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A Future Vision of Nuclear Material Information Systems

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A FUTURE VISION OF NUCLEAR MATERIAL INFORMATION SYSTEMS

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ABSTRACT

Modern nuclear materials accounting and safeguards measurement systems are becoming increasingly advanced as they embrace emerging technologies. However, many facilities still rely on human intervention to update materials accounting records. The demand for nuclear materials safeguards information continues to increase while general industry and government down-sizing has resulted in less availability of qualified staff. Future safeguards requirements will necessitate access to information through unattended and/or remote monitoring systems requiring minimal human intervention.

Under the auspices of the Department of Energy (DOE), LLNL is providing assistance in the development of standards for minimum raw data file contents, methodology for comparing shipper-receiver values and generation of total propagated measurement uncertainties, as well as the implementation of modern information technology to improve reliability of and accessibility to nuclear materials information. An integrated safeguards and accounting system is described, along with data and methodology standards that ultimately speed access to this information. This system will semi-automate activities such as material balancing, reconciliation of shipper/receiver differences, and report generation. In addition, this system will implement emerging standards that utilize secure direct electronic linkages throughout several phases of safeguards accounting and reporting activities. These linkages will demonstrate integration of equipment in the facility that measures material quantities, a site-level computerized Materials Control and Accounting (MC&A) inventory system, and a country-level state system of accounting and control.

I. BACKGROUND

Several major developments – political, economic, and technical – in the last 20 years have had a profound effect on the potential for proliferation of nuclear materials. Some of the more significant include the end of the Cold War, the down-sizing of the nuclear stockpile with the resultant increase in stored weapons-usable materials, the advent of a more global economy which promises to bring increased demand for electricity, and the dawn of the "information age" which has resulted in greatly reduced time scales for technology diffusion and information dissemination. Each of these point to the importance of an international safeguards regime which will provide for the protection, control, and accounting of nuclear materials while promoting the development of technologies for the peaceful use of nuclear energy.

Unfortunately, there is no international convention or treaty which requires common international standards for nuclear materials protection, control and accounting (MPC&A). The 1980 Convention on the Physical Protection of Nuclear Material, covers nuclear material for peaceful purposes while in international transport, but it has neither verification nor enforcement provisions. The International Atomic Energy Agency (IAEA) has also published guidelines for the physical protection of nuclear material (INFCIRC/225/Rev. 3), but these are advisory in nature.

At this point, each nuclear nation has some national or domestic system for safeguarding its nuclear material, but these domestic systems vary significantly both in terms of their legal basis and the technical standards to which they aspire. Non-weapons states subject to the Treaty on Non-proliferation of Nuclear Weapons are obligated to sign nuclear safeguards agreements with the IAEA that outline the legal requirements and technical standards for nuclear material control and accounting, containment and surveillance. While these guidelines and procedures are an important component of the international standards for nuclear material safeguards, the actual implementation of these requirements can vary considerably from country to country and, quite often, from site to site within a country.

The advances in information technology have resulted in the implementation of computerized materials control and accounting (MC&A) systems not only for tracking nuclear material within a facility or country, but for sharing information between facilities and even internationally. As we advance the role of both domestic and international safeguards as well as employ more advanced data collection and storage techniques, the need for common definitions and standards is essential to ensure the comparability of information exchanged between facilities.

II. INTRODUCTION

This paper describes two aspects of a computerized nuclear information system. First, a description of on-going work that deals with the standardization of the interface between safeguards instrumentation and MC&A databases is provided. Second, a prototype information system that utilizes a common communications infrastructure in conjunction with standards and protocols to link distributed information systems is described. Key to this integrated system is the communication infrastructure that will enable data consistency, validation and reconciliation, as well as provide a common access point and user interface for a broad range of nuclear materials information. Information can be transmitted to, from, and within the system by a variety of linkage mechanisms, including the Internet. Strict access control is employed as well as data encryption and user authentication to provide the necessary information assurance. The system provides a mechanism not only for data storage and retrieval, but could also provide the analytical tools necessary to support nuclear materials management and safeguards functions. This integrated approach is applicable to facility, national and international safeguards systems.

III. INTERFACE AND DATA TRANSFER STANDARDS

The current practice at most nuclear facilities for linking measurement systems to computerized information systems is to perform a measurement or isotopic analysis, manually review and validate the data, and then provide a report to the nuclear materials management organization which is then entered into the MC&A information system. Automation of this process would enable the MC&A data to be entered directly into an information system and allow the analyst to review and validate the data on-line. This process would be less labor intensive, provide near real time access to nuclear materials information, and provide for more efficient and cost effective plant operations. Some facilities have integrated the measurement and information systems together, but there is likely little to no consistency between the various systems. Development of a common set of standards for data collection, data validation, data transfer, and automated entry into the MC&A database is necessary to achieve successful implementation of an automated system. These standards would ease integration of instrumentation and databases from different sources: facilities, national laboratories, and commercial providers as technologies are updated to meet a broad spectrum of information needs. A standards based system would also ease the modification of instrumentation or information systems.

