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Nuclear and Radiological Forensics and Attribution Overview

D. K. Smith, S. Niemeyer

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Nuclear and Radiological Forensics and Attribution Overview

Thrust Area Scope

The goal of the U.S. Department of Homeland Security (DHS) Nuclear and Radiological Forensics and Attribution Program is to develop the technical capability for the nation to rapidly, accurately, and credibly attribute the origins and pathways of interdicted or collected materials, intact nuclear devices, and radiological dispersal devices. A robust attribution capability contributes to threat assessment, prevention, and deterrence of nuclear terrorism; it also supports the Federal Bureau of Investigation (FBI) in its investigative mission to prevent and respond to nuclear terrorism.

Development of the capability involves two major elements: 1) the ability to collect evidence and make forensic measurements, and 2) the ability to interpret the forensic data. The Program leverages the existing capability throughout the U.S. Department of Energy (DOE) national laboratory complex in a way that meets the requirements of the FBI and other government users. At the same time the capability is being developed, the Program also conducts investigations for a variety of sponsors using the current capability. The combination of operations and R&D in one program helps to ensure a strong linkage between the needs of the user community and the scientific development.

Key Projects/Partnerships

In FY04, projects were conducted in three major areas:

- A Sample Collection & Analysis Infrastructure to provide an integrated collection and laboratory system that rapidly produces the forensics measurements according to pre-established protocols that meets user requirements
- A Knowledge Management system to provide rapid access to all the expertise, information, and technical tools that are needed to interpret the forensics data that is produced during an attribution investigation
- Attribution Operations by which casework investigations are executed and exercises are conducted to validate and evaluate the current capability

A key partner is the FBI who is also making investments to develop nuclear forensics. The Program aims to develop a capability that will meet the FBI's specific requirements. The Program has also interacted with the Defense Threat Reduction Agency (DTRA) and National Nuclear Security Administration (NNSA) to coordinate with their investments in related areas of attribution.

The US nuclear and radiological forensics and attribution team includes eight national laboratories: Argonne National Laboratory, Idaho National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratory, and Savannah River National Laboratory. The capability utilizes a "hub-and-spoke" network of laboratories in which Lawrence Livermore and Savannah River National Laboratories

are the two national laboratory hubs. All laboratories are involved in various aspects of the R&D element of the program.

Approach/Method

The Sample Collection and Analysis Infrastructure leverages existing capabilities, largely within the complex of DOE national laboratories. A conduct-of-operations (CONOPS) defines how a pre-detonation attribution investigation will be conducted, and the physical infrastructure and protocols are being developed to implement this CONOPS. Diagnostic signatures are being developed and refined to distinguish the origin of nuclear and radiological materials and devices. In conjunction, a knowledge base is being developed that appropriately accesses and utilizes multiple information resources and databases relevant to signatures, processes, origins and pathways. Actual cases and exercises are used to assess the operational status in terms of rapidity, accuracy, and credibility. This work provides the basis for assessing the capability and prioritizing further R&D.

Discussion

This work represents a major step forward in the development of nuclear and radiological forensics and attribution. Nuclear forensics is a newly emerging scientific discipline, and the objective of this program is to develop an enduring capability for the nation. It builds upon earlier seed funding by the Department of Energy. The scope of the Program, and its long-term nature, are critical for attracting young scientists to invest their careers in developing and perpetuating this capability. The linkage between younger scientists and the knowledge generated by earlier generations of nuclear scientists and technicians is a fundamental element of the Program.

Results

The design of a CONOPS has been completed. Plans for a dedicated Sample Receiving Facilities at the two hub labs are now final, and procurements have been initiated. A focus of the initial investment has been to meet the FBI requirement for forensic analysis of radiologically-contaminated evidence while also enabling the receival and handling of the nuclear and radiological materials.

