program would require new rulemaking, public comment, and consensus-building. Changes would include the prescriptive requirement to uniquely identify sources, enter information on sources into a national source tracking system, and perform periodic inventory and reconciliation of sources. Functional requirements may be enhanced to ensure that

---

[8] The WG believes that, over time, most affected licensees and facilities would be able to record their own information using the Internet. However, especially during initial usage of the database system, NRC would need to accept some licensees' data through other means and record them into the system centrally.

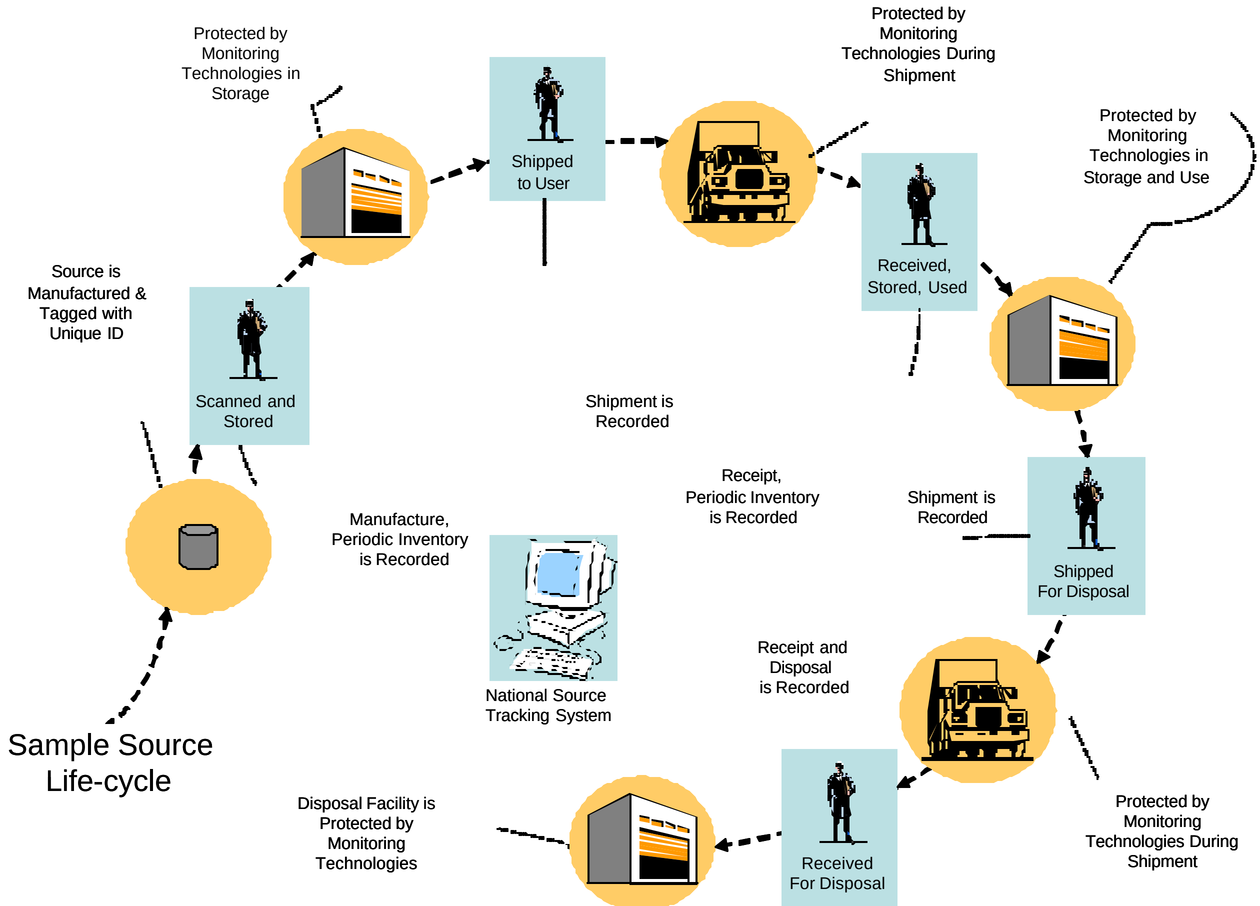


Figure 1 - Radioactive Source Control Program: Supporting Technologies

affected licensees and facilities maintain a high degree of physical source protection and accountability. Licensees and facilities may choose to meet these functional requirements in a variety of ways, including administrative procedures, site-level security, and use of tagging and/or monitoring technologies such as those discussed in Section 3.3. The cost of given technologies would be weighed against the probable benefits of their use.

Figure 1 summarizes the technologies—both the national source tracking system and the use of tagging and monitoring technologies—that can be expected to support a comprehensive source control program The figure assumes that the other elements of the comprehensive program are in place: materials licensing, inspections, site security, and administrative controls and procedures.

Figure 1 shows the life cycle of a sample source, from its manufacture through its disposal. The human figures within rectangles indicate when the source is transferred from one possessor or location to another or when the source is subject to inventory reconciliation. These actions would result in transactions to be recorded in the national source tracking system. The drawings within circles indicate the periods when a source is being manufactured, shipped, used, stored, or disposed. It is during these periods that tagging and monitoring technologies can provide source identification, physical tracking, physical protection, and indication of tampering, as discussed in Section 3.3. These technologies will probably not interface directly with the national source tracking system, although licensees might be expected to record the type of protective procedures and/or technologies they are using during source storage, use, and shipment.

Assessing Existing Systems

The WG reviewed eight existing NRC and DOE systems against the required capabilities of the national source tracking system. None of these systems could immediately accomplish the goal of tracking sources or be suitable for effective and efficient tracking in the long term without extensive modifications.

Preliminary review found that there are many off-the-shelf systems in use in the private sector with inventory and tracking features similar to those that would be needed. These systems should be considered for possible use as part of the analysis of alternatives or business case performed as the next step in developing the national source tracking system.

Benefits and Challenges

A national source tracking system would offer the following safety and security benefits:

- Better accountability for the movement and possession of materials, which could help deter and detect source loss or theft. For example, the system could provide an automatic alert for a source that is shipped but not recorded as received at its destination. This information would allow prompt follow-up action to ensure that the source is secure.
- The ability of U.S. Customs Service and other officials to verify that radioactive materials entering the country are bound for an intended, legitimate recipient.[9]
- Better information for decision-makers about actual movement, storage, use, and final disposition of radioactive materials in the United States. This information would be useful for, among other reasons, refining the assessment of the hazards posed by these materials in various situations.
- Eventual elimination of multiple, existing source tracking systems at DOE, and integration with a planned Internet-based licensing system at NRC. Thus, some costs of implementing the system would be recouped by the elimination of existing systems and by resource sharing.
- An easy-to-use, standard software tool for commercial licensees and DOE facilities to use in managing shipments and inventories of radioactive sources, as well as in fulfilling reporting requirements to regulatory agencies.

The challenges of implementing a national source tracking system include:

- Significant costs and long lead time associated with the necessary rulemaking activities; system development; coordination among organizations (NRC, DOE, Agreement States, and U.S. Customs); and system implementation throughout the country at licensee locations, DOE facilities, and U.S. points of entry.
- Significant operational challenges such as administering a nationwide system, providing adequate system security, providing training, and supporting a large, heterogenous user group.
- Significant management challenges and risk of project failure because of large project scope and complexity. Greater challenges to implementing a national source tracking system exist in the areas of policy development, rulemaking, consensus-building, and coordination among organizations, rather than in information system development.

---

[9] It should be noted that online verification of licensees receiving imports could be made by Customs officials without a national source tracking system. (Licensee verification would involve developing a central database of licensees, although not necessarily of sources.)

To help meet the challenges of developing a national source tracking system, a business case, as required under the Clinger-Cohen Act, needs to be performed. A business case analyzes major Federal government information technology acquisitions and is intended to minimize risk. It includes a requirements analysis, an analysis of alternatives, a system design, an acquisition strategy, and a cost assessment. The business case analysis should begin in the near term with a goal of implementing the tracking system in the longer term.

Interim measures towards the national tracking system are beginning in the near term. For example, both DOE and NRC are taking steps to create an initial inventory of sources containing the materials of greatest concern. This inventory will provide a snapshot of current licensees, facilities, and the sources they possess. DOE will accomplish this inventory using an existing DOE system, the Nuclear Materials Management and Safeguards System (NMMSS),[10] to consolidate approximately 50,000 DOE records from various site systems. The desirability for periodic updates and reconciliation with site records is also being evaluated as a means to assure data reliability and assess data anomalies. NRC is working with its Agreement States on identifying licensees with radiological sources of greatest concern in an expeditious manner. This effort will lead to an initial inventory of sources which will provide immediately useful information and help establish contact with licensees who will participate in implementing the eventual tracking system.

Areas for Further Consideration

A number of areas need further analysis and action. At a policy level, it should be kept in mind that the national source tracking system could track any radioactive sources or materials deemed appropriate, not just those of concern for potential use in an RDD. Eventual consideration should include the merits of consolidating requirements for any radioactive source or material tracking.

