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DEFENSE NUCLEAR FACILITIES SAFETY BOARD

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January 20, 2006

The Honorable Samuel W. Bodman
Secretary of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Bodman:

In its response to the Defense Nuclear Facilities Safety Board's (Board) Recommendation 2004-1, *Oversight of Complex, High-Hazard Organizations*, the Department of Energy (DOE) committed to revitalizing Integrated Safety Management (ISM) with "a set of actions the Department will pursue to re-confirm that ISM will be the foundation of the Department's safety management approach and to address identified weaknesses in implementation." The enclosed technical report, DNFSB/TECH-36, *Integrated Safety Management: The Foundation for an Effective Safety Culture*, provides an assessment of the strengths and weaknesses of the current state of ISM implementation at the National Nuclear Security Administration's (NNSA) production plants and laboratories.

ISM was established 10 years ago as a new approach to integrating work and safety. The concept was adopted by DOE to enhance safety awareness, upgrade formality of operations, and improve safety performance. However, the potential for this practical safety system to achieve operational excellence and instill a sustainable safety culture has not been fully realized. From the broadest perspective, requirements and mechanisms to implement ISM are established, but implementation of safety management systems varies from site to site. This report examines the current status of the effectiveness of ISM systems at the seven NNSA weapons sites, summarizes failures and good practices, and proposes changes to enhance the effectiveness of ISM.

Sincerely,

A. J. Eggenberger
Chairman

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Ms. Patty Wagner
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Mr. Edwin L. Wilmot
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Enclosure

DNFSB/TECH-36

INTEGRATED SAFETY MANAGEMENT:
THE FOUNDATION FOR A SUCCESSFUL SAFETY CULTURE

Defense Nuclear Facilities Safety Board

Technical Report

DECEMBER 2005

INTEGRATED SAFETY MANAGEMENT:
THE FOUNDATION FOR A SUCCESSFUL SAFETY CULTURE

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EXECUTIVE SUMMARY

Integrated Safety Management (ISM) was established 10 years ago as a new approach to integrating work and safety. The concept was adopted by the Department of Energy (DOE) to enhance safety awareness, upgrade formality of operations, and improve safety performance. However, the potential for this practical safety system to achieve operational excellence and instill a sustainable safety culture has not been realized. In the broadest sense, system expectations and mechanisms to implement ISM are established, but execution of effective safety systems varies from site to site. This report examines the current status of the effectiveness of safety management systems at the National Nuclear Security Administration's (NNSA) seven weapons sites, summarizes failures and good practices, and proposes changes to enhance the implementation of ISM.

Important safety improvements have been achieved at the nuclear weapons production plants and the laboratories since the introduction of ISM. For example, work planning is formal, and plan-of-the-day meetings and pre-job briefs are frequent; formal identification of job hazards is regularly practiced; working to standards and using engineered controls to mitigate hazards are applied at the facility and activity levels; authorization of hazardous work, work control, and procedure adherence are common practices; and occurrence reports and incident critiques are focused on preventing similar occurrences.

Thus, ISM has clearly initiated many positive changes. The question is whether NNSA's production plants and laboratories are safer. The answer is not clear; even though formality has improved at all sites, and some safety performance measures have improved, the common-sense approach of the principles and functions of ISM is not always applied. At some sites, workers and line management perceive that ISM has deteriorated into a top-down, process-heavy, compliance-driven system. The perception is that DOE and NNSA set the ISM expectations, directives, and contract requirements; senior contract managers who are not familiar with facility operations develop the implementation processes; and line managers are left to implement a cumbersome program.

Most problems with the implementation of ISM occur at the activity level, particularly in research and development and nonroutine activities. Accidents happen when work is not planned according to the core functions of ISM. At some facilities, researchers and workers are operating outside of the activity-level safety envelope because the institutional-level decision makers do not fully understand the front-line work and hazards, and workers are motivated and rewarded for getting work done. Furthermore, managers do not spend enough time on the floor interacting with workers about ISM. To be more effective, ISM needs to start with the hazards and the work and should be owned, developed, and executed by line management and the individuals who do the hazardous work, with the support of subject matter experts as necessary.

During the review documented in this report, a number of positive attributes and good practices were observed that could improve the effectiveness of ISM at all sites. For example, senior managers at the best sites have an obvious commitment to ISM and actively demonstrate its principles and functions. Top managers spend significant and effective time on the floor, as evidenced by their technical awareness of the work and the hazards. Effective ISM organizations continuously increase safety performance expectations, recognize the reporting of errors, and reward outstanding safety achievements. At the best sites, cooperation between the site office and contractor management is apparent, and effective oversight, self-assessments, and supporting issues management programs are implemented. Nuclear facility operations at the better sites are compliant with Title 10, Code of Federal Regulations (CFR), Part 830, *Nuclear Safety Management*, and supporting DOE directives. At the activity level, clear operational boundaries are maintained and supported by change control programs at all levels. Workers understand the boundaries of their authorized work and what action is to be taken when an authorized boundary is approached. Finally, worker involvement at the activity level in identifying hazards, developing procedures, and improving safety is common practice at the better-performing organizations.

A number of important ISM attributes and good practices are discussed throughout this report. The following are the most important changes that would improve the effectiveness of ISM:

- Establish ISM as the foundation for modernizing safety culture at DOE and NNSA sites, and build an improved culture that engages workers and enables them to work safely and effectively.

- Clearly define a hierarchy of the roles, responsibilities, authorities, and accountabilities on every level in the workforce, from operators to managers.

- Define ownership boundaries and authorities at the institutional, facility, and activity levels, and focus on managing interface issues.

- Assign fully qualified ISM champions at key organizational levels.

- Require managers from line, program, and support organizations to spend time on the floor.

- Develop a process for evaluating the effectiveness of ISM.

- Incorporate safety culture changes, such as the Human Performance Improvement initiative, as an integral part of ISM.

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1. INTRODUCTION

In 1995, the Defense Nuclear Facilities Safety Board (Board) issued Recommendation 95-2, *Integrated Safety Management* (Defense Nuclear Facilities Safety Board, 1995a), which served as the impetus to develop a new approach to doing work safely at the Department of Energy's (DOE) nuclear facilities. Since that time, Integrated Safety Management (ISM), as defined by DOE Policy 450.4, *Safety Management System Policy* (U.S. Department of Energy, 1996), has evolved to a common-sense method for managing hazardous work with realistic controls. DOE and its contractors have invested significant resources in defining, developing, and implementing the five ISM core functions, and the ISM wheel is a commonly used logo throughout the DOE complex. The real return on this safety investment comes from employing the guiding principles of ISM at the management level and putting the core functions into practice at the facility and activity levels—the levels where workers handle hazardous materials, operate nuclear facilities, and perform hazardous activities.

The objective of ISM is succinctly stated in the Implementation Plan for Recommendation 95-2: "The Department and Contractors must systematically integrate safety into management and work practices at all levels so that missions are accomplished while protecting the public, the worker, and the environment." That straightforward tenet created a new focus on work practices throughout the DOE complex because for the first time, safety and mission were combined. After nearly 10 years of implementation, DOE contractors have accepted the functions and guiding principles of ISM as the basis for safety programs that demand standards-based safety management and excellence in the conduct of hazardous operations.

However, evidence suggests that execution of ISM at the activity level has fallen short of expectations for doing work safely. For example, a scan through DOE's Occurrence Reporting and Processing System (ORPS) database shows that many reportable incidents are caused by inappropriate hazard assessments, inadequate controls, and failure to learn from past mistakes. Independent ISM reviews at various DOE sites—discussed later in this report—have noted the failure of contractors to execute work to ISM principles. As a result, the full potential of ISM has not been achieved, and the complex is not as safe as one might hope after 10 years of implementation. Based on the above assessments and personal interactions, the Board began to sense that ISM had not progressed beyond compliance-driven paper processes that may appear to meet requirements, but fail to embrace the essence of ISM, which is to **Do Work Safely**. The objective of this report is to analyze the effectiveness of ISM implementation throughout the weapons complex, to identify best practices, to compare the various sites of the National Nuclear Security Administration (NNSA) with respect to ISM, and to help guide NNSA toward revitalizing the effectiveness of ISM.

2. BACKGROUND

2.1 ISM GUIDING PRINCIPLES AND CORE FUNCTIONS

Environment, safety and health (ES&H) protection requirements have evolved over the years. The Board's technical reports DNFSB/TECH-5 (Defense Nuclear Facilities Safety Board, 1995b) and DNFSB/TECH-16 (Defense Nuclear Facilities Safety Board, 1997) summarize the background of that evolution and the rationale behind ISM. Requirements captured in various pieces of legislation and DOE directives are generally directed at (1) protection of the public, (2) protection of workers, and (3) protection of the environment. Such protection is sought through limiting human exposure, either directly or indirectly, to the hazardous nature of the materials involved. The body of protective legislation was developed as discrete requirements and implemented in parts because organizations subject to such regulations established separate programs to comply. The result was a partitioned and sometimes confusing approach to risk management.

In 1995 the Board recommended that DOE undertake an integration of safety programs for managing the nuclear risks of its weapons program. The major thrust of Recommendation 95-2 was:

> ...to bring the many safety-related directives, implementation efforts, and new initiatives related thereto into a more cohesive, integrated, and effective safety management program, with clearer lines of responsibility and authority for its execution....

DOE's Implementation Plan for Recommendation 95-2 is based upon seven guiding principles:

- Line management responsibility for safety
- Clear roles and responsibilities
- Competence commensurate with responsibilities
- Balanced priorities
- Identification of safety standards and requirements
- Hazard controls tailored to work being performed
- Operations authorized

In sum, these principles articulate the management philosophy underpinning DOE's safety program. ISM, however, is more than philosophy. Its practical implementation is structured to standardize a flexible "think before doing" approach to performing hazardous work. This approach is captured in five core functions:

- Define the scope of work
- Analyze the hazards
- Develop and implement hazard controls
- Perform the work within the controls
- Provide feedback and continuous improvement

The approach is generic. ISM can be applied effectively to any hazardous operation, whether it is at the site, facility, or activity level. According to DOE policy, ISM should be applied to both nuclear and non-nuclear hazards. Its principles and functions can also be applied effectively to safeguards and security and environmental protection activities.[1]

DOE established the ISM program as its reference safety management system through issuance of a policy statement, DOE Policy 450.4 (U.S. Department of Energy, 1996), and modification of its acquisition regulation, Title 48, Code of Federal Regulations (CFR), 970.5223-1, to require implementation of ISM by its contractors. Since then, DOE senior management has been constant in expecting its contractors to be responsible and accountable for managing their contracted activities in keeping with the principles and functions of ISM. The ISM Guide (DOE Guide 450.4-1B) has clear and rigorous descriptions and suggestions for implementing ISM. In addition, DOE has issued numerous directives that define ISM expectations for DOE and its contractors (see, for example, Figure 5 on page 42 of the ISM Guide). The problem with ISM is not in the requirements; rather, both DOE and its contractors have struggled with the detailed implementation of ISM, particularly at the activity level. This is the case even though the contractors have expended significant effort on strengthening self-assessment programs as the first line of surety, and DOE's field offices and the Office of Independent Oversight and Performance Assurance (OA) have periodically assessed ISM system performance. In addition, DOE has held a number of workshops that have identified ideas for maintaining and improving ISM. These assessments and workshops have revealed variability in the robustness of the program from site to site, with most sites not performing to expectations.