A Signatures Program Review was held in July 19-20, 2005 in Washington, DC to evaluate the progress in the many signatures projects; the review also included proposals for new starts in 2006. The review included participation by other agencies that are end-users and stakeholders. The review culminated in guidance on projects to continue, feedback for refocusing some projects, projects to suspend, and recommended new starts. In the area of Knowledge Management, significant progress was made on defining the scope of the RadNuc Attribution domain of the Bio-Defense Knowledge Center. The structural differences between the biodefense and rad/nuc domain have been identified, and work has begun on establishing a ontology and developing an approach for a

distributed knowledge management system that encompasses the spectrum of the civilian and defense nuclear fuel cycle.

During the past year, the program successfully conducted a number of investigations for a variety of customers. Reports were generated for these customers that summarized the measurement results and their interpretation.

Overall Summary

DHS investments over the past eighteen months in nuclear and radiological forensics and attribution have resulted in infrastructure as well as a credible scientific basis supporting enhanced operational response. The Program taps into a broad range of scientific expertise across the nation to address the diverse spectrum of threats. At the same time that the capability is being further developed, the current capability is frequently used to conduct investigations. Many of the methods and capabilities of nuclear and radiological forensics are readily transferred to other weapons-of-mass-destruction threats. The Program has been by design configured to enable integration with companion programs in Bio-Forensics and Chem-Forensics.

Baseline Management Structure and CONOPs

Lead Institution and POC

Lawrence Livermore National Laboratory, Sidney Niemeyer and David K. Smith

Partner Institutions

Argonne National Laboratory, Idaho National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratory, and Savannah River National Laboratory

Purpose

The baseline management structure and CONOPs is the organizational framework that guides the execution of a pre-detonation nuclear forensics and attribution investigation. The technical elements include i) planning for the infrastructure needs for sample receival, sub-sampling, and analysis of nuclear, radiological, and contaminated materials with an emphasis on hub and spoke distributed laboratories, ii) a quality assurance policy and plan that governs aspects of evidence receival, preservation, analysis, and reporting, iii) reliable secure communication protocols, iv) an agreed upon strategy for information flow across the forensics and attribution capability that specifies roles and responsibilities for key elements, v) a process for data acquisition, analysis, reporting and output to related data fusion streams that forms the basis of the attribution response.

R&D Accomplishments and Deliverables

The US attribution community regularly pursues nuclear forensics investigations. The management structure and CONOPs has evolved to reflect demands of actual casework and delineation of programmatic requirements by potential government users. The CONOPS provides a more formal and accountable procedure than has been used in the past. Many cases will involve the seizure of illicit nuclear material that will necessitate potential criminal prosecution; in the course of pursuing a prosecution, legally defensible procedures will be required. For this reason, existing infrastructure and proven technical procedures serve as a starting point for the structure of the national program and these have been adapted to form the basis of a formal management construct.

Discussion

In the past year the pre-detonation program made significant progress in formulating a management structure as well as designing a conduct-of-operations. The domestic program includes tasking at the eight DOE national laboratories. For this reason, expertise is distributed across the complex and necessitates a management construct to ensure that the capability optimizes all national laboratory assets as well as provides rigorous oversight of the development of nuclear forensics and attribution casework. The objective is to deliver an operational program that provides nuclear forensics and attribution products to US government decision makers to formulate an appropriate response to a range of nuclear threats. The baseline management structure and CONOPs acknowledges the distributed nature of the program and positions key technical pieces – including receival infrastructure, technical data acquisition, and knowledge management - at programmatic centers in a "hub and spoke" arrangement. This construct avoids duplication of infrastructure and capability and provides a technical focus that cross-cuts institutions yet capitalizes on their core technical strengths.

Results

A CONOPs was designed relative to a nuclear forensics and attribution timeline that begins with notification of an incident to be investigated and concludes with all source data fusion supporting attribution (see Figure 1). An attribution investigation leader is appointed by the Lead Federal Agency to oversee the case. A Technical Assessment Team (TAT) manages the sub-sampling of evidence, laboratory analysis and evaluation, and data interpretation. There are three primary stages of the attribution investigation. Technical data acquisition and evaluation involves the collection of chemical, isotopic, physical, and morphological signatures in response to an experimental plan developed by the Technical Assessment Team. The technical interpretation and information interface allows for data evaluation and integration. The conclusions are output to all-source fusion where nuclear forensics interpretation is combined with other information about the case to form an attribution judgment. The all-source fusion constitutes the attribution that is communicated to senior-level US government decision makers to formulate an appropriate law enforcement or national security response.