Another policy consideration is that the system will require manufacturers to identify sources with unique identifiers. Fulfilling this requirement may demand a scheme of unique U.S. source identifiers, rulemaking to require source identification by manufacturers, and, in some cases, physical redesign of sources or containers to accommodate identification.

In addition, a major design issue is to decide how aggregation of sources affects what is tracked. The concept of tracking a source that contains a hazardous quantity of materials from “cradle-to grave” seems simple. However, the analysis that led to the identification of materials and near-term actionable quantities examined only single isotopes stored at licensee and facility sites; it did not consider multiple isotopes stored together, or materials in transit. On closer examination, there are questions that arise from source aggregation in storage or transit:

- Sources containing different isotopes may be stored at a given location. Should these sources be tracked because in the aggregate they pose a hazard? Is there a need for an aggregate material tracking threshold regardless of isotope?

[10] NMMSS is the U.S. Government's information system containing current and historic data on the possession, use, and shipment of nuclear materials. This centralized database contains information collected from government and commercial nuclear facilities. NMMSS tracks and accounts for special nuclear, source, and byproduct nuclear materials as defined by the Atomic Energy Act of 1954, and other materials as required by agreements with the IAEA and other countries on the peaceful uses of nuclear energy.

- In transit, multiple sources—each containing a small quantity of materials—can form an aggregate quantity that exceeds a near-term actionable threshold. Should these sources be tracked during transit, even though when present singly at a licensee or facility location they are too small to warrant tracking?

These questions raise the possibility of sources being tracked only in transit, or only at a particular storage location, violating the concept of tracking materials of concern from "cradle to grave." How sources aggregation should affect tracking needs to be considered carefully, using real-world scenarios.

Another issue is deciding how to integrate appropriate disposition pathways for unwanted sources into the design of the system. (See Section 3.4 for a discussion of closing the gaps in current disposition pathways for unwanted sources.) For example, since multiple licensees and facilities would have access to the system, it might be used to help match unwanted sources and licensees in search of reusable sources.

Finally, consideration needs to be paid to designing a system that will ease regulatory burden on commercial licensees and DOE facilities. To the extent possible, the system should fit source handling processes and reporting requirements with regulatory agencies. To this end, user organizations should be involved in choosing or creating the eventual software.

3.3 Tagging and Monitoring Radioactive Sources

The application of a minimal level of tagging and monitoring technology is needed to complement the national source tracking system in a comprehensive program of source tracking and protection as described in Section 3.2. Additionally, tagging and monitoring technology can provide a cost-effective means for licensees and facilities to track, monitor, inventory, and control all of their radioactive sources. Radioactive materials of greatest concern will need to be tracked throughout their entire lifetimes. This will require technology to uniquely identify material, determine the location of the material, and ensure that the material has not been tampered with and is still in the location where it was last placed by an authorized user. These technologies will enhance the safety and security of radioactive materials and ensure that the Federal government maintains near real-time knowledge of the location of radioactive materials of greatest concern and that the loss, theft, or tampering of these materials is properly and promptly reported.

Technologies for tagging and monitoring materials are designed to acquire information concerning the state of a given material at a given time. First, material must be uniquely identified. This can be done in a number of ways including bar-coded labels and radio frequency (RF) tags. Although many sources are too small to be conveniently tagged, most can be tagged by adding the tag to another material that is permanently affixed to the radioactive material. For monitoring and tracking purposes, the state of a radioactive material may be defined in terms of:

- **Material presence** (Is the material in the expected location and of the expected quantity?)
- **Package tampering or storage area intrusion** (Has anyone attempted to move the material in an unauthorized fashion?)
- **Material location** (Where is the material located?)

The state of the material may be determined by measuring or monitoring various attributes such as weight, temperature, radiation type, quantity, unique identification number, motion detection, tamper indication, or position via global positioning system (GPS) or RF tracking. These attributes provide ample opportunity to monitor a source throughout its life cycle—manufacturing, shipping, storage, and use. However, the costs associated with monitoring the various state indicators can be highly variable. The table in Appendix E summarizes representative material states and measured or monitored attributes. Appendix F presents the common uses and descriptions of a representative set of radioactive materials of greatest concern..

The suitability of a particular technology for tagging or monitoring isotopes is entirely dependent on the depth and breadth of the requirements, which will be determined by what material is to be monitored, the objective of the monitoring, and what phase of its life is to be monitored. As discussed in the previous section, the national source tracking system would provide enhanced material accountability, where at each step of a material's life cycle its presence, location, and tamper indication will be determined and recorded. This could be augmented by the use of tagging and monitoring technology to ensure that the radioactive materials of greatest concern are not lost, stolen or tampered with between these life cycle opportunities for detailed human review (e.g., during manufacturing, prior to shipping, at receiving, during inventories). The functional requirement for the monitoring of materials would include the needed level of assurance that the material is where it should be and has not been tampered with.

At those life-cycle points where licensees are required to enter data into the system, as shown in Figure 1, the identity and tamper indications would be of most importance. Each source or material could be tagged with an unique identifier that will make the identification and entry into the national source tracking system as simple and automated as possible. During transportation, long-term and *short-term storage*, and in some cases, use, the presence and location of the sources or material will be of most importance. The use of technology-enhanced security systems and source location technology can provide an alternative method for meeting the functional requirement for any specific level of assurance of a source's location and tampering status. The needed level of assurance that the material has not been lost or stolen will be determined with input from the various stakeholders. The licensees or facilities will then be able to determine the appropriate level and method of internal monitoring.

By employing a more frequent and automated source tracking protocol for the radioactive materials of greatest concern, the licensees and facilities can improve inventory and material control at a relatively low cost and operational impediment. As noted in Section 3.2, automated database technologies are available which use barcode and imbedded data tag technologies and radiation detectors. These systems are quite simple to operate, are relatively inexpensive and robust, and encompass several classes of technologies, the most relevant of which are identified below. They can be used both as a positive means of source inventory control and for internal tracking and accounting for the licensee or facility.

Tamper-indicating devices (TIDs), when used as part of an inspection and reporting program, are very valuable as material monitors. The active TIDs, essentially alarms, can provide significant value for mobile source use. Whether active or passive, these systems, from simple metal wires to advanced ceramic and electronic smart-systems and smart bolts, can provide either an immediate indication of device tampering or provide indication on inspection. Technology costs are highly variable, ranging from pennies for passive mechanical TIDs, to \$1–\$5 for passive RF tags, \$40–\$100 for advanced active tags, and \$200–\$300 for multi-attribute monitoring systems. Although considerable benefit may be realized from the broad use of seal and other TID technologies, these technologies must be implemented in conjunction with enhanced tracking systems to realize the full benefit. For example, a simple system of more regular material accounting (through observing and recording material identifiers and TID condition) and regular electronic reporting to a central database is technically feasible with a minimum of operational difficulty.

In addition to material monitoring technologies, other technologies and technical assessment expertise are readily available, in both the government and commercial sectors, to enhance the physical security of radioactive materials. Some examples are enhanced monitoring of the physical facilities and facility and computer access control, including real-time surveillance and bio-metrics. Facilities may benefit from enhanced access control, real-time material monitoring, or other security measures enabled by available technology. Security systems (e.g., alarms, robust locks) are also available to enhance the secure transit and storage of materials used in mobile applications such as weld inspection devices, well logging devices, and other instruments typically transported to the job site. By employing various technologies to enhance the security of radioactive materials, the materials became less attractive for use in an RDD.

For random auditing purposes and facility/portal monitoring, radiation detection equipment currently exists that is capable of determining the type and quantity of an isotope in a container. Use of such systems for accountability purposes, however, would require trained personnel and detectors that could be costly for certain users. GPS-based vehicle tracking may be feasible for larger shipments from manufacturers over extended distances, and RF technologies may be useful for on-site or short-distance tracking. Together with package identifiers and readers (e.g., electronic tags, bar codes), the GPS and RF tracking methods can provide a continuity of knowledge of material location along a shipment route.
These technologies are commercially available and in routine use. Again, their usefulness depends on the co-deployment of effective accounting and inspection programs. Systems for specialized uses, such as operation in a radiation field, require further technological development to be appropriately functional and cost-efficient.

3.4 Dispositioning Unsecured Radioactive Sources

The WG identified all the potential ways that sources could become unsecured, thereby requiring disposition. The group identified six avenues for recovery, largely according to whether the possessor is authorized, unauthorized, or unknown. A possessor who is not considered a security risk will have different available disposition paths than a possessor who poses a security risk. Appendix G provides further definition of these avenues.