In recognition of the need to reinvigorate ISM, DOE's response (U.S. Department of Energy, 2004a) to the Board's Recommendation 2004-1 commits to revitalizing ISM implementation with "a set of actions the Department will pursue to re-confirm that ISM will be

[1]DOE Policy 450.4 currently specifies that environmental protection is included within ISM. Yet many sites have not fully integrated their management programs to include environmental management.

the foundation of the Department's safety management approach and to address identified weaknesses in implementation." This initiative is a positive development, but may not be sufficient to address some of the attitudes and perceptions that are inhibiting the enthusiasm needed to implement ISM effectively.

2.2 ISM STRUCTURE

As noted earlier, ISM was established by DOE as a new approach to integrating work and safety. In its original construct, ISM was aimed at three levels:

- *The institutional level*—the DOE regulatory and program organizations. This level has responsibility for setting standards and expectations, as well as overseeing the implementation of ISM by contractors. The institutional level also encompasses contractor management of the laboratories and production sites. The seven guiding principles of ISM are basically management requirements for its implementation at the facility and institutional levels.

- *The facility level*—the safe and compliant operation of facilities that house hazardous activities. The primary goal of implementing ISM at the facility level is to provide an approved safety basis for both production and research activities. Properly applied at the facility level, ISM is designed to protect workers from system-level accidents (a facility fire, for example) and the public from the release of hazardous materials and chemicals (plutonium, for example). The five core functions of ISM provide the fundamental logic for developing a compliant facility safety basis; the details are embodied in DOE directives.

- *The activity level*—the safe execution of hazardous work needed to accomplish DOE's national security, environmental cleanup, energy, and science missions. The five core functions of ISM provide the fundamental logic for developing procedures and work controls that protect the technologists, scientists, and engineers working with hazardous materials and energetic processes.

Figure 1 illustrates the successive organizational levels of ISM. The outer, institutional level provides (1) safety requirements in the form of DOE regulations and directives, (2) mission and funding based on NNSA program priorities, and (3) implementing requirements and cultural values from local site and contractor policies and procedures. The middle, facility level provides a safe operating platform that protects the public. The inner, activity level provides procedures and work controls to protect workers and enable hazardous work. Individuals at each level have roles and responsibilities for integrating work and safety, but line management responsibilities focus on the inner activity level, where work and safety must be integrated with other priorities. The five core functions are more applicable at the activity level, while the guiding principles are more relevant at the institutional level.

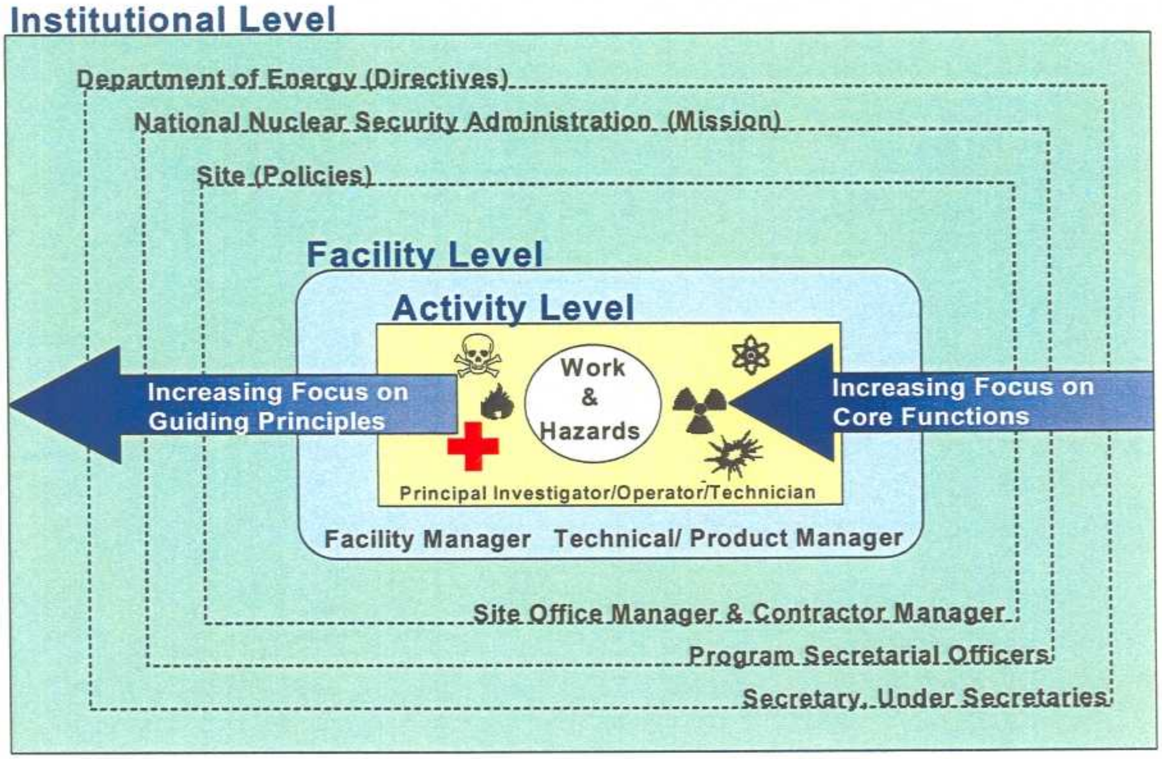

Figure 1. Conceptual illustration of the interactions among the institutional, facility, and activity levels. The safety requirements at each level should be used as the basis for the next-lowest level of requirements, such that the hazard controls at the activity level are traceable to the high-level requirements.

2.3 SAFETY PERFORMANCE

DOE and its predecessor organizations have a long and improving safety performance record in nuclear operations. For example, as shown in Figure 2, the rate of Lost Workday Cases (LWCs) at DOE sites has dropped by more than 50 percent during the past 12 years. Similarly, as shown in Figure 3, the number of deaths in the DOE complex has been declining steadily. These safety performance data suggest that DOE has a good and steadily improving safety record and that implementation of ISM has had a positive impact on safe operations.

However, a closer look at some of DOE's safety performance data reveals some inconsistencies that could give cause to question that conclusion. For example, DOE's LWC rates prior to 1990 were nearly 50 percent lower than those of the early 1990s, indicating that the downward trend after 1990 could be a simple accounting artifact. The apparent downward trend in fatalities shown in Figure 3 looks quite different when one considers only deaths at defense nuclear facilities since 1975. In addition, the numbers of Type A and B Accident Investigations, Price Anderson Enforcement Actions, and Operational Emergency Occurrences have not declined, suggesting that the frequency of serious accidents and near misses has not been reduced by the introduction of ISM.

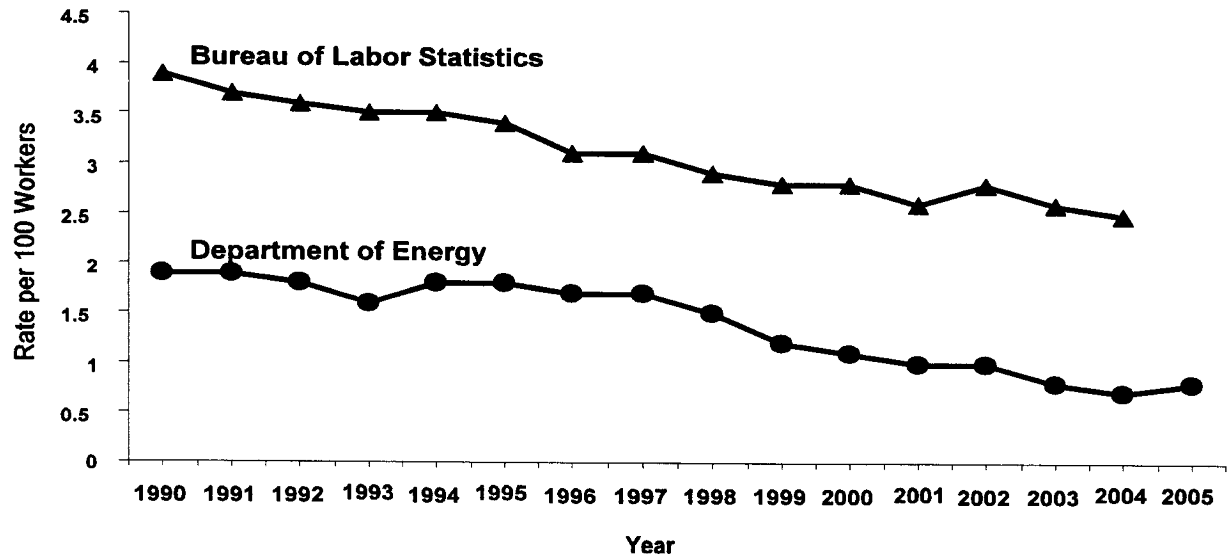

Figure 2. LWCs at DOE sites reported by the Computerized Accident and Incident Reporting System, compared with U.S. industry LWC rates reported by the Bureau of Labor Statistics' Survey of Occupational Injuries and Illnesses, 1990 to 2004.

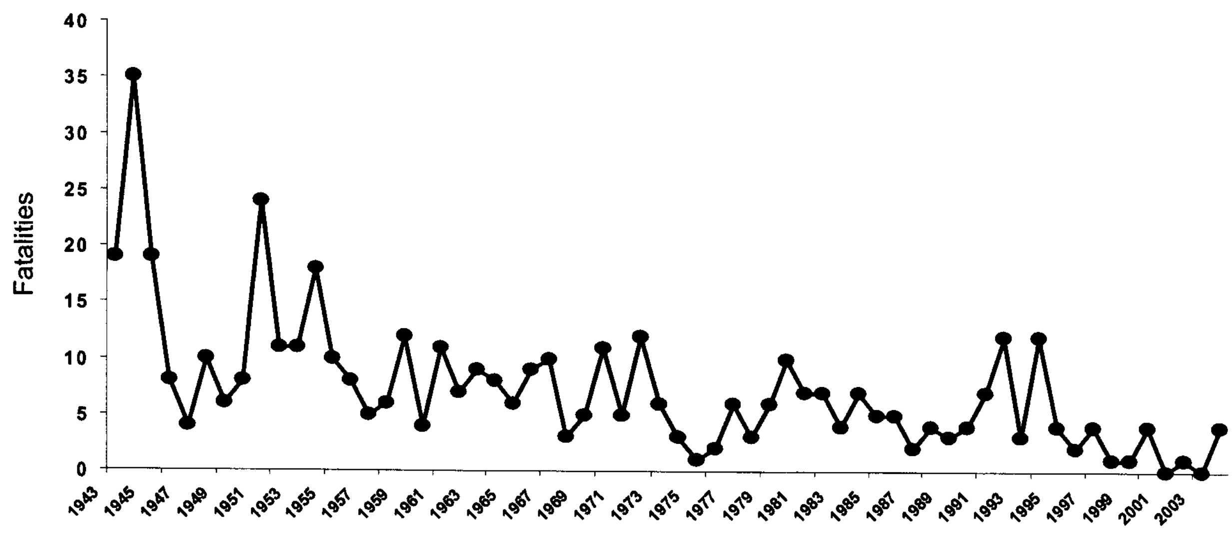

Figure 3. Annual worker fatalities at sites run by the Atomic Energy Commission, the Energy Research and Development Administration, and DOE during the past 61 years.