Initial discussions of a quality assurance program plan for the pre-detonation program began in August, 2004. The pre-detonation quality assurance plan needs to be flexibile to accommodate the range of samples, analysis and interpretation anticipated for the pre-detonation nuclear forensics and attribution program.

Robust communication protocols are essential both for initial notification as well as throughout the data acquisition, review, and all source fusion. Preferred channels for secure communications are in place and used routinely.

The baseline management structure and conduct-of-operations is essential for building an operational program in nuclear forensics for the nation that can analyze, interpret, and attribute a range of nuclear and radiological materials. This framework is important to a

technically complex and highly distributed program. Validation of much of the planning for the organizational framework is derived from casework on actual samples; the roles of data team lead and technical assessment teams will be fully exercised in subsequent years.

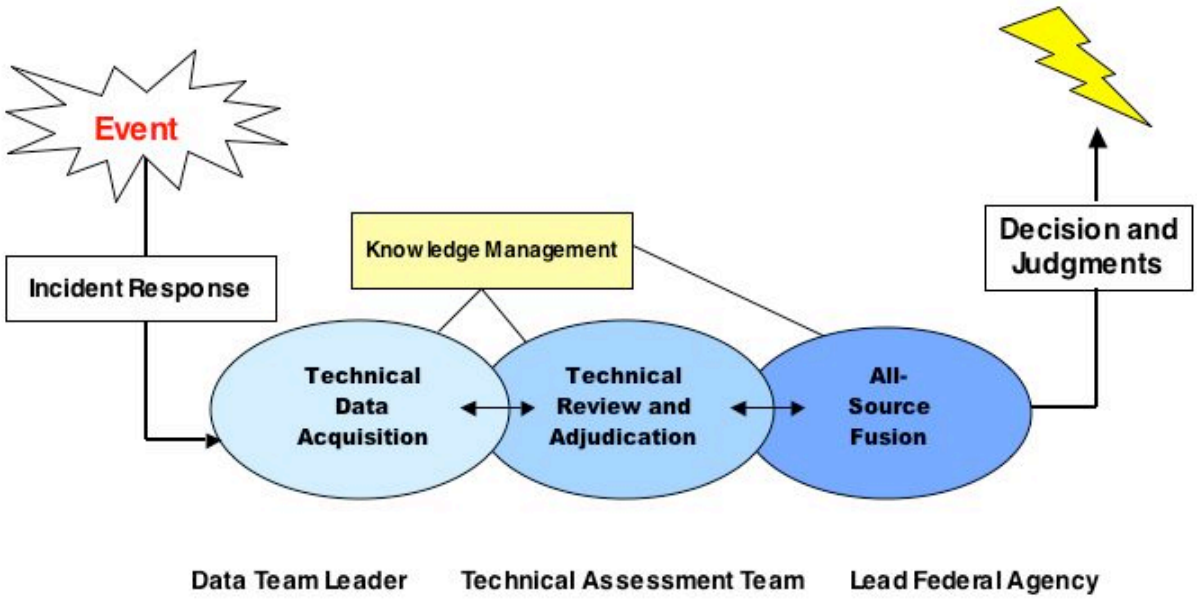

Figure 1. A graphic of the CONOPs structure that shows the interrelationship between the different segments from incident response to all-source fusion and reporting; note the inter-play between technical data acquisition, technical review and adjudication, and all-source fusion that each rely on information flow from knowledge management.