- Unwanted Sources, Authorized Possessors
- Authorized Possessor Posing a Health and Safety Risk (wanted/unwanted sources)
- Wanted Sources, Unauthorized Possessors
- Found Sources
- Confiscated Sources (health and safety or national security)
- International Recoveries

The available disposition pathways to bring the source into a secure environment are short-term storage, *long-term storage, reuse*, recycle, and final disposal. In evaluating the mechanisms to support these pathways, the WG considered the types of sources covered and the services available for each disposition pathway. The supporting mechanisms include programs run by Federal agencies (e.g., DOE, NRC, the National Nuclear Security Administration (NNSA), and EPA), State-related programs (e.g., radiation control programs or low-level waste disposal compacts), and commercial outlets (e.g., commercial low-level waste disposal, manufacturers, and other authorized commercial possessors). Current pathways form a suitable structure for recovery; however, some of the mechanisms need to be fully implemented or enhanced to adequately address current and projected needs. The following mechanisms (more fully described in Appendix G) were identified:

- DOE OSRP
- DOE NISS Management Group
- DOE Central Scrap Management Office
- DOE Office of Plutonium, Uranium, and Special Materials Inventory *Loan/Lease Program*
- Conference of Radiation Control Program Directors National Orphan Radioactive Material Disposition Program
- Transfers to other authorized possessors
- Return to responsible party (owner)
- State programs (Radiation Control, Health, and Environmental Protection)
- Manufacturer/Distributor Return Mechanisms
- Issue or Amend License/Authorization to Ensure Authorized Possessor
- EPA Emergency Response
- Commercial Low-Level Waste (LLW) Disposal Facilities (not available for GTCC waste)
- Future State Compact LLW Disposal Facilities
- DOE LLW Disposal Facilities
- DOE Radiological Assistance Program
- DOE NNSA Material Protection Control and Accountability Program

Not all these disposition mechanisms provide similar services. In fact, although many programs facilitate disposition, few actually take possession and actively disposition sources themselves. Of note, the DOE OSRP is one of the only Federal entities that takes title to sources and holds them in protective custody awaiting their final disposal (only for GTCC waste). Similarly, commercial and DOE LLW disposal facilities are the only entities that provide permanent disposal for sources. Existing disposition mechanisms are typically geared to provide limited disposition assistance, not full cradle-to-grave disposition services.

The WG assessed these disposition mechanisms to determine their capabilities to address recovery of sources and to mitigate a potential or actual threat posed by vulnerability of the source. A gap analysis was performed for each of the identified avenues and disposition mechanisms. A gap was considered to exist wherever there was not a complete disposition pathway for a source or where a disposition pathway was restricted by a lack of funding or storage/disposal capacity. The results of the gap analysis are summarized briefly here and more fully in Appendix G.

The results of the gap analysis demonstrated that no single mechanism exists to comprehensively disposition (i.e., provide short-term storage, long-term storage, reuse/recycle, and/or disposal) sources under all recovery scenarios. At the same time, homeland security concerns may result in an increase in the types and numbers of sources to be recovered.

U.S commercial LLW disposal options may be limited for some sources in the existing three LLW disposal sites in the U.S. The Envirocare facility accepts only Class A waste and not the many sources that are higher activity Class B and C waste. The U.S. Ecology facility in Hanford Washington is specifically prohibited from accepting waste from States outside of the Northwest and Rocky Mountain compacts. The Barnwell facility, although it accepts LLW from all States outside of the Northwest and Rocky Mountain compacts, will prohibit out-of-compact waste in 2008. The LLWRPAA makes states responsible for disposal of their own LLW, however, there may be certain cases where the State imposes site-specific restrictions on certain sources so that not all radioactive materials are accepted to the full limits allowed by the waste classifications defined in 10 CFR 61.55. Because these radioactive materials are below the Class C limits (i.e., not defined as GTCC waste), they lack a disposal path.

Consistent with the LLRWPAA, the Federal Government is responsible for the disposal of GTCC waste. Uncertainty remains as to how to ensure that beneficiaries of the activities that resulted in the generation of such waste bear all reasonable disposal costs. A GTCC-waste disposal capability has not been identified, and the LLRWPAA does not establish a deadline for GTCC waste disposal to take place. DOE has accepted some forms of GTCC sealed sources for long-term storage, pending GTCC waste disposal, through its OSRP (within the funds specifically appropriated for the recovery effort). However, the GTCC sources the OSRP can currently accept are limited; for instance, the OSRP is unable to accept Pu-239 sources because of a lack of storage capacity.

The gap analysis also showed that disposition mechanisms providing short-term storage on an emergency basis are limited. There are many entities with roles in short-term storage (e.g., States, EPA, NRC licensees, and DOE); however, the emergency capabilities vary. Further, if confiscation is required significant questions arise as to who has authority to confiscate, possess, and take title to sources.

Of the various disposition mechanisms that exist, sources that contain material considered “wanted” by other authorized users are the easiest to address. In these cases, those who want the sources facilitate disposition activities, though it still takes time and effort to determine whether a source is wanted, and by whom, and to ensure appropriate authorization is in place before transfer. When a source is unwanted, issues of funding, liabilities, and authorities are harder to resolve within the current disposition framework. Although some DOE programs (e.g., DOE’s Loan/Lease Program) have clear mechanisms in place to distribute sources (e.g., through loan/lease agreements), they do not always have clear policies in place to address return/recovery of those materials. Under any condition, few existing disposition mechanisms provide for the transport of sources under recovery scenarios to another user or to storage/disposal.

The analysis showed that international recoveries currently appear to lack a well-defined process because of the varied recovery mechanisms used involving DOE, Department of State, Department of Defense, the IAEA, and others.

In assessing solutions, DOE and NRC must be careful to balance mechanisms for source disposition such that the Federal agencies do not undermine the LLRWPAA (currently most States have not been able to fulfill their LLRWPAA commitments). Alternative mechanisms must be carefully crafted so as to not reduce or eliminate the need for the compacts and to avoid abuse of Federal mechanisms (e.g., do not create incentives to licensees to declare bankruptcy to become eligible for Federally-assisted recovery of unwanted sources).

4.0 Conclusions

The WG’s primary conclusions in each of the four focus areas are provided below.

4.1 Radioactive Materials of Greatest Concern

(1) Although there are gaps in available data and the Sandia methodology would benefit from enhancements, the relative evaluation of radioactive material provides sufficient basis for

determining initial radioactive materials of greatest concern. These materials should receive priority, near-term attention to assess the need for security enhancements.

(2) This initial assessment identified only a small percentage of radioactive materials in use by DOE and NRC licensees that pose a risk to public health and safety if attempts are made to use them as RDDs because of form, half-life, quantity, and protections currently in place.

(3) To confirm final determinations regarding risks to materials, the threat needs to be characterized.

(4) Vulnerability assessments for the different types of uses of radioactive material are needed to determine appropriate protective measures.

4.2 Tracking and Inventorying Radioactive Sources

(5) There are no requirements to report much of the information needed for a national tracking system to regulatory agencies. Consequently, there is no current single source of data on the radioactive sources in circulation in the United States. Currently, no nuclear industry information system—whether government or private sector, single or collective—satisfies all the objectives of a national source tracking system. Existing related NRC and DOE systems have many deficiencies that preclude any single system from being used directly to start a national source tracking system.

(6) A national source tracking system would offer benefits including: better accountability for radioactive materials of greatest concern; verification of imports, better information on source use, location and movement; and potential elimination of existing systems. However, costs will be high, lead time will be long, and there would be many challenges associated with developing and operating a complex, national system.

(7) Although it will provide greater source accountability, a national source tracking system will not provide physical protection of sources. The system should be developed as part of a comprehensive radioactive source control program for radioactive materials of greatest concern.

(8) The objective of a national source tracking system needs to be satisfied through a combination of rulemaking, coordination among government agencies and licensees, system development, and integration of existing business technologies.

4.3 Tagging and Monitoring Radioactive Sources

(10) Many tagging technologies—from the relatively inexpensive and simple to the more exotic—exist that can be adapted readily for use in commercial and government environments.

(11) Tagging of all radioactive materials of greatest concern with unique identification numbers is currently feasible.

(12) Tagging technologies with the potential for the greatest immediate application to increase source security are electronic tag technologies and TIDs. These technologies, when used in conjunction with the national source tracking system, will improve source accounting.

(13) Technology costs per device are highly variable, ranging from pennies for passive mechanical TIDs, to $1–$5 for passive RF tags, $40–$100 for advanced active tags, and $200–$300 for multi-attribute monitoring systems.

(14) Additional technology development may be necessary to tailor available devices to specific needs including radiation hardening, reduction in logistics support (power, cooling, maintenance, etc.), or secure data transmission.

4.4 Dispositioning Unsecure Radioactive Sources

(15) No single mechanism exists to comprehensively disposition sources under all recovery scenarios.

(16) Sources that are wanted by other authorized users are the easiest to store or disposition.

(17) Few existing disposition mechanisms provide for the transport of sources under recovery scenarios to another user or to storage/disposal.

(18) GTCC waste lacks a disposal path.

(19) Disposition mechanisms to provide short-term storage on an emergency basis are limited.

(20) In some cases, LLW disposal options are limited by site-specific restrictions due to the compact laws or restrictions imposed by the States.

(21) DOE programs (e.g., DOE's Loan/Lease Program) do not always have clear policies in place to address return/recovery of DOE-owned materials.

(22) International recoveries currently appear to lack a well-defined process.

5.0 Recommendations

Presented below are the WG recommendations for actions that require a decision by the Secretary or Commission to implement. Remaining WG recommendations are considered operational-level actions and are summarized in Appendix H. No effort has been made to prioritize these actions; such prioritization would be part of the implementation process.