Note: Fatality data were compiled from: (1) U.S. Department of Energy (a) *Annual Reports to Congress 1979–2003*, (b) *Operational Accidents and Radiation Exposure Experience with the Energy Research and Development Administration 1975–1978*, and (c) *Operational Accidents and Radiation Exposure Experience within the United States Atomic Energy Commission 1943–1975*; (2) U.S. Department of Energy, Office of Environment, Safety and Health, *Annual Reports, Fiscal Years 1980–1985*; (3) *U.S. Atomic Energy Commission, Annual Report to Congress 1943–1974*; and (4) *U.S. Energy Research and Development Administration, Annual Reports to Congress 1975–1978.*

3. RECENT ISM ASSESSMENTS

Full realization of an effective ISM program can be divided into three logical phases: (1) establishing the program expectations; (2) establishing the mechanisms to implement the program; and (3) applying these mechanisms at the facility and activity levels. In 2000, DOE declared that initial efforts to implement ISM had been completed at all DOE sites and subsequently initiated actions to "take ISM to the next level." Several recent reviews have assessed ISM at the sites. In 2002, DOE held a workshop (Idaho National Engineering and Environmental Laboratory, 2002) that provided some interesting insights into the level of implementation of ISM. The following conclusions are paraphrased from the workshop report:

- ISM systems have not been fully established, and the maturity of implementation varies significantly from site to site.

- DOE and its contractors are aware of ISM requirements, and action is being taken to achieve compliance.

- Problems with adequacy of requirements, guidance, intent, and expectations for ISM make effective implementation difficult.

The workshop participants recommended improvements, primarily in the areas of changing requirements, establishing implementation plans, and performing annual reviews.

DOE's OA issues an annual ES&H evaluation that provides valuable insights into the implementation of some ISM principles and functions. Generally, the reports state that ISM programs are well established and functioning adequately across the DOE complex. For example, in the 2003 and 2004 reports (U.S. Department of Energy, 2003 and 2004b), OA concludes that sites with mature ISM systems have had lower reportable injury rates, that ISM processes are in place at most sites, that work hazards are being identified, and that all sites have effective performance on the guiding principles of ISM. However, the evaluations also indicate that improvement is needed in developing and implementing hazard controls, performing work within the controls, and providing feedback and improvement. Although the assessments assert that ES&H trends across the complex are improving, a close reading of the reports suggests that while the processes are well documented, the effectiveness of ISM implementation at the activity level is inadequate.

The Board reviewed ISM work control practices at five NNSA sites in 2003 and 2004 (Defense Nuclear Facilities Safety Board, 2004a). On the positive side, all sites used formal procedures, applied processes to identify and analyze hazards, authorized hazardous work, and conducted pre-job briefings. Negative aspects included deficiencies in work planning, hazard identification and analysis, implementation of adequate controls, and feedback and improvement. As a result of issues identified by OA's assessments and the Board's observations, NNSA held a workshop to review work planning and control practices. The workshop participants identified a culture problem "where line management has often failed to ensure that work is strictly conducted in accordance with established ISM system processes and procedures, and that, in some cases, has included inappropriate practices such as over-reliance on automated job hazard analysis tools."

Effective work control is at the heart of implementing ISM at the activity level; therefore it is troubling that these assessments suggest there has been no significant change in processes for analyzing and controlling hazards during the past 5 years. This conclusion is supported by data from the ORPS database, in which more than 40 percent of reported occurrences are related to failures to perform adequate hazard analysis and to develop and implement adequate controls. Further, a scan through the weekly reports of the Board's Site Representatives indicates that many of the issues discussed in those reports are associated with inadequate hazard analysis and definition of controls. In addition, nearly 50 percent of the Board's correspondence between 2000 and 2004 addressed ISM issues; development and implementation of hazard controls was the core function mentioned most frequently, and identification of safety standards was the guiding principle addressed most often.

Overall, these recent assessments reveal a robust set of ISM expectations and relatively strong ISM implementing mechanisms[2] at most sites, but their conclusions indicate poor execution of these mechanisms, particularly with regard to the core functions of analyzing and controlling hazards and providing feedback and continuous improvement. In addition, specific assessments to evaluate the effectiveness of ISM implementation are not common, and the "think before doing" safety culture that ISM promotes has not been fully realized. Fortunately, DOE and NNSA appear to have taken these identified ISM deficiencies seriously and have outlined steps to revitalize ISM in the Implementation Plan for Recommendation 2004-1. The remainder of this report evaluates the effectiveness of ISM in improving safety performance and safety culture in order to assist DOE in its initiative to revitalize ISM.

[2]DOE Policy 450.4 states that a safety mechanism defines "how the core safety functions are performed."

4. REVIEW PROCESS

As a follow-up to the ISM assessments discussed in Section 3, an approach for independently evaluating the effectiveness of ISM at NNSA's nuclear sites was developed. The basic plan consisted of examining ISM practices at the institutional, facility, and activity levels at each site. A vertical slice through the organization began with interviewing the highest level of contractor and site office management and ended with observing work activities and talking with operators and first-line supervisors in their workspaces. Typically, five managers (including directors and site office managers, facility managers, and technical leads) were interviewed and three operations (including experiments, facility modifications, and manufacturing processes) were observed at each site. A total of 2 days was spent at each site over a 2-month period, so the observations in this report represent a Blink (Gladwell, 2005) type of analysis. However, the rapid vertical slice through the organization was an effective method for probing underlying practices, attitudes, and perceptions that may be inhibiting the effective implementation of ISM.

Lines of inquiry based on the seven ISM guiding principles were developed and used for interviewing the managers responsible for instituting ISM expectations and requirements. Not all of the questions were asked of every manager; the goal was to develop an understanding of the depth of knowledge and commitment by management to each of the guiding principles. Similarly, lines of inquiry based on the five core functions of ISM were developed and used during on-the-floor interactions with the men and women responsible for doing hazardous work. The goal of these questions was to establish the depth of workers' understanding of hazards and controls and commitment to formality in conduct of operations.

5. ANALYSIS OF RESULTS

5.1 COMMENTS/OBSERVATIONS ON ISM IMPLEMENTATION AT NNSA SITES

Sites in NNSA's weapons complex are composed of two basic types of organizations: (1) multidisciplinary laboratories (Lawrence Livermore National Laboratory [LLNL], Los Alamos National Laboratory [LANL], and Sandia National Laboratories [SNL] and the Nevada Test Site [NTS][3]) and (2) weapon production plants (Savannah River Site [SRS] Tritium Operations, Y-12 National Security Complex [Y-12], and Pantex Plant). Weapons program elements, such as surveillance, assessment and certification, assembly and disassembly, testing, research and development (R&D), and manufacturing, are interconnected, and the design laboratories have close partnerships and working relationships with the production plants. Therefore, one might expect to see some similarities in operational safety. However, the nature of activities at these two distinct types of sites differs significantly, as do the composition and type of staffing.

The laboratories are essentially NNSA "think tanks." They serve as the source of new weapon concepts and the facilities for research, development, and testing on nuclear weapon materials and components. While the laboratories have manufactured parts for years, and their production program work is increasing, the work atmosphere has its cultural roots in scientific creativity and intellectual freedom. The laboratories operate a number of unique, state-of-the-art nuclear, chemical, physics, and computer facilities. Even though NNSA owns the laboratories, a significant portion of their work is supported by agencies other than NNSA and DOE. The staff is heavily populated with doctoral-level specialists supported by laboratory technicians who are skilled in the use of sophisticated instruments and testing techniques. Products have been primarily advances in the physics and chemistry of nuclear materials, advanced engineering and computing technologies, and their application to nuclear weapon performance.

The production facilities, on the other hand, are more akin to industrial facilities that turn out multiple identical products. Uniformity and quality are achieved through rigor in production, supported by repetitive processes and compliance with proven production processes and protocols. The skill mix in the production facilities is quite different from that in the laboratories, with greater dependence on engineers to design, construct, operate, and maintain complex engineered systems for reliability and safety. For the most part, the work at the production plants is devoted to NNSA-supported weapons activities, and products are weapon components and systems. Operations rely on technicians with skills typically taught by the trades or acquired from on-site experience and training.

Given these fundamental differences, it may be informative to consider the reactions of the organizations at the laboratories and plants to ISM. Generally, management in both types of organizations has adopted the principles of ISM and worked diligently to implement its functions

[3]NTS is a unique site that combines production-like activities, such as mining, with laboratory experimental activities.

at the facility level. However, different perceptions of the usefulness of ISM at the activity level emerged from this study. Basically, experimental scientists approach their work differently from production engineers. A perception at the production plants is: "Operators don't need to understand the science behind what they are doing. They simply need to follow procedures and trust that the procedures will keep them safe."[4] In contrast, the laboratory view tends to be: "For scientists, you have to construct a flexible system in which the experimenter can operate safely." Some at the laboratories believe that ISM is primarily a compliance-driven process, forced on the laboratories by DOE to transition from an expert-based approach to safety to a standards-based approach. As a result, workers who understand the scientific principles behind their work see ISM as an unnecessary documentation process that does not necessarily benefit safety. On the other hand, some with manufacturing responsibilities feel forced to comply with a system developed by the laboratories to do research safely. Not all plant contractors believe they need ISM or view their previously existing safety processes as inadequate. When asked, "How would you have done this job 5 years ago?" some replied: "Exactly the same. The only difference is the paperwork. I consider myself just as safe as I was 5 or even 20 years ago."

Interestingly, a common perception at both laboratories and plants is that ISM at the activity level is too focused on paper and not focused enough on work. The question implied in several conversations was: "When does compliance interfere with productivity and not improve safety?" A more cynical view was: "ISM is good to have because it makes a nice safety sales package." Clearly, important barriers to effective implementation of ISM remain in the minds of some who have the responsibility for dealing with hazards.

Notwithstanding these differences between the plants and the laboratories, important safety improvements have been achieved at both types of sites since the introduction of ISM nearly 10 years ago. For example:

- Prior to ISM, work planning was largely informal and individual, whereas today all sites have plan-of-the-day meetings and conduct pre-job briefs that integrate safety and work.