Nuclear Forensics Analysis Centers (NFAC)

Lead Institutions and POCs

Lawrence Livermore National Laboratory, Glenn Fox
Savannah River National Laboratory, J. Todd Coleman

Purpose

The Nuclear Forensics Analysis Centers constitute the two hubs in a "hub-and-spoke" arrangement for conducting forensics and attribution investigations incidents involving nuclear and radiological materials. The NFAC facilities will give the nation the needed dedicated facilities and infrastructure for an operational capability that meets the requirements of law enforcement and national security. Investments in the infrastructure (i.e. facilities, personnel, and instrumentation) are necessary for a robust and responsive capability.

R&D Accomplishments and Deliverables

The first year of this project (FY04) established the need and developed the plan for dedicated infrastructure focused on forensic activity dedicated to rad/nuc threats. Currently, the FBI via their nascent Scientific Working Group for Forensic Analysis of Radiological Materials (SWGFARM) is developing a federal laboratory "hub-and-spoke" network for responding to rad/nuc events, similar to that for biological and chemical events. This network is being assembled so that questioned samples containing radioactive materials in any matrix can be effectively and quickly sampled, analyzed and interpreted. Work in this area will focus on establishment of enduring capability utilizing recognized national radiological and nuclear forensic assets and assess and incorporate other pertinent and unique resources within the relevant federal agencies and national laboratories. DHS coordination will initially include the necessary relationships, infrastructure and responsibilities between pertinent federal organizations.

A technical capability will be developed at both Lawrence Livermore National Laboratory (LLNL) and Savannah River National Laboratory (SRNL) to provide the FBI and DHS with facilities that meet their requirements for the analysis of radiologically contaminated evidence, as well as materials from radiological and improvised or other nuclear devices. The approach is to draw upon the existing infrastructure and scientific expertise at these two laboratories that provides a combination of radiological and forensic capabilities. The overall goal is to make the forensic investigation transparent to the nature of the evidence; radiologically-contaminated materials will be examined no differently than conventional forensic evidence.

For FY05, the primary milestones included:

- LLNL: Implementation of the plan developed in 2004 for rad/nuc receival area for law enforcement and DHS sponsors, including mobile capability for sample transportation of questioned samples.

- SRNL: Make operational the shielded cells facilities for primary use by the FBI and DHS and for forensic examination of contaminated evidence and complete the plan for building modifications for analysis of radiologically-contaminated evidence.

Discussion

DHS has undertaken the development of a national capability to assign responsibility for criminal acts or acts that threaten the national security involving nuclear or radiological materials as well as provide the U.S. government with information to formulate the appropriate response. As a lead federal agency, the FBI relies on attribution for potential prosecution of the criminal case. The infrastructure and analytical support network enables legally defensible attribution of radiological contaminated evidence.

The development of specific operational plans for the NFAC at both SRNL and LLNL requires coordination with other institutional programs and approvals by local Department of Energy site offices. These plans are now sufficiently mature so that the implementation stages have begun.

Results

LLNL: An integrated radiological and nuclear receival capability involves different facilities that can handle a spectrum of low-to-high activity nuclear and radiological materials. These receival facilities are fully integrated with the LLNL Forensics Science Center. To facilitate evidentiary chain-of-custody required for potential criminal prosecution, ISO-17025 certification has been obtained for all laboratory facilities.

SRNL: Planning for dedicated laboratory facilities required a complete assessment of FBI requirements and an evaluation of options for the infrastructure. A high-level radioactive receipt facility will be retrofitted for the receipt and processing of evidence. SRNL will separately dedicate a facility to support the FBI and other DHS agencies for the receipt and examination of moderate level radioactive evidence.

Diagnostic Signatures

Lead Institutions and POCs

Argonne National Laboratory, David Chamberlain
Idaho National Laboratory, Kevin Carney
Lawrence Livermore National Laboratory, Sidney Niemeyer
Los Alamos National Laboratory, George Brooks
Oak Ridge National Laboratory, Brad Patton
Pacific Northwest National Laboratory, Greg Eiden
Sandia National Laboratory, Charlie Richardson
Savannah River National Laboratory, Justin Halverson

Purpose

A central thrust of the Forensics and Attribution Program is to conduct R&D that determines the set of diagnostic signatures that are most useful for distinguishing the origin of nuclear and radiological materials and devices. Developing better signatures is the cornerstone for improving specificity, accuracy, and credibility of forensics and attribution judgments.