1. **Establish a national RDD protection level in coordination with the Department of Homeland Security and other agencies.** In the near term, each agency will use their thresholds to evaluate its facilities to determine if material exceeding the thresholds needs to be better protected. This protection level should be consistent with that of other elements of the national infrastructure. Evaluate the consequences for criteria other than radiological dose, including economic impacts and disruption of society. Consider dose as a surrogate for these other criteria.

2. **Develop a national threat policy.** Define threat characteristics that could impact use of radioactive material in an RDD in coordination with the Department of Homeland Security. Continue assessing vulnerabilities of specific facilities or licensees or classes of licensees. These threat characteristics should be used to confirm scenarios considered in vulnerability analyses of the materials of concern.

3. **Initiate development of a national source tracking system** to better understand and monitor the location and movement of sources of interest. Develop in the near term, a business case that includes a system requirements analysis, an analysis of system alternatives, a system design, an acquisition strategy, and a cost assessment to support such a system. Utilize interim databases to gather available data and gauge system capabilities. In both policy and system design decisions, the availability and cost-effectiveness of tagging and monitoring technologies should be considered.

4. **Develop an integrated national response strategy for rapid recovery of unsecured sources in coordination with the Department of Homeland Security.** Through the Office of Homeland Security RDD Working Group, develop a Federal/State partnership to establish appropriate controls and implement a system to rapidly recover and store unsecured sources. The system should provide funding to ensure emergency transport of unsecured sources and effective interactions with Federal, State, and local emergency response personnel. The DOE OSRP should continue providing for rapid recovery in the interim, and long-term program management should be clearly defined.

5. **Develop an integrated national strategy for disposition of unsecured sources.** This includes: clearly defining organizational responsibility within DOE for the decision on where to dispose of sources that are GTCC; accelerating recovery of sources by NRC and DOE consistent with this report's findings; and adhering to the LLRWPAA, including the Federal government establishing GTCC waste disposal capability and securing adequate funding for such disposal consistent with ensuring that beneficiaries of the activities that resulted in the generation of greater-than-Class C waste bear all reasonable costs of disposing of such waste, and States conforming to their responsibilities as set out in the Act. The LLRWPAA should be reviewed for further enhancements to allow more effective and uniform management of radioactive sources in each State. If necessary, site specific restrictions on sources should be re-examined to determine if some sources can be safely disposed using alternate criteria. If new disposal facilities are developed, DOE and NRC should work with the States and developers to ensure that the widest range of sources can be disposed of safely.

6. Enhance coordination and communication with other Federal agencies, including the Department of Homeland Security (including its Transition Management Office) and Department of Defense, that have activities underway related to RDD prevention and mitigation. Seek common and/or complementary technology and data approaches. Achieve efficiencies in consequence modeling and research initiatives. Evaluate current agreements between Federal agencies to determine the need for update or modification (e.g., determine whether the memorandum of understanding between the NRC and DOE applies to source recoveries for security reasons).

7. **Continue U.S. coordination with the IAEA** to finalize the Code of Conduct on the Safety and Security of Radiological Sources and Categorization of Sources.

6.0 References

1. U.S. Department of Energy (DOE)/U.S. Nuclear Regulatory Commission (NRC) Hazards Subgroup, *Assessment of the Relative Radiological Dispersal Device Hazards of Materials Under NRC License and DOE Control*, February 21, 2003.

2. DOE/NRC Tracking Sources Subgroup, *Information Systems for Tracking Radiological Sources,* January 24, 2003.

3. DOE/NRC Technological Methods Subgroup, *Technologies for Enhanced Safeguards of Radioactive Materials,* October 28, 2002.

4. DOE/NRC Source Disposition Subgroup, *Recovery, Storage, and Disposition of Radiological Sources,* March 15, 2002.

5. Sandia National Laboratories, *An Initial Study to Identify Materials of Greatest Concern For Use in a Radiological Dispersal Device,* November 15, 2002.

6. International Atomic Energy Agency, *Categorization of Radiation Sources*, TECDOC-1191, December 2000.

7. International Atomic Energy Agency, *Categorization of Radioactive Sources*, TECDOC-1344, April 2003.

Appendix A

Acronyms and Abbreviations

AEA	Atomic Energy Act
Ci	Curies
CRCPD	Conference of Radiation Control Program Directors
CSMO	Central Scrap Management Office
DOE	Department of Energy
EPA	Environmental Protection Agency
FRERP	Federal Radiological Emergency Response Plan
g	gram
GPS	global positioning system
GTCC	greater-than-Class C
IAEA	International Atomic Energy Agency
LLW	low-level waste
LLRWPAA	Low-Level Radioactive Waste Policy Amendments Act
LTS	Licensing Tracking System
mg	milligram
NARM	naturally-occurring and accelerator-produced radioactive material
NISS	Nonactinide Isotope Sealed Source
NISSMG	Nonactinide Isotopes and Sealed Source Management Group
NMMSS	Nuclear Materials Management and Safeguards System
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
OSRP	Off-Site Source Recovery Program
PAG	Protective Action Guideline
RAP	Radiological Assistance Program
RED	radiological exposure device
RDD	radiological dispersal device
RF	radio frequency
TID	tamper-indicating device
WG	DOE/NRC Interagency Working Group on Radiological Dispersal Devices

Appendix B

Glossary

Agreement State
A state that has signed an agreement with the Nuclear Regulatory Commission under which the state regulates the use of byproduct, source, and small quantities of special nuclear material within that state. There are 32 Agreement States and approximately 16,300 licenses issued within those states.

Business Case
An analysis that defines major Federal government information technology acquisitions and that is performed to minimize risk. A business case includes a requirements analysis, an analysis of alternatives, a system design, an acquisition strategy, and a cost assessment. Performance of a business case for acquisition of significant information systems is required under the Clinger-Cohen Act.

Database System
An automated information system, including the hardware, networks, computer programs, database, and other software used to define, create, transmit, store, manage, and analyze the information.

Final Disposition
The end of the life cycle of a source, including final disposal, reuse, and recycling.

Greater-Than-Class-C (GTCC) Radioactive Waste
Defined in the Low-Level Waste Policy Amendments Act of 1985 as LLW that exceeds the Class C limits in 10 CFR 61.55, "Licensing Requirements for Land Disposal of Radioactive Waste." This section classifies LLW as Classes A, B, or C, according to concentration of specific short- and long-lived radionuclides; this section also sets varying requirements on waste forms for disposal. Most forms of GTCC waste are generated by moisture and density gauges and contaminated trash, and routine operations at (1) nuclear power plants, (2) fuel research facilities, and (3) manufacturers of radiopharmaceuticals and sealed sources used in medical and industrial applications. GTCC waste is generally unacceptable for near-surface disposal.

Hazard Index
An index that provides an relative indication of the level of concern for radioactive materials. It is based on dose impacts combined with material quantity and the ability to obtain the material.

Improvised Nuclear Device (IND)
Nuclear weapons that are fabricated by an adversary State or terrorist group from illicit nuclear material and that could produce nuclear explosions.

License
A license issued under the regulations of Parts 30 through 36, 39, 40, 50, 60, 61, 63, 70, or 72 of Title 10 of the Code of Federal Regulations or by an Agreement State under its equivalent regulations. About 21,000 specific licenses are issued for medical, academic, and industrial uses of nuclear materials. Reactor-produced radionuclides are used extensively throughout the United States for civilian and military industrial applications, basic and applied research, the manufacture of consumer products, civil defense activities, academic studies, and for medical diagnostics, treatment, and research. The regulatory

programs of NRC and Agreement States are designed to ensure that licensees safely use these materials and do not endanger public health and safety nor cause damage to the environment. Approximately 5000 specific licenses are administered by NRC.

Loan/Lease Program
DOE provides nuclear materials under the Loan/Lease Program to academic, medical, and research institutions, under contractual agreements that specify the material be returned to DOE for final disposition although at this time no program within DOE has been designated to accept returned material.

Long-Term Storage
Storage with little or no limits on its duration. This type of disposition mechanism can be used while arrangements are made for final disposition, because of: (1) lacking a final disposal option; (2) lacking available funds; (3) needing time to complete an amended or new authorization; (4) needing time to establish a new disposition pathway; or (5) pending the availability of transportation to a new disposition location. Long-term storage can be an effective mechanism to alleviate a health and safety or security risk posed by a source. However, long-term storage may not permanently alleviate the risk associated with the source.

Naturally-occurring and Accelerator-produced Radioactive Material (NARM)
Naturally-occurring radioactive materials such as radium-226 and accelerator-produced materials such as cobalt-57, which are regulated by the States.

Monitoring
The continuous or near-continuous observation of some material attribute that provides a measurable indication of location, condition, and/or use.

Radiological Exposure Device (RED)
A device whose purpose is to expose people to radiation, rather than to disperse radioactive material into the air, as would an RDD. An RED could be constructed from unshielded or partially shielded radioactive materials in any form placed in any type of container.

Radiological Dispersal Device (RDD)
A device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means.

Recycle
Reprocessing a source by altering its sealed container or form.

Reuse
Transfer (including the title) of a source from one entity to another with the intention of the receiving entity to use the source in its current form.

Short-Term Storage
Interim storage, typically on-site or at a near-by facility, pending a decision on the appropriate mechanism for final disposition. Short-term storage is used to mitigate an immediate health and safety or security risk. Generally, such storage cannot completely alleviate the risk.