- Ten years ago, knowledge of hazards was intuitive and experience-based; now formal identification of job hazards is more commonly practiced.

- The concept of working to standards and applying engineered controls to mitigate hazards was applied only at the facility level; now many understand the importance of implementing and maintaining safety controls at the activity level.

- Ten years ago, work control was often left to the individual, especially at the laboratories; now authorization of hazardous work by responsible line managers is a common practice at all the weapons sites. Likewise, work control and procedure adherence have been implemented at all sites.

[4]Note that quotations such as these are paraphrased from comments made during the interviews conducted for this study.

- The reporting of occurrences has improved since the implementation of ISM, and the proper use of incident critiques is focused on preventing similar occurrences at most sites.

The following is a brief synopsis of some of the observations, good practices, and difficulties with the implementation of ISM at the seven NNSA sites.

5.1.1 Lawrence Livermore National Laboratory

LLNL's focus is primarily on R&D experiments involving a variety of hazardous materials and operations. The contractor and the Livermore Site Office (LSO) manage a number of facilities where the potential for high-consequence accidents exists, including plutonium releases that are complicated by the proximity of the plutonium facility to the public. LLNL runs three Hazard Category 2 and four Hazard Category 3 nuclear facilities.[5] The dose to the maximally exposed offsite individual (MEOI) for an unmitigated accident at LLNL's plutonium facility is calculated to be approximately 50 rem total effective dose equivalent (TEDE).[6] The variety of activities at LLNL, combined with an entrenched expert-based safety culture, appears to have slowed ISM implementation. In fact, even though ISM has been a DOE expectation for nearly 10 years, LLNL adopted its basics only recently. On the other hand, LLNL's safety performance record, as measured by its LWC rate, has been improving steadily since 1990 (see Figure 4); however, LLNL has had four serious accidents that required Type A and Type B accident investigations since 1990.

> **ISM at the Institutional Level:** LLNL management appears to understand the ISM problems that have been pointed out by independent assessments and is determined to change the laboratory's safety culture by driving ISM implementation from the top. In general, LLNL managers did not provide clear answers to questions about safety functions and responsibilities. Discussion of the seven guiding principles of ISM was handled better by LSO managers. LLNL managers have developed improved work control processes that meet external expectations but may not meet the needs of operators. On-the-floor observations by line managers, which would facilitate understanding operators' needs, do not occur as frequently as they should. The LLNL system for identifying specific Authorizing Organizations, Authorizing Individuals, and Responsible Individuals appears good in concept. However, LLNL suffers from inconsistent implementation of work control processes across the site and within the various directorates.

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[5]The hazard analysis for a Hazard Category 2 nuclear facility shows the potential for significant onsite consequences. The hazard analysis for a Hazard Category 3 nuclear facility shows the potential for only significant localized consequences.

[6]The number of nuclear facilities and MEOI data quoted throughout this report are based on Safety Analysis Reports and Documented Safety Analysis reports published as of the time of the site visits.

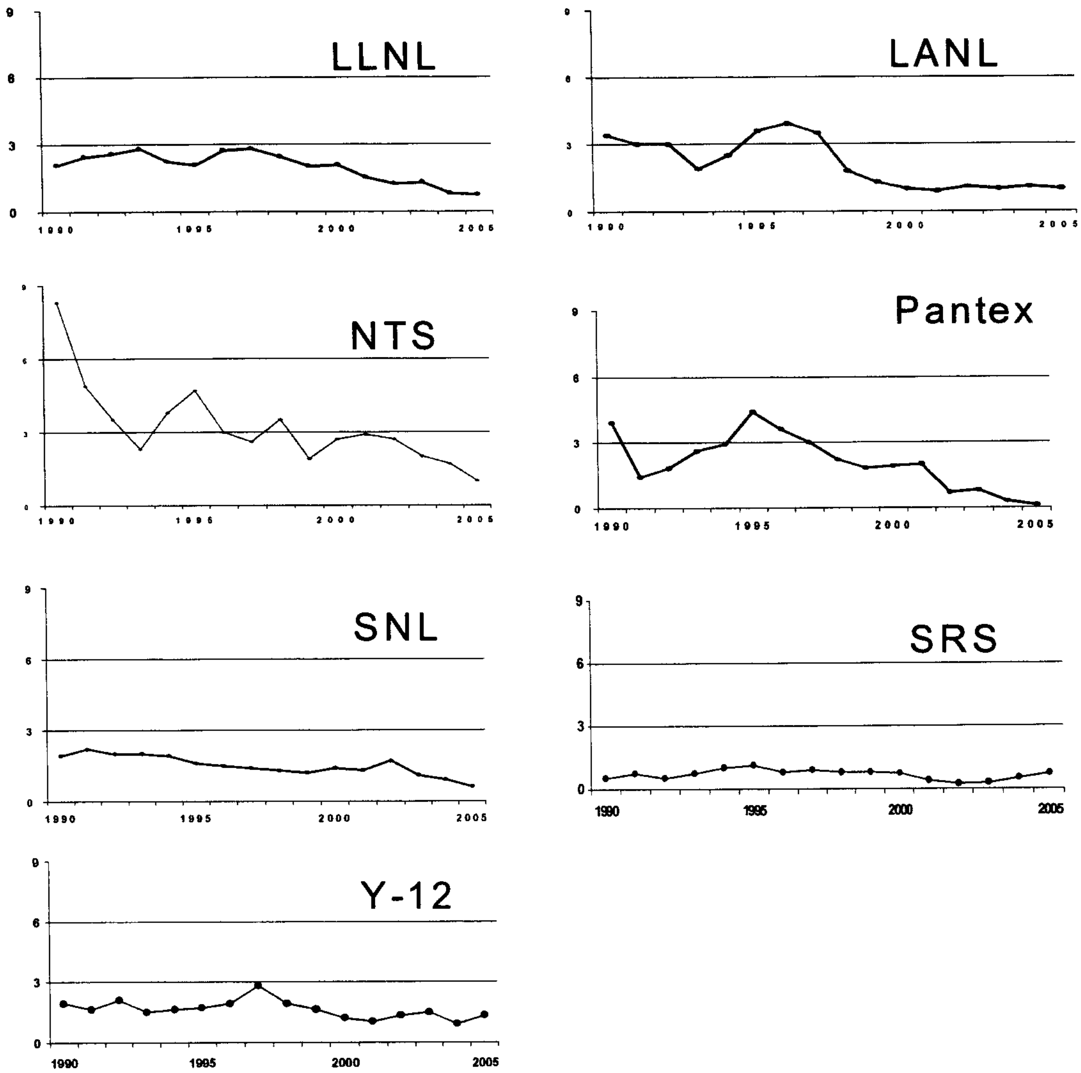

Figure 4. LWC rates for specific NNSA sites.

ISM at the Facility Level: LLNL's plutonium facility does not have an authorization basis compliant with Title 10 CFR Part 830, *Nuclear Safety Management* (10 CFR Part 830), and the classification of safety systems has not met expectations. A recent OA assessment identified (LLNL self-reported) violations of the Configuration Management Control Program, the Radiation Protection Program, the Unreviewed Safety Question Program, the Maintenance Program, the Quality Assurance Program, and Occurrence Reporting at the LLNL plutonium facility. LLNL management, in conjunction with LSO, is addressing these long-standing problems.

ISM at the Activity Level: Operational safety at LLNL is still largely experience/expert-based. Technicians and first-line supervisors were comfortable with discussing the scope of work they were authorized to perform; they understood that work must be authorized before being performed; and they were well-versed in the need to stop work when unexpected situations were encountered. LLNL's improved work planning processes (ES&H teams review hazards and controls) appear sound in concept, but their application appears to workers to be more administrative than practical. Workers at LLNL have the perception that the work planning processes are cumbersome and do not emphasize the necessary safety controls. In particular, the processes for hazards analysis and control documentation do not lead to explicit understanding of the hazards and clear identification of controls.

5.1.2 Los Alamos National Laboratory

LANL is probably the most complex NNSA site: It's activities range from fundamental R&D to manufacturing and production. Various hazardous materials, including plutonium-238 and high explosives, are handled routinely, and 11 Hazard Category 2[7] and 4 Hazard Category 3 facilities were operating at the time of this review. In addition, LANL and the Los Alamos Site Office (LASO) manage a number of facilities with potential high-consequence accidents, including inadvertent criticality, fire-induced plutonium releases, and accidental impacts that could breach waste drums. Activities at LANL deal with a broad range of hazards, from basic industrial hazards to unknown reactions resulting from chemical research. Finally, the pace of operations is high, and changes in mission, management, and oversight are frequent. LANL's LWC rates have been relatively steady during the past 5 years, but show significant improvement relative to the 1990 rate (see Figure 4). LANL has experienced too many serious accidents and near misses during the past 15 years, however, as evidenced by 12 Type A and Type B accident investigations.

ISM at the Institutional Level: During the mid-1990s, LANL was a Defense Programs leader in ISM, had an empowered ISM champion, and implemented good ISM programs in some nuclear facilities. Since that time, other priorities have diluted management's attention to ISM, and attempts to institutionalize ISM have encountered resistance. Similar to LLNL, LANL has had difficulty in implementing hazard analysis and control processes consistently across the various directorates. Recently, safety (and security) became an institutional focus, resulting in a 6-month standdown of all nonessential activities; the subsequent high-level attention to safety management should improve implementation of ISM. In general, responsible line managers have the competence to manage work safely, but understanding of the guiding principles of ISM does not appear to be comprehensive at the senior management level. This apparent lack of understanding can contribute to inconsistent implementation of ISM at the activity level.

ISM at the Facility Level: Facility-level work control has been a past focus at LANL and is generally effective. ISM functions are applied to develop facility safety bases;

[7]Three facilities have unmitigated MEOIs with calculated doses that exceed 200 rem TEDE.

however, the quality of safety analyses and Technical Safety Requirements varies from organization to organization. In addition, the safety basis documents for several Hazard Category 2 nuclear facilities are out of date by 2 to 10 years and therefore are not compliant with the Nuclear Safety Management Rule.

ISM at the Activity Level: Most facility work is well planned, and most researchers can identify hazards and controls; however, lack of formality in operations is a persistent problem at LANL, particularly in R&D activities. Many of the findings identified during preresumption management self-assessments were related to work control, and approximately 30 percent of the pre-start findings were ISM related. Therefore, actions to improve work control are essential to improving safety at the activity level. Implementation of LANL's Integrated Work Management program, which focuses on the functions of ISM, builds on previous work control initiatives, and clarifies expectations, appears to be a good path forward.