R&D Accomplishments and Deliverables

Developing diagnostic signatures to perform source and route attribution requires a multi-pronged approach to determine what attributes constitute unique or diagnostic characteristics of materials. Three general approaches are modeling of the processes, evaluation of existing databases, and empirical studies of materials. In addition, technical enhancements of established signatures will be made to improve the speed, accuracy, or specificity of the signature measurement. The objectives for development of diagnostic signatures include the ability to:

- characterize sample materials using isotopes, elements (trace and bulk), and morphologies
- infer the processes used to develop and manufacture the materials
- infer the "age" since last irradiation or processing of the materials
- infer the end-use of the materials
- infer the country of origin for the materials
- inferr the point of loss-of-control.

All eight laboratories contributed to the further development of diagnostic signatures. Each drew upon their historical technical strengths and expertise to investigate different aspects of signatures for nuclear and radiological materials. Many studies are collaborative and require close coordination between different technical partners. A

comprehensive exchange of information on progress to-date took place at a Signatures Program Review that was held in Washington, DC on July 19-20, 2005.

Discussion

Signatures are created and erased throughout the lifecycle of a nuclear or radiological material. Figure 2 below illustrates a simplified view of the nuclear fuel cycle. Ultimately, the signatures program aims to determine the mechanisms that control the development, and removal, of signatures through this cycle.

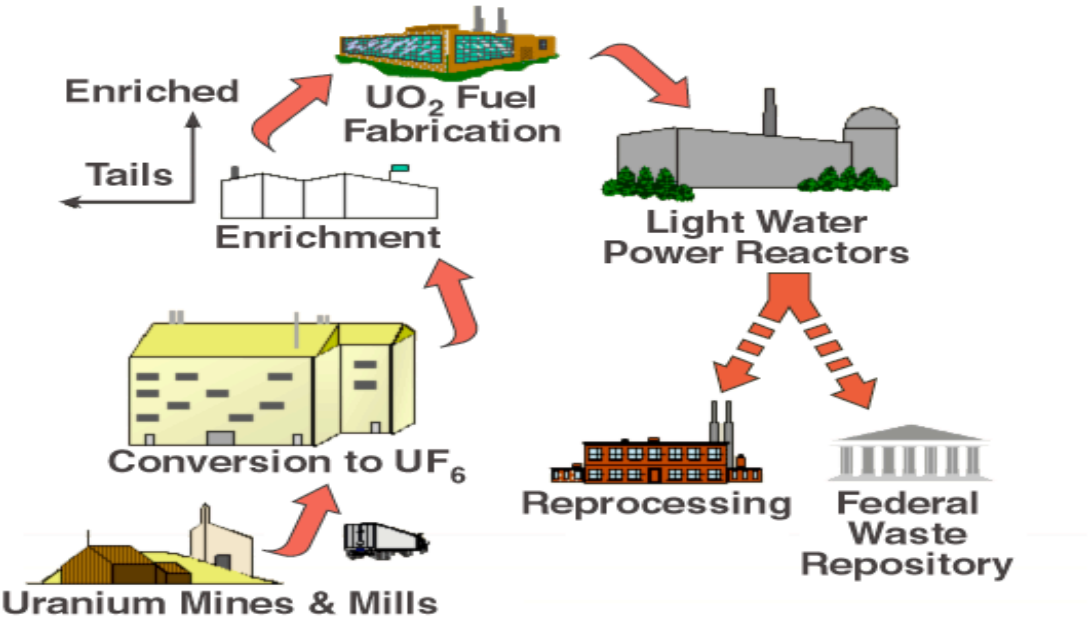

Figure 2. Signature and data reflect process information imparted throughout the nuclear fuel cycle.