Tracking
For the purposes of this report, performing some act or implementing some system to facilitate the maintenance of knowledge of the location of a given material at any given time.

Appendix C

Charter for the U.S. Department of Energy/U.S. Nuclear Regulatory Commission Interagency Working Group on Radiological Dispersal Devices

1.0 Purpose

In June 2002, the Secretary of Energy and the Chairman of the Nuclear Regulatory Commission (NRC) agreed to convene a joint working group (WG) to address key issues associated with radiological dispersal devices (RDDs). The WG is tasked with identifying those areas in which Federal resources should be directed to improve protection of materials of interest and to provide this information in a final summary report (non-classified, with classified appendices as necessary). The four priority focus areas are determining: (1) the relative hazards of the materials within NRC's regulatory jurisdiction and the Department of Energy's (DOE's) responsibility; (2) an appropriate database framework for tracking sources of importance; (3) actions for facilitating short-term and long-term disposition of unsecured excess and unwanted sources; and (4) the feasibility of tagging sources for tracking while in use, storage, and transit.

2.0 Schedule

The WG will provide a final report, including specific recommendations for consideration by the Secretary and Commission, by November 29, 2002.

3.0 WG Structure

An Executive Team functions to provide overall policy direction and guidance to the WG. To address the four priority issues as fully as possible within the time available, the WG established subgroups corresponding to each of the priority focus areas enumerated in the "Purpose" section, above. Lead agencies have been assigned for each subgroup: joint DOE/NRC lead for Hazards; NRC lead for Tracking Sources; and DOE lead for Source Disposition and Technological Methods. Each subgroup has membership from both DOE and NRC, as well as assigned lead individuals from each agency to ensure appropriate organizational interfaces. The WG also established a Writing Team comprised of representatives from DOE and NRC. This Team is responsible for drafting the final report based on products provided by each subgroup and serves as the liaison between the Executive Team and the subgroups. The membership section identifies the teams and subgroups and their members.

4.0 Supporting Subgroup Goals

Each subgroup has determined the scope of its assigned task consistent with the overall product schedule. Each will prepare a final report, including specific recommendations for programmatic and policy changes, to improve Federal control of materials of interest, as well as suggest further research and efforts to answer key questions needed for ultimate policy decisions. Subgroups will attempt to provide resource requirements for specific recommendations. The specific goals of each subgroup follow.

4.1 Hazards Subgroup

Determine the relative hazard of radionuclides or classes of sources, considering health effects in terms of dose and quantitative dimensions of attractiveness. Investigated dimensions would include: half-life, accessibility, portability, quantity, convertability to usable form, location, weight and size, and physical characteristics. The assessment will include available data on health effects and qualitative components and will categorize radionuclides or classes of sources in accordance with relative hazard. The utility of having threshold criteria will be explored.

4.2 Tracking Sources Subgroup

Evaluate the options for establishing a database to track sources that have been identified as being the greatest hazard. The primary purpose of the database would be to enhance the accountability for those sources by having a closer-to-real-time location of any source and an accurate listing of all sources by location. The subgroup will analyze data needs for tracking sources, summarize the current similar databases, including their shortcomings and the feasibility of their use for this purpose, and review relevant past databases for lessons learned.

4.3 Source Disposition Subgroup

Describe the issues and concerns related to recovery; storage; and disposition of unsecured, excess and unwanted sources (both greater-than-Class-C (GTCC) and non-GTCC waste) by generally describing current processes and capabilities to recover sources, assessing options associated with accelerating source recovery, and addressing the framework necessary to continually capture these types of sources. Discussion will include activities to accelerate recovery, short- and long-term storage issues, and identification of a final disposition path for sources.

4.4 Technological Methods Subgroup

Evaluate the feasibility of tagging radioactive sources to make them identifiable and trackable while in use, storage, and transit in a cost-effective manner. This will involve reviewing materials identified as the greatest hazard to identify which sources should be tracked; identifying where the tracking should begin and end; and developing a summary of available technologies that could be used for identification, tagging, and monitoring of sources. The subgroup will suggest a decision framework for determining what sources warrant tagging and/or monitoring.

5.0 **Membership**

The WG includes individuals from DOE and NRC organizations with responsibilities for safety, security, management, and disposition of radioactive materials. They are:

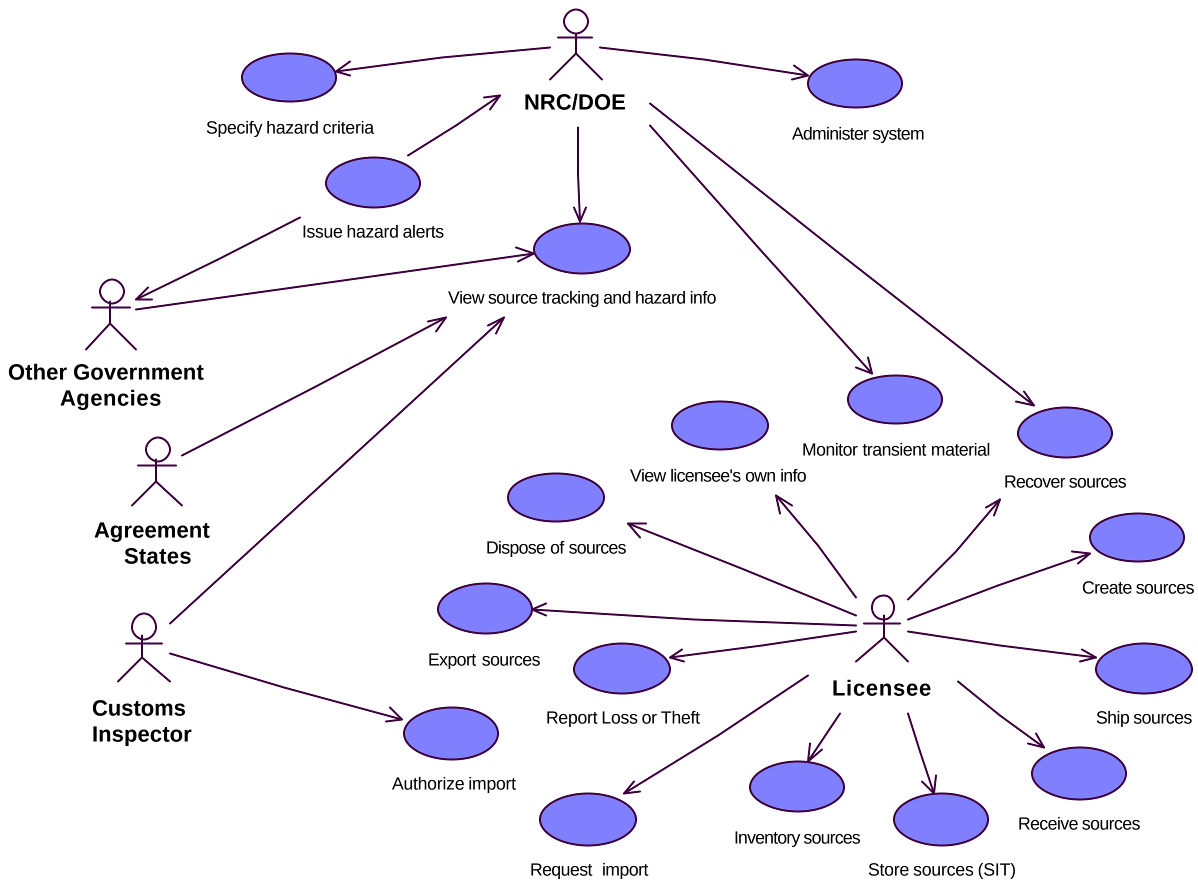
	DOE	NRC
Executive Team	Patrice Bubar Steven Aoki	Carl Paperiello Margaret Federline
Writing Team	Ruth Watkins	Melanie Galloway Tamara Trocki
Hazards Subgroup	Samuel Callahan (Lead) Steven Aumeier Melanie May	Melanie Galloway (Lead) John Hickey Jocelyn Mitchell Sami Sherbini
Tracking Sources Subgroup	David Crawford (Lead) Ruth Watkins	William Ward (Lead) Walt Schwink Tamara Trocki
Source Disposition Subgroup	Karen Guevara (Lead) Melanie May Sujita Pierpoint	Tamara Bloomer (Lead) Doug Broaddus Michele Burgess
Technological Methods Subgroup	Steven Aumeier (Lead)	Steven Arndt (Lead)

Appendix D

National Source Tracking System

This appendix provides Figure D-1, which presents an illustration of the interrelationships of a recommended national source tracking system, where the human figures stand for users—individuals or organizations—and the oval shapes represent major functions users will accomplish using this system

Figure D-1. National Source Tracking System



Appendix E

Representative Material States and Attributes

State	Attribute Monitored/Measured	Deployment Examples
Unique identification	• Serial number, code, etc.	Identification of item using bar code readers, electronic tags or other technology.
Presence	• Weight • Temperature • Radiation • Visual depiction (video) • Material quantity	Sensors placed on storage cans, around use areas, and in storage vaults/locations that sense material presence and/or state.
Tamper Indication /Intrusion	• Package tamper (fiber optic, electrical, and mechanical seals and TIDs) • Gas/isotope packaging matrix • Package motion • Storage area beam breaks and other area monitors • Video	TIDs placed on storage cans, in shipping containers, in and around use areas, and on or around facilities where used or manufactured. Radiation portal monitors.
Location	• Electronic tag or button with radio relay • Global positioning system or radio frequency tracking of package or shipping container • Radiation	Tags placed on material containers or shipping vehicles while in transit, signal relayed to tracking system in either passive or active mode, and regular item accounting. Radiation monitors provide indication of material presence.