5.1.3 Nevada Test Site

Little hazardous nuclear work is currently being done for NNSA at NTS. The Device Assembly Facility (DAF) is being refurbished to accommodate some experimental and subcritical plutonium assemblies and activities, and shipments of special nuclear material for criticality experiments are being received and stored. One or two subcritical assemblies are tested annually in the U1a Complex, and plutonium dynamic experiments are being conducted at the Joint Actinide Shock Physics Experimental Research facility. The workload is deliberately paced, and hazardous activities are far removed from the public. However, the scope of operations will likely increase when the criticality experimental facility comes on line, when and if weapon dismantlement activities increase, and when tunnel upgrades to permit disposal of damaged nuclear weapons are funded. For an unmitigated accident at DAF, the MEOI is calculated to receive 325 rem TEDE; for subcritical tests, MEOIs are calculated to receive doses less than the evaluation guideline of 25 rem TEDE at the site boundary. Workers must deal with radiological hazards and a variety of industrial and transportation hazards. The major difficulty at the site is integrating the activities of three "equal" users: Bechtel Nevada Incorporated, LANL, and LLNL. Other agencies also conduct hazardous activities at the site, thereby making the integration of safety management practices a challenge for the site office. NTS had a high LWC rate in the early 1990s, but recent performance has been steadily improving (see Figure 4). Since 1990, NTS has had four serious accidents that required Type A and Type B accident investigations.

ISM at the Institutional Level: Because of the hiatus in activity after the 1992 moratorium on nuclear testing, NTS did not fully employ ISM practices until the startup of subcritical testing. The Nevada Site Office (NSO) used expert consultants to develop safety management processes, and the site user organizations are working together to implement ISM at the facility and activity levels. NSO's expectations encourage the user organizations to improve safety practices by insisting on compliance with a comprehensive set of site operating standards to which all contractors must adhere. The issues management system implemented by NSO appears to be effective, and overall management oversight, facility safety analyses, and formality of operations are improving. In general, NNSA and contractor managers are committed to ISM, but lack experience in implementing rigorous safety programs in a high-productivity environment.

ISM at the Facility Level: NSO has developed a Real Estate/Operations Permit (REOP) process to coordinate facility interface issues among the site user organizations. For example, LLNL is the primary REOP holder for DAF and is responsible to the NSO manager; LANL is a secondary REOP holder and is responsible to the LLNL REOP holder. The system appears confusing on paper but apparently functions to ensure that work is properly reviewed and authorized. Prior to 2000, facility authorization bases at the test site were basically nonexistent, primarily because little nuclear facility work was being conducted. The nuclear facility safety culture changed, and DAF has a rule-compliant Documented Safety Analysis. Overall, the understanding of nuclear facility requirements and operations is limited—the site operators rely on safety basis consultants to write Documented Safety Analyses and Technical Safety Requirements—but is improving with experience.

ISM at the Activity Level: NTS has a rich history of formality of operations based on mining safety and control and oversight of underground tests. The site is building on that experience to bring activity-level work control up to modern standards. Most of the "hands-on" work at the site is done by Bechtel Nevada employees. Employees from both laboratories stated that safety operations were better at NTS than at their home sites. A hazards-based, graded approach to work control is used. All levels of work must be authorized, but the complexity of reviews and oversight increases with risk. The work authorization for moderate- and high-risk activities is intensive and may be too cumbersome if the work pace increases.

5.1.4 Pantex Plant

The Pantex Site Office and contractors manage activities with the highest accident consequences in the NNSA complex: nuclear weapons, nuclear materials, and high explosives are assembled, disassembled, and stored at the site. About 17 Hazard Category 2 buildings support nuclear operations at the Pantex Plant. The safety of nuclear operations at Pantex has improved over the years, and the likelihood of a high-consequence nuclear explosive accident is extremely low. Individual weapon systems vary in complexity, but work is carefully planned for each campaign. While the pace of assembly/disassembly activities is fairly constant, it could increase with potential new dismantlement and life extension missions. The conduct of operations at Pantex must meet the highest standards achievable, and the acceptance of equipment and operational errors should be exceedingly low. Significant improvements in some elements of formality of operations and safety have occurred during the past several years, and progress is expected to continue. For example, NNSA has expended significant resources at the Pantex Plant on developing Seamless Safety for the 21st Century (SS-21) processes that rely on specially designed tools and a minimal number of hoisting operations to eliminate or minimize potential hazards of nuclear explosive operations.

ISM at the Institutional Level: ISM works on a macro scale at Pantex with multiple interfaces among different organizations. The Pantex Site Office approves operations after multiple levels of review and analysis:

- The design laboratories (LLNL, LANL, SNL) participate in the development of requirements and approval through the weapons response process and nuclear explosive safety reviews.
- Contractor engineering organizations—including process engineers, authorization basis analysts, planners, tooling engineers, and safety experts—plan each campaign, identify hazards, and establish controls for operations.
- The facility organization authorizes work within nuclear facilities and ensures that the authorization basis requirements for the bays and cells are implemented.
- The maintenance organization performs preventive and unscheduled maintenance on safety systems and components.
- Manufacturing teams authorize work and assemble/disassemble weapons following the procedures developed as part of the SS-21 process.

Because interfaces can be weak points in any system, coordinating these multiple interfaces into an effective safety management program is a challenge. Site office personnel and contractors are well-versed in the guiding principles of ISM and appear to believe that current practices are fully consistent with the spirit of ISM. LWC rates have dropped during the past 10 years (see Figure 4); one accident requiring investigation was reported in 1994.

ISM at the Facility Level: Pantex has a complex facility safety basis process; the site is transitioning to 10 CFR Part 830 compliance, and the method for developing and implementing new Technical Safety Requirements while old requirements are still active is slow and cumbersome. Safety basis documents at Pantex fall into three categories: site-wide, facility-specific, and weapon-specific. In the site-wide safety basis, the dose to the MEOI from an unmitigated tritium release is calculated to be 325 rem TEDE; weapon-specific calculations for assembly/disassembly operations indicate the MEOI will receive in excess of the 25 rem TEDE evaluation guideline. Some safety basis documents are approved and in the process of being implemented, and some are still in the process of being developed. In addition, the practice of having nested safety bases, with a weapon-specific safety basis within a facility-specific safety basis within a site-wide safety basis, can lead to confusion as to who is the integrated owner and who authorizes work.

ISM at the Activity Level: Rigorous compliance with procedures is a strong point of safety at Pantex. Assembly and disassembly campaigns are thoroughly planned to identify hazards, develop controls, and write procedures; 2 years from start of planning to start of work is typical. Manufacturing personnel are heavily reliant on the design laboratories and safety analysts for technical knowledge, planning, hazard identification, and safety controls. Pantex relies on rigid procedural compliance for nuclear explosive operations, and as a result, ISM concepts do not appear to be an integral part of the culture at the activity level. Some operators could not identify hazards and safety controls, even though Pantex relies on the technicians to stop work as the last line of defense.[8] In addition, many procedures rely heavily on administrative controls. Verbatim compliance with procedures works well as long as activities are within analyzed hazards and defined boundaries. However, rote compliance could weaken the understanding of knowledge-built and experienced-based safety; the risk is that lack of understanding of hazards and experience could result in an inappropriate reaction during an unexpected event.

5.1.5 Sandia National Laboratories

SNL's nuclear operations are relatively straightforward and of low consequence to the public. Two Hazard Category 2 and two Hazard Category 3 nuclear facilities are housed in Technical Area V, but calculations show that the MEOI will receive considerably less than the evaluation guideline of 25 rem TEDE at the site boundary. Workers deal with radiological and standard industrial hazards. Safety practices are largely expert-based, and SNL management has only recently been awakened to the importance of implementing ISM principles and functions at the facility and activity levels. The Sandia Site Office (SSO) compiled a list of safety incidents that occurred during the past several years to impress the need for change on SNL management. However, SNL's LWC rate is declining (see Figure 4), and DOE reports only one accident investigation since 1990.

ISM at the Institutional Level: Even though SNL partnered with LLNL and LANL in 1996 to develop safety management principles for the three weapons laboratories, ISM has not taken root and become part of the way the site is operated. When SSO pointed out safety issues at SNL, laboratory management acted deliberately to improve facility safety analyses and formality of operations. Throughout the interviews conducted for this study, a consistent theme emerged: several federal and contractor personnel believe that SNL's nuclear operations are safe—despite management's self-identified problems with ISM implementation (one manager's perception was that one in five SNL employees can expect to be hurt on the job at some point in their career). Given this fundamental belief in the safety of the status quo, it is not difficult to see why the principles and functions of ISM have not been translated into tools that are used consistently to ensure that work is safe.

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[8]Note that potential accidents have been avoided when Pantex technicians have called a "stop work" as soon as off-normal operations have been discovered.

ISM at the Facility Level: SNL has had fundamental problems in the approach used to analyze the safety of nuclear facilities in Technical Area V. For example, the approved Documented Safety Analysis for the Auxiliary Hot Cell Facility had significant inadequacies, including deficiencies in the analysis of hazards to members of the public, hazards not adequately identified or controlled, and inadequate design requirements. The site office and the contractor have committed to improving all Documented Safety Analyses to make them consistent with the safe harbor methodologies of the Nuclear Safety Management Rule, and to provide adequate assurance that operational hazards have been identified through a comprehensive hazard and accident analysis.

ISM at the Activity Level: Workers and first-line mangers are technically skilled, and for the most part, operations are executed safely. Even on this brief site visit, however, informal and improper safety practices were observed. In most cases, experts are performing work safely, but often without an approved process, contrary to good formality of operations. Many at the working level apparently believe that change is necessary to keep pace with current requirements and expectations, but that current expectations do not really add to safety.

5.1.6 Savannah River Site—Tritium Operations

Four Hazard Category 2 and two Hazard Category 3 facilities at SRS house weapon system tritium production operations that are designed to load and test tritium reservoirs. Operations are relatively uncomplicated and present a low hazard to the public and workers. Unmitigated MEOIs are calculated to receive less than the 25 rem TEDE guideline, partly because of the distance to the site boundary. The new Tritium Extraction Facility is designed to extract tritium from irradiated target fuel rods. When this facility becomes operational, the radiological hazards from processing the irradiated targets will increase significantly. The tritium operations at SRS are an NNSA operation embedded in the much larger and more complex Environmental Management (EM) site. The NNSA Site Office is separate from the EM site office, but the operations are managed by the same contractor organization in accordance with many common procedures. LWC rates for tritium operations at SRS have been consistently low (see Figure 4), and only one accident investigation has been reported since 1990.

ISM at the Institutional Level: Safety practices at the tritium facilities benefit from the long history of application of ISM at SRS. In fact, the tritium operations at SRS are probably the best example of the implementation of ISM and formality of operations in the NNSA complex. Contractor managers gave crisp and clear answers to the questions raised, indicating in-depth understanding of the guiding principles of ISM. Most, though not all, in the NNSA Site Office also demonstrated a clear understanding of ISM. Managers gave consistent answers to questions about risks at the site and clearly made safety their first priority. Notably, all managers spend significant time on the floor as part of their weekly walkaround requirements. Management presence at shift changes, rotating presence during weekend shifts, and informal time interacting with operators are common management practices. When a midlevel manager was asked about accountability for a safety problem, the answer was, "I get lots of help," suggesting that at the management level, the practice is assistance rather than reprimand.