A three-pronged approach is applied to signatures development. First, an empirical approach involves analysis of different materials to determine their characteristic differences. Second, database mining discovers characteristic differences. Third, modeling of different processes identifies characteristic differences. Using all three approaches bolsters interpretive confidence.

Results

During the past eighteen months, the 8 national laboratories pursued an array of R&D projects in signatures. Preliminary reports on empirical, modeling, and database signatures were submitted at the beginning of 2005 to monitor progress to date. The project teams were then brought together for a Signatures Program Review on July 19-20, 2005. The primary purpose for this Program Review was to evaluate the current status of

the DHS-funded Signatures Projects, and to provide constructive feedback to the project teams and the program managers. To better understand interrelationships between the DHS forensics and attribution program and other federal efforts in this area, talks were also given on related topics that have been funded by other agencies and several case studies were presented to illustrate the current state-of-the-art. A panel of technical and program reviewers from multiple agencies provided detailed recommendations on all the projects. A collateral benefit of this scientific meeting was to help nurture the development of an "attribution community" that together will advance the development of nuclear forensics as a new discipline.

The output of this program review provided a basis for developing a path forward for signature development in the DHS Program. The criteria for prioritizing signature R&D were: priority of the threat, discriminatory power, cost-benefit analysis for addressing database gaps, interrelationship with other signatures, and degree that the signature research helps answer the question "Who did it?"

Knowledge Base

Lead Institution and POC

Lawrence Livermore National Laboratory, Frank Wong & Sidney Niemeyer

Partner Institutions

Argonne National Laboratory, Idaho National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratory, and Savannah River National Laboratory

Purpose

Rapid and credible interpretation of forensics data for nuclear attribution is predicated on a knowledge management system that accesses and analyzes information derived from the full spectrum of the nuclear fuel cycle. Knowledge management allows for 1) the ready comparison of analytical signatures obtained from nuclear samples against known signatures from nuclear production, reprocessing, manufacturing, and storage, 2) the analysis of existing knowledge and data with the aim of identifying the most diagnostic attribution signatures, and 3) data mining to harvest arrays of information that together bears on a specific attribution case. DHS has initiated a knowledge management system that provides rapid access to all the expertise, information, and technical tools needed to interpret the forensics data from an attribution investigation. The envisioned knowledge base will develop and incorporate tools and architectures for data sharing, data mining, and knowledge discovery, and it will be designed to leverage and link with other WMD knowledge management architectures and tools.

R&D Accomplishments and Deliverables

Given the many signatures associated with pre-detonation nuclear forensics, the ability to correlate disparate data to make meaningful comparisons is complex. The knowledge base activity involves two broad functions. The first is to further identify existing data that will be useful for interpretation of the forensic evidence. The second is to provide a format and architecture where knowledge and data can be accessed for optimal analysis and interpretation. This work will leverage the investments being made by DHS's Bio-Defense Knowledge Center (BKC).

The pace of knowledge base activities accelerated in 2005. The RadNuc attribution domain of the BKC is expected to utilize the same architecture as the BKC, but the requirements and needs of the RadNuc domain bear some significant differences from the biodefense domain. All eight laboratories are a part of this Thrust Area and will contribute to development of the Knowledge Base. The Knowledge Center will provide a central point of coordination for accessing information sources and evaluating the quality and depth of existing assets.

Discussion

The knowledge base will develop and incorporate tools and architectures for data harvesting, information fusion, and knowledge discovery (see Figure 3). The knowledge management function will be designed to leverage and link with other WMD knowledge management architectures; it will enable subject-matter experts to access the right information in order to interpret forensics data and draw conclusions regarding attribution. This activity will require skills that combine understanding of forensics interpretation and attribution signatures with the data structures relevant to supporting analytic engines. While ontologies have been developed for the biological domain, this effort will create for the first time ontologies for rad/nuc forensics and attribution.

The primary individual users of the product will be technical experts seeking to attribute nuclear and radiological materials and devices. The major agency users are federal law enforcement and national security organizations.