LLNL is currently leading an effort under the auspices of the Department of Energy for the development of standards and guidance that will define the minimum set of data required for a given safeguards requirement. Data file format standards and standards for instrument application programming interfaces (APIs) will also be considered. The working group formed by this project will consist of stakeholders in the process: facilities operations, materials management, instrumentation developers, and information system developers and implementers from various areas of the DOE complex.

Specific issues for instrumentation interface standards for MC&A include the following. Data collection needs to be accomplished in a way that meets the data transfer needs. There is a minimum amount of information that needs to be collected and has to be stored or translated into a format consistent with data transfer requirements. This effort might also touch on data file format standards and standards for instrument application programming interfaces (APIs). An analyst can validate data at the instrument or the data can be transferred to the MC&A Information System (IS) as a transaction and validated there before automated transfer to the database. Two concerns for data transfer are protocol (format) and content. Since different facilities have different data needs, the working group will define a kernel or minimum set of transferred data. The data transfer format must be extensible to handle this kernel with various facility-specific data fields. The automated data transfer (after validation) will be facilitated by a standard API for the MC&A information system. Like the data transfer format, this standard must be extensible to handle facility-specific needs. There are aspects of database design and implementation that can help or hinder automated transfer and the integration of subsystems of different sources. Standards or guidelines will be discussed by the working group for this aspect of the topic. The working group will consider standards and guidance for existing instrumentation and upgrades as well as new instruments.

IV. AN INTEGRATED NUCLEAR INFORMATION SYSTEM

LLNL envisions a fully integrated nuclear information system that could handle both domestic and international safeguards needs. This system will automate the process for data collection and transfer as well as provide a communication infrastructure to enable the user to access data at the appropriate level of detail.

Some of the key goals of this integrated approach are to:

- *Provide rapid availability of safeguards information*
- *Reduce the labor involved in maintaining the MC&A system*
- *Reduce errors and improve QA on safeguards data*
- *Facilitate integration of instrumentation and databases from different sources*
- *Promote unattended and remote monitoring applications*
- *Provide a rapid response mechanism to address questions regarding data interpretation or anomalies*
- *Anticipate the need for more data analysis*
- *Provide both information security and surety*

A. The System Engineering Process

The successful development and implementation of a system that will handle the complex nuclear material processing and safeguards requirements within the U. S. requires a rigorous software systems engineering approach. LLNL has chosen to use a rapid prototyping approach to the development of the integrated nuclear information system described here. This technique was chosen to aid in the development of the functional requirement and the system. Extensive user participation is required in the evaluation of the prototypes to refine the requirements and design.

B. Some Key Elements Of An Integrated Nuclear Information System.

1. Infrastructure. A key element of a successful integrated nuclear information system is the declaration, definition, existence and implementation of a common infrastructure (including data standards and communication protocols) through which all integrated elements communicate. One potential approach to implementation would include the distribution of responsibility between the central infrastructure management (e.g., the State System of Accounting and Control (SSAC) or IAEA) and operational organization, and the distributed elements that control information and utilize the communication infrastructure to pass data. The central organization would, in collaboration with the distributed elements, identify the standards by which nuclear materials information would be shared. These standards include data definition and format standards, interface standards, communication protocol standards, security standards, etc. that are common to a well defined, robust electronic communication infrastructure. An open, standards-based, documented interface definition for elements of an integrated system will, along with these other standards, accommodate changes to a given element, integration with future elements, and will make it easier to modify or enhance the infrastructure.

The central organization may also provide core services that become building blocks for tools needed by both central operations and the distributed elements. These services include a data dictionary for publishing and implementing the data definition and format standards, directory services for obtaining contact information on key personnel and organizations, common application program interface objects and modules for data sharing, security services for compatible implementation of access control and information assurance among all integrated elements, among others. It would also operate and maintain the necessary hardware and software to enable electronic linkages with the system's integrated elements, as well as develop and publish common mechanisms that enable electronic submittal and retrieval of data, a query capability, and report production and distribution services.

All services and standards would be clearly documented in infrastructure specification and policy documents. In addition, migration plans would be developed jointly with each currently existing element that would be integrated to assist in incorporating and/or developing necessary standards and services to enable appropriate communication.

2. Measurement Technique and Data Definitions. Each facility's nuclear materials safeguards systems has been developed independently and often there is little consistency among them in terms of how the data are represented. This means that the data dictionaries for these systems, which define the usage,

intent, and format for each data element, are largely incompatible. A consequence of this incompatibility is that comparison, validation, or reconciliation of the data among these many systems is difficult to accomplish manually, and virtually impossible to do in any sort of automated fashion. Furthermore there is often significant variation in measurement and analysis technique.

An example of the importance of understanding and communicating information such as the measurement technique and data definitions can be found in the common problem of shipper/receiver differences. When one facility ships nuclear material and/or parts to another, each must provide quantitative measurement of the material. The receiving MC&A program compares the shipper's measurements to their own. Any significant differences must be investigated. Differences in measurement uncertainty models can cause a false indication of a significant difference. Considerable resources may be spent in resolving these differences. There have been cases within the DOE complex where hundreds of hours were spent resolving a shipper/receiver difference that was eventually traced to differences in methods for calculating limits of error for shipment values.