ISM at the Facility Level: The tritium facilities are compliant with 10 CFR Part 830. Facility operations are managed with ISM principles and functions as fundamental guidelines. In addition, ISM principles are integrated into the design and construction of the new Tritium Extraction Facility.

ISM at the Activity Level: Workers engage in good safety practices and participate in behavioral-based safety performance observations. Hazards are understood, and controls are implemented and maintained. Pre-job briefings are thorough and focus on safety discussions with the operators. Operators stated that constant management attention was the key to their receptivity toward ISM. Job hazard analysis is a routine process, but some off-normal scenarios have not been considered.

It is worth considering why SRS has been more successful than other sites in implementing ISM. The following attributes may have contributed: (1) a strong industrial safety culture and centralized control of safety was established by Dupont; (2) a strong nuclear safety culture was developed by Westinghouse as a result of focus, urgency, and significant resources applied to the restart of K-Reactor; (3) continuing and effective management presence on the floor has resulted in technical understanding and awareness of the work and the hazards; and (4) management is always increasing the expectations for safety performance. A potential down side to SRS's safety philosophy is that with so much emphasis on safety, a culture of safety arrogance could create a false sense of security.

5.1.7 Y-12 National Security Complex

Y-12 is basically a uranium and weapons parts manufacturing facility. The site office and contractor manage a wide variety of hazardous operations, including storage of significant quantities of nuclear materials, testing of weapon components, dismantlement of weapon components, manufacturing of highly enriched uranium parts, and chemical recovery of highly enriched uranium. Operations are complex, and major hazards include inadvertent criticality and facility fires. The pace of work at Y-12 has been increasing slowly since the 1994 standdown of operations; in fact, wet chemistry operations were recently restarted after a long hiatus. Y-12's LWC rate is slowly improving (see Figure 4); five accidents have required investigation since 1990.

ISM at the Institutional Level: As recently as 2 years ago, Y-12 was having significant problems with safety; reportable incidents were high, near-miss accidents were occurring, and conduct of operations was deficient. However, the Y-12 Site Office credits clear expectations and improvement initiatives by the contractor with significantly enhancing the implementation of ISM at the site. Managers are walking down their spaces frequently and apparently being effective in transmitting the importance of safe operations to the working level. As a good management practice, the Y-12 contractor is subject to an annual corporate ISM review. This turnaround in ISM at Y-12 could serve as a model for other sites. However, recent improvements have been accomplished during a time of relatively low workload; management will need to maintain safety awareness as the workload begins to increase.

ISM at the Facility Level: The nuclear facilities at Y-12 are old; some have been operating since the 1950s, and even though all but one have 10 CFR Part 830—compliant safety bases, some systems (e.g., seismic and fire protection safety systems) do not meet modern standards. For the worst case at the Y-12 facility, the MEOI is calculated to receive an unmitigated dose of about 30 rem TEDE; for the remaining nuclear facilities, MEOIs are calculated to receive less than the 25 rem TEDE guideline. Construction of a new storage facility for special nuclear material has begun, and a new enriched uranium processing facility is in the planning stage. Timely completion of these two facilities is important to replace several aging facilities at the site.

ISM at the Activity Level: Y-12 has made significant improvements in safety at the activity level during the previous 3 years. Pre-job briefings are effective; first-line supervisors ask operators questions about safety requirements and off-normal responses; lessons learned from previous similar jobs are discussed; job hazards are reviewed; and operators participate by asking sensible questions. In addition, the contractor has plans to strengthen post-job briefings to focus on feedback and improvement. Operators were able to identify hazards, controls, and expected responses to off-normal events clearly and accurately. However, some operators saw little value in formal conduct-of-operations processes; some personnel expressed their belief that the new work control processes do not make work safer, but only add paper. Criticality safety violations still occur at an unacceptable rate, but Y-12 has an opportunity to improve criticality safety by integrating its conduct-of-operations initiatives with conventional criticality safety analyses.

5.2 STATUS OF ISM IMPLEMENTATION AT NNSA SITES

Using the information presented above, results of the previous ISM assessments discussed in Section 3, and the Board's expertise, a relative ranking of ISM implementation at the seven NNSA sites was performed with a pairwise comparison technique (Saaty, 1990). Each site was evaluated using the guiding principles and core functions of ISM as major criteria; subcriteria were based on the lines of inquiry. The major criteria and subcriteria are shown in Boxes 1 and 2. The outcome of the ranking shows that NNSA's production plants have significantly more effective ISM systems than those of the laboratories. While it is not important to dwell on the individual rankings, it may be informative to consider why the sites differ in the effectiveness of their ISM systems.

Box 1. Criteria Used to Rank NNSA Sites Relative to the Guiding Principles of Integrated Safety Management

- Line management responsibility for safety
  - Roles, responsibilities, and authorities are defined and understood.
  - Line management is aware of the status of work and hazards (operational awareness).
  - Communication is frequent and effective.
  - Senior leaders drive safety.

- Clear roles and responsibilities
  - Safety ownership boundaries are defined and managed properly.
  - The organization has an empowered Integrated Safety Management champion.
  - Authorities and accountabilities are clear.

- Competence commensurate with responsibilities
  - Technical excellence exists throughout the organization.
  - The organization has adequate numbers of safety staff.
  - Operators understand the fundamentals of hazards.
  - Safety decisions are made on the basis of sound technical principles.

- Balanced priorities
  - Decision makers are aware of and understand risks.
  - Safety, security, and environmental requirements are balanced.
  - Safety and productivity have equal priority.

- Identification of safety standards and requirements
  - Nuclear facilities are operated in accordance with approved directives.
  - Exceptions and exemptions from directives are rare.
  - Resources are available to make facility upgrades as necessary.

- Hazard controls tailored to the work being performed
  - Formal job and facility hazard analyses are conducted.
  - All work is performed within approved controls.
  - Operators and first-line managers respond properly to off-normal events.

Box 2. Criteria Used to Rank NNSA Sites Relative to the Core Functions of Integrated Safety Management

- Define the scope of work
  - Operators are identified and involved in work planning.
  - Physical and organizational boundaries are clearly defined.
  - Line managers are identified and involved in work planning.
  - The work site is reviewed prior to the start of work.

- Analyze the hazards
  - All important hazards are systematically identified.
  - New or emerging hazards are identified.
  - Operators can identify hazards.

- Develop and implement hazard controls
  - Controls are developed using an appropriate hierarchy.
  - Operators can identify controls.
  - Controls are implemented.

- Perform work within controls
  - All hazardous work activities are formally authorized.
  - Work instructions and procedures are explicitly followed.
  - Operators and first-line managers have a questioning attitude.
  - Pre-job briefings address hazards and controls.

- Provide feedback and continuous improvement
  - Safety issues are addressed in a timely manner.
  - Self-assessment and issue management programs are effective.
  - Post-job briefings address lessons learned.
  - Reporting of errors is rewarded.

First, the production plants are not as complex as the laboratories:

- The production plants usually have only one or two customers and missions, while the laboratories have multiple customers and missions with divergent requirements.

- The production plants generally have well-planned deliverables; the laboratories have multiple schedule and program commitments.

- The pace of work at the production plants is relatively steady and predictable; the pace of work at the laboratories is more random.

- The number and variety of hazards at the production plants are better known than is the case at the laboratories.

A conclusion might be that ISM is easier to implement and more effective in a consistent environment. The fact is that some organizations at the laboratories have very good ISM programs, and the important lesson for the laboratories is that ISM may be more effective if implementation is designed to meet the needs of discrete/uniform units, applying the principle of hazard controls tailored to the work being performed. Note that tailoring does not mean relaxing controls; it means implementing appropriate controls that are necessary and sufficient to protect the public and workers.

Second, the production plants have been managed by contractors with long-standing corporate safety cultures. Safety tends to be built into productivity goals because accidents have a negative impact on profits. The laboratories have been managed by organizations with long-standing science cultures and deep-seated values of intellectual freedom. This is not to say that safety and science are incompatible, but it is important to recognize the difference when attempting to modify the values and culture of an institution. Culture can be defined as a behavior that is acquired by imitation and passed on to a population; therefore, a culture change can take decades. ISM is the foundation for a shift in safety culture; 10 years is not enough time to effect the desired culture change. Senior leaders at DOE and the laboratories need to persist until that culture shift is passed on to the next generation of scientists. An apparent anomaly in the ISM ranking was discovered at NTS, which, although a multilaboratory site, equals the production sites in the effectiveness of ISM. The anomaly may be explainable by the rigorous safety culture developed during the era of underground nuclear weapons testing.

Third, the nuclear facility Documented Safety Analyses and Technical Safety Requirements are generally more up to date and compliant at the production plants than at the laboratories, which tend to have difficulties with meeting nuclear facility safety requirements. A nuclear facility safety basis that is compliant with 10 CFR Part 830 forms the foundation for protection of the public and workers and implementation of the principles and functions of ISM. Conversely, a site that has not adequately updated its Documented Safety Analyses and Technical Safety Requirements has clearly not fully implemented an ISM system.

Finally, it appears that the interaction between the NNSA Site Office and the contractor at the production plants is collaborative, roles and responsibilities are clear, and DOE oversight is accepted and effective. By contrast, the interaction at the laboratories appears to lack mutual trust and confidence; oversight is viewed as an unnecessary burden, and as a result, safety improvements are sometimes stalled.

One might ask: "So what? Safety statistics show improvement. Major accidents are rare, and all sites are implementing ISM." However, it should be clear from the above discussion that the laboratories need to improve their implementation of ISM not for the sake of compliance, but for the compelling purpose of reducing risks. The "think before doing" concept is so fundamental to safety that it should be embraced willingly and enthusiastically by all who do hazardous work. One could argue subjectively that the safety risks at the laboratories are greater than those at the production plants. Numerous hazards, complex operations, significant quantities of nuclear materials, proximity to the public, and weak authorization bases translate into greater risk to the public and workers, and therefore greater urgency to implementing an effective safety management system.

6. CONCLUSIONS

In his book *Human Error*, James Reason (1990) introduces the concept of latent and active safety errors. Latent errors are typically made by managers, designers, safety analysts, and other decision makers and can lie dormant in a system or operation before they reappear as an accident. Active errors are those made by operators, technicians, and scientists who handle hazardous materials or perform hazardous operations, and their impacts are immediate. Operators are often left to deal with the latent errors made by decision makers far removed from the time of an accident. Reason argues that latent errors pose the greater threat to safety, and the more removed decision makers are from front-line activities, the greater is the danger of introducing latent errors.

Application of the functions and principles of ISM should reduce both active and latent errors. The five core functions of ISM are well known, probably because they are relatively easy to apply and can have an immediate positive impact by reducing active errors, while the successful implementation of the seven guiding principles should reduce the introduction of latent errors into safety management systems. The following is a summary of observations on the effectiveness of implementation of the seven guiding principles and five core functions of ISM at the NNSA sites. Recommendations for improving the implementation of the core functions are also presented.