Appendix F

Characteristics of Certain Isotopes of Greatest Concern

Isotope	Common Use	Description (size, radiological characteristics, quantity, form, storage configuration, etc.)
Am-241	Measurement instruments, including well logging instruments and gauges	Sources are typically small to moderate in physical size and radiological emission (up to 1 inch in diameter, 6-inches long, and tens of millicuries to tens of curies in strength); smoke detectors use microcurie quantities. In neutron sources, the Am-241 is typically mixed with beryllium oxide, which is a toxic substance; double-encapsulated in stainless steel holders; and used for a variety of industrial assay applications. Thousands of these sources are in use.
Cs-137	Medical imaging, food/other irradiation, gauges	Found in sealed portable sources and in large irradiation facilities. The sealed sources are often found as cesium chloride, a form of particular concern for RDD use.
Pu-238	Medical devices and measurement instruments	In the past used as a heat source for pacemakers, an application that was phased out in the early 1970s. Also used as a thermal-electric generator heat source where it is contained as an oxide in stainless steel or other containers. As with the Am-241 and Pu-239, and unlike the gamma emitters, a great deal of shielding is not required in application.
Sr-90	Heat source for thermal-electric generators and sealed sources.	Used in large quantities in heavily shielded configurations.
Po-210	Static eliminators	Typically found as metal foils.
Co-60	Food/other irradiation and radiography	Typically cast as metal rods, or pins, several to dozens of which are combined in a holder to provide desired radiation intensity. Storage requires heavy shielding, typically in large facility.
Ir-192	Gamma source used for mobile and fixed radiography applications.	Used in many fixed and mobile irradiation applications, these sources are found in instruments used for weld inspections and other industrial applications. The mobile application of these sources and availability make them a particular concern.
Pu-239	Alpha or neutron source, typically used in research	Used in research facilities, these sources are generally small because significant quantities of Pu-239 are tightly regulated because of weapons potential.
Cm-244 or Cf-252	Neutron source used in research and measuring instruments	Sources are small, and those in instruments are shielded.

Note: Am: americium; Cs: cesium; Pu: plutonium; Sr: strontium; Po: polonium; Co: cobalt; Ir: iridium; Cm: curium; Cf: californium

Appendix G

Source Disposition Definitions and Matrix of Gap Analysis Results

1. Definitions of Avenues of Discovered/Recovered Sources

A. ***Unwanted, Authorized Possessors:*** Unwanted sources possessed by an authorized user, adequate controls in place.

B. ***Authorized Possessor, Health and Safety Risk (wanted/unwanted):*** Unwanted sources possessed by an authorized user, insufficient controls in place.

C. ***Wanted, Unauthorized Possessors:*** Wanted sources in the possession of a non-authorized entity.

D. ***Found***: Unsecured source in the public domain, unwanted by possessor, if any, with no immediately apparent responsible entity (owner). The responsible party may be identified on investigation.

E. ***Confiscated (Health and Safety and National Security)***: Confiscation would be because of a perceived threat. On investigation, the threat may be resolved and the item returned, or the item may be permanently confiscated.

F. ***International Recoveries***: The avenues for identification of sealed source materials requiring international recovery are defined by several parameters, consistent with various recovery avenues as identified for domestic recoveries. The determining factors in international recovery may include: (1) origin of the materials (U.S. vs. non-U.S.), (2) nature of recovery (planned return vs. emergency recovery), (3) subject of concern (hazard or environmental vs. non-proliferation or security), (4) countries involved, (5) scope of recovery (material quantity and type), (6) legal obligations, (7) responsibilities (including international treaties and agreements in place), and (8) sensitivity of the recovery operation. Once these determining factors for international recovery are defined, the actual mechanism for recovery is established, documented, and implemented.

2. Definitions of Current Sealed Source Disposition Mechanisms

A. ***Department of Energy (DOE) Off-Site Source Recovery Program***

- Applicability: U.S. Nuclear Regulatory Commission (NRC) licensees[1]
- Services: packaging assistance, transportation assistance, long-term storage
- Accepts Atomic Energy Act (AEA) material for long-term storage from commercial licensees, subject to availability of appropriated funds
- Currently accepts only transuranic GTCC sealed sources for long-term storage
- Does not currently accept Pu-239 transuranic GTCC sealed sources

[1] Used here, NRC licensees should be interpreted to include Agreement State licensees.

B. ***DOE Nonactinide Isotopes and Sealed Source Management Group (NISSMG)***

- Applicability: DOE sites
- Primarily information broker
- Services: packaging assistance, transportation assistance, information sharing
- Available to DOE sites to help them disposition non-actinide isotopes and sealed sources

C. ***DOE Central Scrap Management Office (CSMO)***

- Applicability: DOE sites
- Services: facilitates disposition, provides information assistance, provides contract mechanism
- Available to DOE sites to help them disposition scrap nuclear material

D. ***DOE Loan-Lease Program***

- Applicability: colleges/universities, other government agencies, foreign entities
- Services: financial, administrative, contractual, and technical
- DOE is responsible for managing and disposing of nuclear materials loaned or leased to universities, research organizations, commercial industries, military facilities, and hospitals.

E. ***Conference of Radiation Control Program Directors (CRCPD) National Orphan Radioactive Material Disposition Program***

- Applicability: States, for AEA and non-AEA materials
- Services: information sharing, funding assistance (includes packaging and transportation assistance)
- National orphan source assistance program:
  - Provides assistance to States to address and respond to orphan sources
  - Scope includes unwanted radioactive material for which the custodian either cannot afford disposition or should not be held liable
  - Requires State arrange for appropriate disposition, and CRCPD provides funding commitment only
  - Uses existing disposition mechanisms
  - Assisted by NRC for AEA materials and DOE funding for naturally-occurring and accelerator-produced radioactive material and naturally-occurring radioactive material
  - Excludes disposal of greater-than-Class C (GTCC) waste sources
  - Provides assistance with unwanted materials that do not require financial assistance

F. ***Transfer to Other Authorized Possessor***

- Applicability: NRC licensees
- Services: information sharing
- All types of materials and forms have the potential to be covered.

G. ***Return to Responsible Party/Owner***

- Applicability: NRC licensees and DOE
- Services: information sharing

- S Primarily for use when the current unauthorized possessor does not have sufficient health and safety ability to be authorized by amendment or newly issued authorization to possess the material.

H. ***State Radiation Control Program, Health Department, or Environmental Protection Division***

- S Applicability: Some States, for non-AEA materials
- S Services: information sharing, funding assistance (may include packaging and transportation assistance)
- S Some States have recovery and disposition programs for orphan sources.
- S Some States have capabilities to confiscate materials when they pose threats to the public health and safety or the environment.

I. ***Return to Manufacturer/Distributor***

- S Applicability: NRC licensees
- S Services: packaging assistance, transportation assistance, long-term storage
- S Current mechanism applicable where manufacturer/distributor must accept pursuant to license or where willing and able

J. ***Issue or Amend License/Authorization to Ensure Authorized Possessor***

- S Applicability: NRC licensees, DOE authorized users
- S Services: licensing/authorization assistance
- S For non-authorized entities possessing materials, used to provide appropriate license/authorization or license/authorization amendment to cover quantity/type of material possessed or to be possessed.
- S Would not do this when the entity is perceived to pose a security risk; may confiscate rather than authorize in that situation, but could do this after the entity resolves the security risk.

K. ***Environmental Protection Agency (EPA) Emergency Response***

- S Applicability: NRC licensees for AEA materials; States for non-AEA materials
- S Services: technical assistance, funding assistance
- S EPA's Radiological Emergency Response Team responds to emergencies involving releases of radioactive materials.
- S It is unclear whether EPA can actually take control of materials.

L. ***Active Commercial Low-Level Waste (LLW) Disposal Sites for Classes A/B/C LLW***

- S Applicability: NRC licensees, DOE sites, States
- S Services: disposal
- S Only three commercial LLW disposal facilities exist in the United States.
- S Two of them are State compact facilities: Barnwell and U.S. Ecology.
- S The third facility, Envirocare, Utah, accepts Class A waste only from all regions of the United States.

M. ***Future State LLW Disposal Compacts/Facilities for Classes A/B/C LLW***

- Applicability: NRC licensees and DOE sites within states authorized to dispose at given compact facility
- Services: disposal

N. ***Active DOE LLW Disposal Facilities***

- Applicability: DOE sites and certain authorized Department of Defense waste generators
- Services: disposal
- Seven DOE sites currently dispose of LLW:
  - (1) Nevada Test Site; (2) Hanford, Washington; (3) Savannah River Site, South Carolina; (4) Idaho National Engineering and Environmental Laboratory; (5) Los Alamos National Laboratory, New Mexico; (6) Oak Ridge Reservation, Tennessee; (7) Fernald Environmental Management Project, Ohio
- Two DOE sites, Hanford and the Nevada Test Site, are planning to begin accepting mixed LLW, which is radioactive LLW mixed with hazardous constituents.