The ultimate success and usability of an integrated system of nuclear information databases will rest on the development of a set of commonly used data definitions, and perhaps an agreed upon translation mapping among related but dissimilar data element definitions to achieve a level of compatibility required for effective sharing and understanding of collections of data from multiple data sources. Development of standardized statistical methodology for things such as modeling measurement uncertainty, propagating measurement uncertainty to develop limits of error for inventory difference and shipper receiver difference is an import part of the planning and requirements definition stages in the system engineering model. The development of appropriate data definitions must include input from and consensus among all of the user's of a system. In the U. S., the Department of Energy has used the process of working groups to develop effective and usable data content and format definitions. The identification and use of a set of commonly used data definitions will provide consistent data across all elements and sub-elements of an integrated system.

3. Specific Technologies Envisioned. The infrastructure's flexible, standards-based architecture will enable module re-use as new (sub-) elements are added or existing ones are modified. Strict access control could be enabled through Kerberos/DCE. Data encryption and sender/receiver authentication could be implemented using public key infrastructure (PKI) constructs along with sophisticated, automated need-to-know (NTK) technology to provide the necessary information assurance. A Java-based data entry engine could accommodate both a graphical user interface (GUI) and hands-off data submission for time savings in system operations and for users in the field. A similar engine could also be employed for some report generation, report retrieval, and on-line analyses. The infrastructure would likely be based on TCP/IP, which is the underlying communication protocol for the Internet and would accommodate the development of interfaces to other non-TCP/IP-based protocols such as direct-dial. X.500 is a likely candidate for implementation of directory services, as it is now in common use worldwide.

C. Prototype Description

LLNL has developed a web browser user interface as part of the communications infrastructure for enabling access to a broad spectrum of nuclear inventory and plant design information. The prototype demonstrates a means to access nuclear materials and/or facilities information for several countries including the United States, Russia, China, and India. This tool and its data are organized into layers. The **Top Layer** presents a map of the world including the names of pertinent countries. It also includes a flow chart and "pull down" tutorial for the nuclear fuel cycle. The **Country Layer** consists of several pages. The main page in this layer presents a map of the selected country, showing locations, names, and types of facilities in that country. It also presents a diagram of the nuclear fuel cycle, showing the names of the facilities that are part of that countries nuclear fuel cycle infrastructure, as well as a high level summary of the nuclear materials inventory for that country's. Other pages in this layer show more specific information about the country's inventory of nuclear materials, facility descriptions, and general information on the nuclear programs and safeguards activities in that country. The **Facility Layer** presents specific information about individual nuclear facilities. It includes facility inventories, diagrams, photos, design specifications, and other general information about the facility. The purpose of this prototype was to demonstrate a number of features of an integrated nuclear information system including the ability to quickly access information at varying levels of detail and to securely transmit this unclassified information via the Internet.

V. IMPLEMENTATION ISSUES

There are a myriad of implementation issues associated with the vision presented here, both administrative and technical. Not surprisingly, technology is not most challenging impediment to be overcome. Developing a comprehensive and in-depth understanding of the functional requirements for future safeguards information systems will require working with a broad spectrum of users including plant operators, domestic and international safeguards inspectors, and various regulatory and policy making organizations. On the one hand, to minimize the impact on facility operations one must utilize the existing facility MC&A systems and strive to avoid duplication of resources. On the other hand, each of the elements of this integrated system must be willing to move towards an environment in which common standards for data collection, transfer, and storage are utilized. This evolution will undoubtedly be slow in the highly regulated nuclear environment of existing plant operations.

With respect to technology challenges, the rapid interface between MC&A instrumentation and safeguards information systems does not currently exist. The power of information and computing technology will continue to grow exponentially for the foreseeable future. Computers/microprocessors will be embedded in almost everything and the speed of communications will approach the speed of light. Investment in the "information age" will require an investment in maintenance and evolution of the system. Data transmission and authentication issues must be carefully considered as part of system deployment. Security and protection of the information infrastructure is critical to transmission of data via the Internet. Standards for enabling the privacy, integrity, and non-repudiation of transported data as well as the authentication of users must be strictly enforced.

A. CONCLUSION

While we recognize the impediments to implementation of the system described, we believe the benefits to such a system far out weigh them. The consequences of illicit diversion of nuclear material are potentially catastrophic. The resources to devote to improving protection are finite. While there have been significant improvements in many areas of the world, many experts have warned it is not nearly enough. Commercial competitiveness and the disparities in wealth among nations also cause differing assessments of how much can be allocated to MPC&A activities There has been much written in recent years regarding the globalization of the world economy and the transformation of societies as a result of the spread of technology, the information explosion and the communications revolution. All of these facts underscore the need for international standards that are verifiable. Although safeguards cultures in most countries are slow to change, enhancing the ability to communicate with one another through the development of common standards and methodologies and speeding the access to important safeguards information, will promote an environment of trust and cooperation.

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