6.1 OBSERVATIONS ON THE EFFECTIVENESS OF THE SEVEN GUIDING PRINCIPLES

Line management responsibility for safety is probably the most commonly stated and least understood guiding principle. Inconsistent definitions of line management were heard during many of the site interviews. Answers ranged from “Line managers follow the money,” to “Line managers are responsible for executing work,” to “Everybody above operators is a line manager.” The guidance given in DOE Policy 450.4—“Line management is directly responsible for the protection of the public, the workers, and the environment”—does not provide sufficient clarity. Clearly, the buck stops with line managers, who have the responsibility to direct, authorize, and supervise hazardous activities. However, line managers are only one group responsible for integrating safety; in fact, everyone has a role in this endeavor. Perhaps the guiding principle should be, “Line management owns safety.” Ownership of safety means that hazardous work—whether at the institutional, facility, or individual activity level—is planned, analyzed, controlled, and authorized by an accountable line manager. The owning line manager must understand the technical basis and associated hazards of the work, be aware of all activities, be knowledgeable of institutional and facility safe operating requirements, and manage change control.

Clear roles and responsibilities are generally defined and documented by NNSA Site Offices and contractors. The principle is adequately implemented, but existing definitions of responsibility fail to deal directly with two important elements: accountability and ownership. Weaknesses in ownership of boundaries between organizations and functions are not uncommon. For example, the management of interfaces such as work by other organizations, facility/tenant agreements, line versus program management, line organizations versus support organizations, and even laboratories versus plants is a common source of confusion and potential accidents.

While line managers may have the most important responsibility for ensuring that hazardous work is done safely, they are only one element in a hierarchy of responsibilities for safety. An example of how this hierarchy might work is outlined below:

- Operators, engineers, technicians, and scientists make up the bulk of the workforce that perform hazardous operations. They own their work and are responsible for operating safely as defined by procedure.

- Line managers are responsible for authorizing hazardous work and must understand requirements and maintain daily awareness of those activities at the front lines.

- Facility managers own the safety basis of their facility and are responsible for providing a safe operating envelope for users.

- Program managers are responsible for allocating resources to fulfill safety, programmatic, and operational requirements.

- Senior leaders own the operations and are responsible for balancing priorities, maintaining operational awareness, and establishing realistic and compliant expectations.

Various approaches to accountability for poor performance, ranging from termination to no accountability, are employed by the contractors and site offices. Line managers and operators are often held accountable for active errors that result in safety incidents or failure to comply with safety requirements. But processes for holding individuals accountable for latent errors were not found. For example: What about the ES&H support personnel who write safety requirements and procedures that cannot be followed? What about program managers who do not allocate adequate funds to working safely, thereby encouraging workers to take unnecessary risks to meet programmatic requirements? What about safety analysts and designers who miscalculate conditions for safety components? These latent errors might be avoided if individuals understood that they were to be held accountable. DOE's Human Performance Improvement initiative (Institute of Nuclear Power Operations, 2002), if fully implemented, could result in significant improvement in this area.

Competence commensurate with responsibility is the foundation of performing work safely. In general, the technical capabilities of operators, technicians, scientists, and engineers are exceptional, and the formal technical qualifications of NNSA facility representatives, system engineers, and safety experts are excellent. As a result, contractor employees understand the technical basis of their work, and federal oversight employees understand safety requirements. At the same time, however, more in-depth scientific education for NNSA employees and more detailed nuclear safety certification of contractor workers might strengthen the implementation of ISM practices. Federal oversight appears to be driving contractors to standards-based safety management, and while that may be a desirable goal, some bureaucrats may be losing sight of the importance of technical competence to doing work safely. The misperception that "high-level direction comes without understanding the subject" is commonly held.

Balanced priorities are reflected in words but not always in actions. "Safety is the first priority" and "Our first priority is not to hurt anyone" are common statements of NNSA leaders and contractor managers. Unquestionably, no manager wants to hurt anybody, but a different message can be delivered when:

- Contracts generally apply rewards when program milestones are achieved, and penalties when safety infractions occur.

- Facility safety upgrades are delayed in favor of program deliverables.

- Nonconformances are rationalized by reperforming calculations.

Actions can deliver a different message about priorities to workers who sometimes feel that "managers talk about ISM, but don't do it." In point of fact, productivity should be the first priority; after all, this is why the production plants and laboratories exist in the first place. However, the end result of good safety practices is productivity. Leading companies in the private sector have found that implementing strong process safety programs benefits company performance and improves the bottom line (Center for Chemical Process Safety, 2003). Similarly, productivity gains in mission output were realized at the LANL Plutonium Facility after formality of operations was implemented using ISM as the basis (Los Alamos National Laboratory, 2000). One scientist said, "If you want to do world class science, you need world class safety."

Decision makers must always balance priorities. The problem is that decisions are often based on external influences such as pressures from programs, complaints from stakeholders, issues raised by Congress, and even letters from the Board. At the institutional level, the guiding principle of balanced priorities might be better realized if priority decisions were made using a risk-informed approach and consistently communicated to workers, regulators, and customers. In addition, the sometimes conflicting priorities of safety and security could be better balanced using risk-informed methods.

Identification of safety standards and requirements appears to be working at the institutional (site office and contractor) and facility levels. However, national engineering safety standards need to be applied more formally and effectively at the activity level. Use of standards can be especially valuable when planning and designing R&D processes involving hazardous operations. In addition, a perception that DOE directives lack consistency and are vague and sometimes confusing is still found among some contractors.

Hazard controls tailored to the work being performed is a principle that can be unevenly applied. Generally speaking, facility-level controls are appropriately graded, and oversight systems (such as readiness reviews) are in place to ensure compliance with requirements. However, considerable lag time in implementing Technical Safety Requirements defined in Documented Safety Analysis upgrades is common. Tailoring is often accomplished at the activity level by identifying hazards and defining the appropriate levels of work control needed to protect workers. For example, low-level hazardous work may rely on the training and experience of the operators and supervisors to meet requirements. Medium-hazard activities may require standard work procedures, job-specific hazard identification, and controls. High-hazard activities may require observance of Technical Safety Requirements, mockup training, and engineered design features. This type of grading can be sound in concept as long as the screening criteria are set appropriately, and independent reviews ensure that all hazardous work is controlled. There have been a number of unfortunate accidents, especially in R&D activities, in which more rigorous work controls would have avoided injuries. For example, recently two researchers were injured while attempting a new method of chemical synthesis; contamination was spread in another event involving improper handling of radiological materials. SRS has a particularly effective ISM process for conducting research (Westinghouse Savannah River Company, 2004). One of the keys to the success of its work control is that researchers developed the process and own the activity.

Operations authorization for facilities is accomplished formally through Safety Evaluation Reports and Authorization Agreements between the contractor and the site office. The process generally works; however, the Authorization Agreements vary in content from site to site, and are not always kept current. Hazardous work is authorized after hazard assessments have been completed and controls have been implemented. An authorizing individual, person in charge, shift supervisor, or some other responsible individual is found at most sites. These first-line managers can have vast safety responsibilities and a wide span of control. While the concept is sound and the persons interviewed take their responsibilities seriously, senior managers must back this up with moral, financial, oversight, and training support.

6.2 COMMENTS ON THE EFFECTIVENESS OF THE FIVE CORE FUNCTIONS

ISM defines a rational process for systematically analyzing hazards and identifying safety measures. Rigorous application of the five core functions of ISM at the facility and activity levels is a practical approach to avoiding active errors. This common-sense safety logic can be effective in reducing accidents, near misses, LWCs, and reportable incidents, and thereby improve the safety culture. Safety culture initiatives attempt to get at the human causes of poor safety performance, and a number of programs have been developed to engage workers and management in improving safety culture and human performance (Institute of Nuclear Power Operations, 2002; Krause, 1995). Efforts to improve safety culture are important, but if they are to be successful, organizations must first lay the foundations for safety. The Board's technical report DNFSB/TECH-35 (Defense Nuclear Facilities Safety Board, 2004b) sets forth the attributes of high-reliability organizations that are necessary to establish the foundations for an effective institutional safety culture, while the five core functions of ISM provide the essential foundation for improving safety culture at the facility and activity levels. In many cases, the safety programs that workers are expected to implement were not developed by current managers, and that separation between expectation and execution may be a reason for poor implementation. If safety programs are to be successful, workers[9] must be involved in their development, design, execution, and continuous improvement, and essentially own the five ISM core functions. The following is a summary of observations on and recommendations for improving the implementation of the ISM core functions.

Define the Scope of Work. Work planning that integrates safety and work is a common practice at all NNSA sites. The level of rigor may vary, but planning is done at multiple levels, from project plans to pre-job briefs. What appears to be lacking is integration from top to bottom and integration among the safety disciplines before work is actually planned. Senior managers should understand the working environment at the front line; workers need to understand mission and safety goals. If the hazardous work environment is disconnected from top-level planning of the work scope, misunderstandings can develop that in turn can lead to inappropriate pressures to attempt shortcuts that can result in safety incidents. Such disconnection is unnecessary and can be avoided if managers spend more time on the floor discussing programmatic and safety issues with front-line workers.

Analyze the Hazards. Identification of job hazards is common practice. However, the inappropriate use of automated hazard analysis tools is growing, and errors occur in the classification of jobs because of the misapplication of screening tools. Line managers must be cautious of overdependence on these tools; hazard analysis programs can be an excellent confirmation step, but cannot substitute for technical knowledge and experienced teams in identifying and potentially eliminating hazards. As one respondent noted, "If not careful, the automated hazard analysis process can allow one to suspend rational thought." Answers during this inquiry sometimes revealed disconnects between the perceptions of managers and workers with regard to hazards and risks. Again, opposing views can be corrected simply by managers spending more time on the floor, seeking a better understanding of the issues facing those doing the work.

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[9]Workers include operators, engineers, technicians, and scientists who perform, design, authorize, oversee, and manage hazardous operations and facilities.

Develop and Implement Hazard Controls. Safety controls are generally well defined, implemented, and maintained at NNSA's nuclear facilities. Safety controls are more informal at the activity level, especially in R&D activities. Some workers incorrectly assume that the facility-level controls are adequate to protect them from hazards encountered in their specific work activities. Work procedures need to state clearly controls and the steps necessary to ensure that those controls are operating as designed.

Perform the Work within the Controls. Authorization of hazardous work by responsible line mangers has become common practice at all of the weapons sites. Similarly, work control and adherence to procedure have been implemented at all sites. Many procedures at the production plants are followed to the letter, and step-by-step reader/worker controls are common. While effective, however, rote compliance can lead to a "stop thinking" approach to work that can be dangerous when responding to off-normal events. Managers need to use innovative methods to avoid operator complacency when following detailed procedures. The procedures for R&D activities are necessarily less constraining than those used for routine, repetitive operations. However, R&D procedures need to define operational boundaries for authorized activities and controls. Operational boundaries are necessary for workers to recognize when their control space has been exceeded and understand that work outside of that space is unauthorized. Such a stop-work control should force workers to reanalyze the hazards and help eliminate unanticipated accidents.