O. ***DOE Radiological Assistance Program (RAP)***

- Applicability: AEA and non-AEA materials
- Services: information sharing, technical assistance (no packaging, transportation, or funding assistance)
- DOE's flexible, around-the-clock, first-response capability

P. ***DOE National Nuclear Security Administration (NNSA) Material Protection Control and Accountability Program***

- Applicability: DOE sites
- Services: information assistance, coordinates expertise, develops policy
- Integrates and orchestrates DOE's assets and expertise, including those of its national laboratories and contractors, in planning, directing, and implementing U.S. cooperation with the Russian Federation.
- Provides international emergency assistance and cooperation with foreign governments responding to a nuclear smuggling or trafficking incident.

Table G-1 Results of Gap Analysis of Recovery Avenues versus Disposition Mechanisms

This table identifies gaps in the applicability of existing mechanisms to possible avenues for identification of materials requiring recovery. A gap was considered to exist wherever there was not a complete disposition pathway for an avenue. A gap was also considered to exist if a disposition pathway was restricted by a lack of funding or storage/disposal capacity.

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
A. DOE Off-Site Source Recovery Program Services: Packaging and Transportation Assistance, Long-term Storage (progress is subject to availability of funding specifically appropriated for this effort)	**Short** = None **Long** = Partial: GTCC waste only, long-term storage pending a final disposal option. Only Am-241 and Pu-238 can currently be accepted. **Final** = Disposal capability not available	**Short** = Partial: Not for lower risk (i.e., non-emergency) cases **Long** = Partial: GTCC waste only, no more Pu-239 now; no non-transuranic GTCC waste. Long-term storage pending a final disposal option **Final** = Partial: Exceptions as noted in the DOE/NRC memorandum of understanding. No disposal capability available	Same as Avenue 2	Same as Avenue 2	Same as Avenue 2	N/A

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
B. DOE Nonactinide Isotopes and Sealed Source Management Group Services: Packaging and Transportation Assistance, Information Sharing Limitations: FY03 final central DOE funding, FY04 by task order funding request only	**Short/Long** = Partial: DOE sites only. Assist in finding an authorized possessor, assist with transfer. **Final** = None	**Short/Long** = Partial: DOE sites only. Assist in finding an authorized possessor, assist with transfer. No imminent risk or emergency response cases **Final** = None	Same as Avenue 2	Same as Avenue 2	Same as Avenue 2	N/A
C. DOE Central Scrap Management Office Applies to DOE sites. Also, applies to universities that have DOE loan/lease material. Material cannot be waste, it has to be reusable scrap that has some value. Services: packaging assistance, storage, recycle and recovery	**Short** = Partial (sites are not charged for storage) until a final disposition path is established. **Long/Final** = Partial (covers all storage and processing costs; provides recovery and reuse as the final disposition path for returned material).	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Not applicable, based on past history of CSMO use

Mechanisms/ Disposition Pathways	Avenues for Identification of Materials Requiring Recovery					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
D. DOE Office of Pu, U, and Special Materials Inventory Loan/Lease Program Only applies to material documented to be loan/lease. Services: financial, administrative, contractual, and technical	**Short/Long** = Partial: Since return costs are charged to the returning facility/agency on a full- cost basis, lack of funds from returning facility/agency (except university or medical research) may restrict availability. **Final: N/A**	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1
E. Conference of Radiation Control Program Directors (CRCPD) Committee on Unwanted Radioactive Materials Services: Information Sharing, Funding Assistance if considered an orphan source, including packaging, transportation, and disposal.	**Short/Long/Final** = Partial: Information exchange only, such as assisting in finding an authorized possessor. Cannot own, possess or store material.	**Short/Long** = Partial: Information exchange only, such as assisting in finding an authorized possessor. Cannot own, possess, or store material. **Final** = Partial: Disposition option must be available. Funding assistance is limited ($225K/yr for AEA, $100K total for NARM). Cannot provide funding assistance for disperse material or disposal of GTCC waste.	Same as Avenue 2	Same as Avenue 2	Same as Avenue 2, except cannot provide funding assistance if only national security risk	N/A

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
F. Transfer to Other Authorized Possessors Services: Receipt and possession	**Short/Long** = Partial: Is limited by whether an authorized recipient can be found who is willing to temporarily accept material. **Final** = Partial: Gap for materials that are no longer useful and for which demand is low and supply is high. Does not cover final disposal.	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1, except if material is considered a national security risk, this mechanism is limited to "secure" authorized possessors	N/A

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
G. Return to responsible party (owner)	N/A	N/A	**Short/Long/Final** = Partial: may be limited by whether a previous owner can be identified, whether any of the previous owners are authorized to possess the material	Same as Avenue 3	Same as Avenue 3 If risk is substantiated or not corrected, then could not be returned to the holder, but may be able to be returned to a previous owner if possible (for transport, this would be return to sender). The pool of acceptable entities that could take the material may be limited if the material itself is considered a security risk.	Same as Avenue 5

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
H. State programs (Radiation Control, Health, and Environmental Protection)	**Short/Long** = Partial: Very limited. Typically handled through license amendments and increased oversight. Little to no capability to accept material not a high risk. Capabilities vary by state. **Final** = None.	**Short** = Partial: Very limited. Typically handled through license amendments and increased oversight. Little to no capability to accept material not a high risk. Capabilities vary by state. Most have some means to temporarily store high-risk materials. **Long** = Partial: Capabilities vary by state. Most do not have means to store materials long term. **Final** = Partial: Capabilities vary by state. A few have programs for recovery and disposition of materials that present a health and safety risk. Few, if any, can disposition disperse material. Funding assistance is available through CRCPD if considered an orphan source.	**Short** = Partial: Very limited. Typically handled through license amendments and increased oversight. Capabilities vary by state. Limited authority to accept lower-risk material. Most have some means to temporarily store high-risk materials. **Long** = Partial: Capabilities vary by state. Most do not have means to store materials long term. Typically handled through license amendments. **Final** = Partial: Can issue license or amendment. Capabilities vary by state. A few have programs for recovery and disposition of materials that present a health and safety risk. Few, if any, can disposition disperse material. Funding assistance is available through CRCPD if	**Short** = Partial: Very limited. Typically handled through storage on site or transfer to another licensee. Capabilities vary by state. Limited authority to accept lower-risk material. Most have some means to temporarily store high-risk materials. **Long** = Partial: Capabilities vary by state. Most do not have means to store materials long term. **Final** = Partial: Capabilities vary by state. A few have programs for recovery and disposition of materials that present a health and safety risk. Few, if any, can disposition dispersed material. Funding assistance is available through CRCPD if considered an orphan source.	**Short** = Partial: Most have some means to temporarily store high-risk materials. **Long** = Partial: Capabilities vary by state. Most do not have means to store materials long term. **Final** = Partial: Capabilities vary by state. A few have programs for recovery and disposition of materials that present a health and safety risk. Can be handled through transfer to another licensee who is not a risk. Few, if any, can disposition disperse material. Funding assistance is available through CRCPD if considered an orphan source. No "I" pathway (license amendment) allowed.	N/A

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
I. Manufacturer/ Distributor Return Mechanisms	**Short/Long/Final** = Partial: Gap exists for out- of-business vendors, vendors that do not have a return program, and sources that cannot be traced to a vendor.	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1 If at risk, confiscated source could be returned to original user after risk was mitigated.	Partial. Does not apply when source is identified as non-proliferation risk or where the manufacturer cannot be identified or is out of our jurisdiction.
J. License/ Authorization Amendment Provisions	**Short/Long/Final**: ***N/A*** Does not address the issue of being unwanted.	**Short/Long/Final** = Partial: additional license restrictions or increased oversight may be used to minimize the risk factors. Does not address the issue of being unwanted.	**Short/Long/Final** = Partial: for use only when owner has sufficient health and safety ability to be authorized by amendment or newly issued authorization to possess the material.	**Short/Long/Final**: Partial: Must identify the responsible possessor first, then same as Avenue 2. If no responsible possessor identified or risk cannot be mitigated, then may need to be used in conjunction with other pathways (i.e., F, F1, H) to secure the source.	Same as Avenue 4 May be further limited if the material itself is considered the security risk.	Same as Avenue 4

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
K. Environmental Protection Agency (EPA) Emergency Response	**Short** = N/A **Long** = N/A **Final** = N/A	**Short** = N/A **Long** = N/A **Final** = N/A	**Short** = Partial: can arrange/provide Federal assistance under the Federal Radiological Emergency Response Plan (FRERP), if requested by the State. EPA policy is to provide assistance only for "radiological emergencies." **Long** = N/A **Final** = N/A	**Short** = Partial: can arrange/provide Federal assistance under the FRERP, if requested by the state. EPA policy is to provide assistance only for "radiological emergencies." **Long and Final** = Partial: can provide transfer and disposal assistance under the National Contingency Plan if the state requests Federal assistance and the activity is not subject to the financial assurance provisions of the Price-Anderson Amendments Act (i.e., no commercial nuclear power plants and DOE facilities). EPA policy is to provide assistance only for "radiological emergencies."	Same as Avenue 4	**Short** = N/A **Long** = N/A **Final** = N/A