Results

Subject Matter Experts List

A subject matter expert (SME) database has been developed to begin capturing SME information and to allow rapid search and retrieval. The database is structured to contain individual contact information as well as relevant professional experience in the realm of the nuclear fuel cycle, forensics signatures, analysis, and interpretation. The design is for rapid retrieval of data supporting informed attribution judgments. This database will be incorporated in the Rad/Nuc Knowledge Center where it will be further refined and populated to provide a tool for accessing needed attribution expertise.

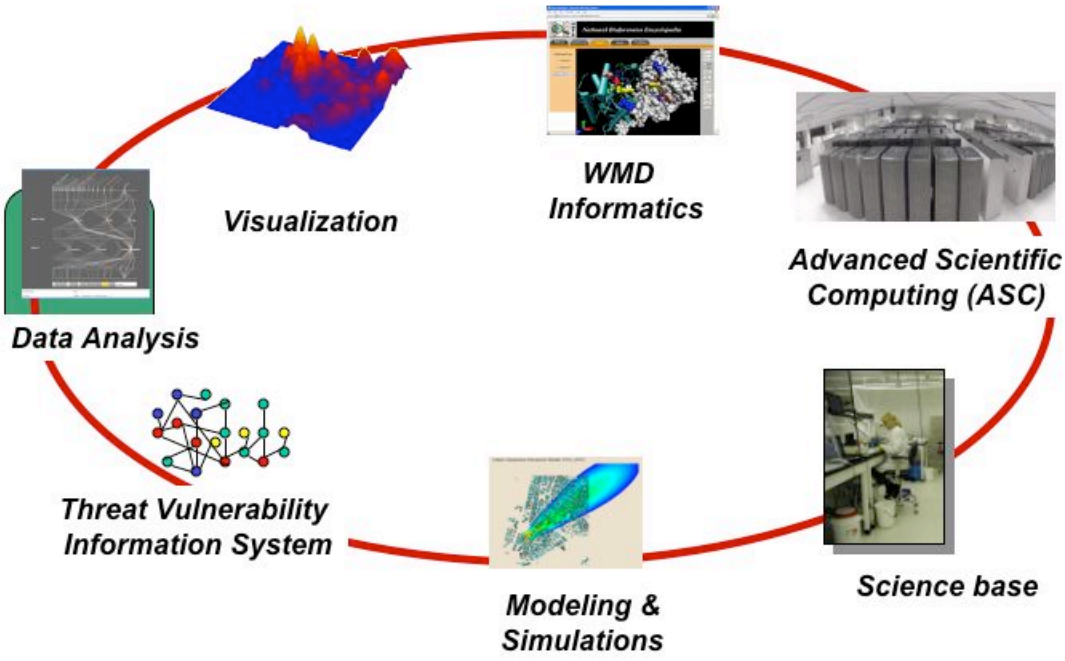

Figure 3. A knowledge management system allows for identification, organization, and retrieval of nuclear and radiological information necessary for attribution.

Rad/Nuc Knowledge Center Scope

The effectiveness of any knowledge management system is predicated on the specification of an applicable ontology that defines the information links between data or data clusters. For attribution analyses, the ontology will be formulated to allow diagnostic signature interrogation of data or data clusters that will aid in forensic data interpretation. In addition, the ontology will also enable knowledge harvesting of available information that may be pertinent during an attribution analysis and also possibly identify new diagnostic signatures to be used in attribution.

As part of the FY05 scoping activities, a template was developed to assess available nuclear and or radiological data bearing on forensics and attribution and was organized according to data descriptors (e.g., numerical or text), location of archive, data quality and completeness, format, and access controls among other attributes.

The key findings of the FY05 scoping activities are that the rad/nuc attribution knowledge base will by necessity be a distributed capability (e.g. not a centralized "library"). The distributed architectural layout will, for the most part, be transparent to

the user and relies on a forensics and attribution ontology. The rad/nuc attribution knowledge base will leverage current DHS investments in computational and analysis tools for data mining, information fusion, and knowledge discovery.