Provide Feedback and Continuous Improvement. DOE's Office of ES&H publishes a series of Just-In-Time reports and a periodic Operating Experience Summary to promote the exchange of lessons-learned information among DOE facilities; nevertheless, feedback and improvement remains an ineffective ISM core function. DOE is well aware of the problem and has undertaken initiatives to strengthen this important function. Accurate reporting of issues is the first step in feedback and improvement; DOE and contractor management must remain actively on guard against individuals not reporting injuries for fear of retaliation and managers downgrading occurrence levels to avoid losing performance incentives. Some NNSA organizations reward safety performance and self-reporting of errors—an important attribute of highly reliable organizations that can help avoid accidents. Workers and managers alike need to be held accountable for blatant errors and willful unsafe acts, and critiques and accident investigations are essential components of continuous improvement. But a system of recognition and rewards is equally important if the complex is going to improve its safety performance.

7. SUMMARY

Figure 5, based on Figure 1, illustrates the three levels of ISM (institutional, facility, and activity); high-hazard nuclear facilities and production operations generally adhere to this conceptual model. The key is to start with the hazards and work at the activity level, and envelope those activities within a safe operating platform that in turn is enveloped by safe contractor management practices and DOE/NNSA requirements. The important point is that institutional requirements and facility safety systems surround the hazards at the activity level and thereby protect workers and the public. The nested levels of protection in this model represent a common-sense approach to doing work safely. ISM basically defines a safety culture that is practical in form and function.

Clearly, ISM has initiated many positive changes. The question is whether NNSA's production plants and laboratories are safer. The answer is not clear; even though formality has categorically improved at all sites, the safety performance measures employed are somewhat ambiguous. Managers sometimes have a compliance-driven attitude toward the implementation of ISM; workers, for the most part, understand the importance of working safely. However, comments such as "We have done this safely for years," "ISM is a compliance-driven paper process," and "As a researcher I think work control stinks" suggest that safety attitudes still need adjustment. At some sites, workers and line management perceive that ISM has deteriorated into a top-down, process-heavy, compliance-driven system. Their perception is that DOE and NNSA set the ISM expectations, directives, and contract requirements; senior contract managers who are not familiar with facility operations develop the implementation processes; and line managers are left to implement an unworkable program.

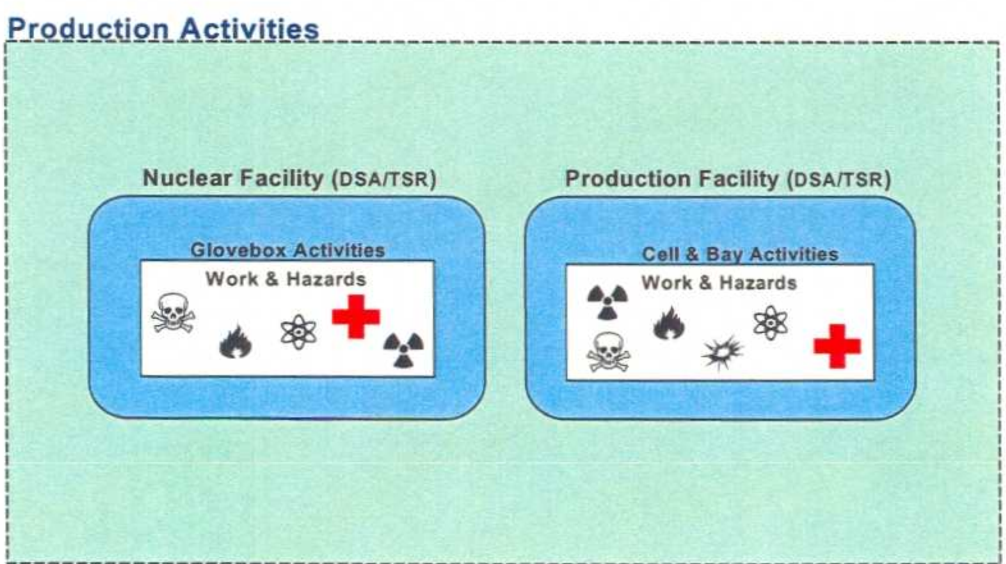

Figure 5. Concentric layers of ISM protection at the institutional, facility, and activity levels.

Note: DSA = Documented Safety Analysis; TSR = Technical Safety Requirements.

Problems with the implementation of ISM occur at the activity level, particularly in R&D and nonroutine activities. A common problem appears to start with managers and ES&H support personnel who are responsible for providing input to the work planning and control processes, but do not fully understand the work, do not participate in job walkdowns, and do not fully understand how to implement controls efficiently. As a result, front-line managers and workers do not have faith in a system that to them appears to be a paper-intensive, bureaucratic process that does little to improve safety or productivity. The consequence can be a grudging acceptance by technical experts and a slow degradation of the model shown in Figure 5. Accidents happen when work is not planned according to the core functions of ISM. At some facilities, researchers and workers are operating outside of the activity-level safety envelope because the institutional-level decision makers do not fully understand the front-line work and hazards, and workers are motivated and rewarded for getting work done. The result is illustrated in Figure 6, in which some of the hazardous work—often though not always R&D activities—is performed outside of the institutional boundary and facility safety envelope, thereby increasing the likelihood of an accident. To be more effective, ISM needs to start with the hazards and the work and should be owned, developed, and executed by line management and the individuals who do the hazardous work, with the support of subject matter experts as necessary. Leaders must be diligent and not allow a disconnect between requirements and the activities being performed to occur.

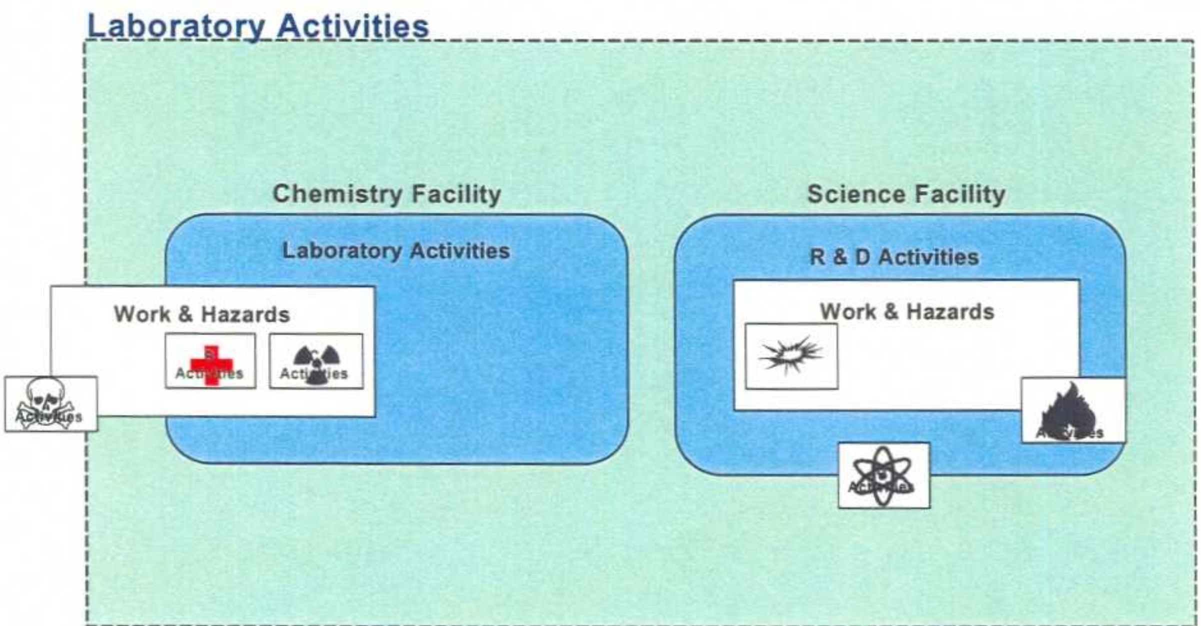

Figure 6. ISM at the institutional, facility, and activity levels.

During this review, a number of positive attributes and good practices were observed that could enhance the effectiveness of ISM at all sites. For example, senior managers at the best sites have an obvious commitment to ISM and actively demonstrate its principles and functions. Top managers spend significant and effective time on the floor, as evidenced by their technical awareness of the work and the hazards. Effective ISM organizations continuously increase safety performance expectations, recognize the reporting of errors, and reward outstanding safety achievements. At the best sites, cooperation between the site office and contractor management is apparent, and effective oversight, self-assessments, and supporting issues management programs are implemented.

Nuclear facility operations at the better sites are compliant with 10 CFR Part 830 and supporting DOE directives. At the activity level, clear operational boundaries are maintained and supported by a change control program at all levels. Workers understand the boundaries of their authorized work and what action is to be taken when an authorized boundary is approached. Finally, worker involvement at the activity level in identifying hazards, developing procedures, and improving safety is common practice at the better-performing organizations.

8. SUGGESTIONS FOR IMPROVEMENT

A number of important ISM attributes and good practices have been discussed throughout this report. The following are the most important changes that would improve the effectiveness of ISM:

- Establish ISM as the foundation for modernizing safety culture at DOE and NNSA sites, and build an improved culture that engages workers and enables them to work safely and effectively.
- Clearly define a hierarchy of the roles, responsibilities, authorities, and accountabilities on every level in the workforce, from operators to managers.
- Define line management ownership boundaries and authorities at the institutional, facility, and activity levels, and focus on managing interface issues.
- Assign fully qualified ISM champions at key organizational levels.
- Require managers from line, program, and support organizations to spend time on the floor.
- Develop a process for evaluating the effectiveness of ISM.
- Incorporate safety culture changes, such as the Human Performance Improvement initiative, as an integral part of ISM.

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GLOSSARY

Abbreviation	Definition
Board	Defense Nuclear Facilities Safety Board
CFR	Code of Federal Regulations
DAF	Device Assembly Facility
DOE	Department of Energy
DSA	Documented Safety Analysis
EM	Office of Environmental Management
ES&H	Environment, Safety and Health
ISM	Integrated Safety Management
LANL	Los Alamos National Laboratory
LASO	Los Alamos Site Office
LLNL	Lawrence Livermore National Laboratory
LSO	Livermore Site Office
LWC	Lost Workday Case
MEOI	Maximally Exposed Offsite Individual
NNSA	National Nuclear Security Administration
NSO	Nevada Site Office
NTS	Nevada Test Site
OA	Office of Independent Oversight and Performance Assurance
ORPS	Occurrence Reporting and Processing System
R&D	Research and Development
REOP	Real Estate/Operations Permit
SNL	Sandia National Laboratories
SRS	Savannah River Site
SS-21	Seamless Safety for the 21st Century
SSO	Sandia Site Office
TEDE	Total Effective Dose Equivalent
TSR	Technical Safety Requirement
Y-12	Y-12 National Security Complex