Mechanisms/ Disposition Pathways	Avenues for Identification of Materials Requiring Recovery					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
L. Commercial LLW Disposal Facilities	**Short** = N/A **Long** = N/A **Final** = Partial: Doesn't accept GTCC sources; existing Classes B/C facilities are compact facilities, therefore restricts (by State) who can dispose there; does not accept sources that possessor cannot afford to dispose of	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	**Short** = N/A **Long** =N/A **Final** = N/A

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
M. Future State Compact LLW Disposal Facilities	**Short** = N/A **Long** = N/A **Final** = Partial: Same gaps as "Pathway L" above, if additional facilities are sited. Currently most states have not been able to fulfill their LLRWPAA commitment. For unwanted/authorize/ compromised control sources, ensure no incentive to licensees to declare bankruptcy thus making them eligible for Federally-assisted recovery.	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	**Short** = N/A **Long** =N/A **Final** = N/A

Mechanisms/ Disposition Pathways	**Avenues for Identification of Materials Requiring Recovery**					
	1. Unwanted, Authorized Possessors	2. Authorized Possessor, Health and Safety Risk (wanted/unwanted)	3. Wanted, Unauthorized Possessors	4. Found	5. Confiscated (health & safety or national security)	6. International Recoveries
N. DOE LLW Disposal Facilities	**Short** = Partial: Does not accept commercial LLW; at site discretion, could retrievably store in disposal facility. **Long** = Partial: Does not accept commercial LLW; at site discretion, could retrievably store in disposal facility **Final** = Partial: Does not accept commercial LLW	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1	Same as Avenue 1
O. DOE Radiological Assistance Program (RAP)	**Short** = N/A - RAP team not typically called until scenario considered high risk **Long** = N/A **Final** = N/A	**Short** = Partial: Assist in finding authorized possessor **Long** = N/A **Final** = N/A	Same as Avenue 2	Same as Avenue 2	Same as Avenue 2	N/A
P. DOE NNSA Material Protection Control and Accountability Program	N/A	N/A	N/A	N/A	N/A	**Short** = Partial: Assist in finding authorized possessor **Long** = N/A **Final** = N/A

Appendix H

Operational-level Recommendations

1. Security and Safeguards		Resp. Org.	Time Frame to Complete*
1.1	**Assess which additional licensees/facilities, if any, need to increase security measures** for materials and quantities of greatest concern. Assess whether other material/use groupings require increased security given the arbitrary distinction between hazard index levels. Assess the limitations of the Sandia study to ensure that licensees/facilities that do not specify radionuclides possessed have not been unduly excluded from the study. Consider material convertibility and portability.	NRC & DOE	intermediate-term
1.2	**Make licensing changes.** Emphasize the consideration of dispersibility as part of the license review and approval process. Confirm what material is actually possessed and encourage licensees to revise possession limits as appropriate.	NRC	intermediate-term
1.3	**Consider limiting material amounts at a single location.** Assess value in certain facilities being encouraged/required to only store up to a certain amount of material in the same location at a single site.	NRC & DOE	intermediate-term
1.4	**Consider the feasibility and cost-benefit of using nonradioactive material** instead of radioactive sources.	DOE	long-term
1.5	**Consider the feasibility and cost-benefit of producing sources in forms resistant to dispersal**.	NRC & DOE	long-term

* Dependent upon resources available.

2. Materials Assessment		Resp. Org.	Time Frame to Complete
2.1	**Perform vulnerability assessments including consideration of insider threat.** Consider the full life cycle (manufacture, use, storage, transportation, and disposition) based on knowledge of identity, form, and quantity of material by location, custodian, and transfer parameters. Study material shipping/transportation patterns by user category. Expand consideration beyond materials of greatest concern to account for greater quantities in transit than at a single location.	NRC & DOE	intermediate-term
2.2	**Increase knowledge of what materials require protection:** ▸ **Study impact of encapsulation.** Evaluate, through experimentation, the impact of encapsulation on airborne release fraction and respirable fraction. ▸ **Study how materials would behave in RDDs.** Identify and conduct experiments to better understand how the various materials behave in certain classes of dispersal devices or events. ▸ **Enhance radiological plume modeling capabilities** and evaluate selected scenarios to ascertain the potential effects from various forms of material dispersal for specific isotopes. ▸ **Develop an RDD materials assessment methodology** that incorporates components of consequence—flexible dose thresholds, disruption, remediation (or environmental vector) issues—using contemporary approaches to combining uncertain data and fuzzy information. ▸ **Study decay products in assessing materials of concern.** Decay products of specific isotopes and certain contaminants may contribute more significantly to the consequences than the parent isotope. Evaluate isotopes with significant alpha, beta, and gamma decay products or contaminants.	NRC & DOE	intermediate-term

3. Tracking and Monitoring Radioactive Sources		Resp. Org.	Time Frame to Complete
3.1	**Develop an interim database** of information on material possessed in the government and private sectors. The interim database will not track material but will provide a "snap shot" at the time of data collection and will be updated at some frequency. This information will be useful in further assessments of security risks and materials of concern.	NRC & DOE	< 6 months
3.2	**Track sources in transit.** Assess the feasibility of tracking items currently in transit using existing technologies in the commercial sector (Federal Express, United Parcel Service, or others).	NRC	short-term
3.3	**Identify a mechanism to track sources through all phases of disposition** to facilitate their moving through the pathways, increase the security of the sources, and assist in identifying sources currently in long-term storage that might benefit from alternate solutions.	NRC & DOE	intermediate-term
3.4	**Consider implementing low-cost tagging technology.** Consider requiring local low-cost systems such as TIDs, electronic tags, and seals and requiring enhanced inspections/reporting for materials.	NRC & DOE	intermediate-term
3.5	**Consider implementing improved security and monitoring technologies.** Consider requiring improved security systems on transporters of mobile sources and at areas of high source density (manufacturers, storage sites, or material in transit) including active tags, measurement, instruments and alarm systems.	NRC & DOE	intermediate-term
3.6	**Research tagging and monitoring technologies.** Perform an assessment of materials to identify the opportunity for low-commercial-impediment, high-value data acquisition and physical protection systems. Provide necessary research and development to support technology deployment.	DOE	intermediate-term

4. Disposing of Unsecured Radioactive Sources		Resp. Org.	Time Frame to Complete
4.1	**Establish a well-defined storage mechanism**. Fund an entity to identify who can hold sources on a short- or long-term basis. Expand funding of the Conference of Radiation Control Program Directors (CRCPD) to allow it to pay sites who are willing to accept and hold sources, or pursue interstate agreements to have States share solutions among themselves. State policies/capabilities should be shared through a centralized database of State capabilities. DOE sites should be made aware of State capabilities and vice versa. Pursue agreements with select Federally-funded storage sites (particularly Department of Defense and DOE) to store sources if no entity offers to store them (on either an emergency confiscation or long-term basis). Revise the NRC inspection process to ensure inspectors look to the CRCPD for emergency disposition assistance. Encourage licenses to seek disposition assistance from CRCPD for unwanted sources. For situations in which sources are to be placed in long-term storage, clarify which organization has title to make liability and responsibility issues clear.	NRC & DOE	intermediat e-term
4.2	**Fund emergency transport of sources.** Assure there is a funding vehicle (e.g., transportation tender) to fund transportation company(s) for emergency transport of sources to protect public health, safety, and security. Allow access directly by emergency responders.	NRC & DOE	intermediat e-term
4.3	**Encourage recycling and reuse of sources.** Decide whether to fund an entity to aggressively canvass the commercial market to identify additional alternatives for recycle/reuse subject to applicable requirements. Enhance existing information-sharing mechanisms to facilitate matches between unsecured sources and potential new users. Inform authorized possessors of these alternatives. Maintain information regarding companies/organizations that have sources available and those who want them to decrease the need for long-term storage and minimize the use of limited disposal capacity. Maintain information on vendors that accept source returns.	NRC & DOE	intermediat e-term
4.4	**Seek disposition assistance from CRCPD.** Revise the NRC inspection process to ensure inspectors look to the CRCPD for emergency disposition assistance. Also encourage licensees to seek disposition assistance from CRCPD for unwanted sources.	NRC	short-term
4.5	**Consider whether to require all vendors to accept return of their products**.	NRC	intermediat e-term
4.6	**Establish a clear mechanism for the return of national and international sources to the DOE loan/lease program**.	DOE	intermediat e-term

4. Disposing of Unsecured Radioactive Sources		Resp. Org.	Time Frame to Complete
4.7	**Identify a disposition mechanism for international confiscations**. Evaluate whether appropriate health, safety, and security standards are in place. Ensure sources are managed and safety is maintained for those individuals involved in the confiscation. This mechanism must identify under what authority (AEA or otherwise) safety, health, and security will be maintained. Coordinate across Federal programs (e.g., DOE, Department of Defense, State Department, and NRC).	NRC & DOE	intermediate-term