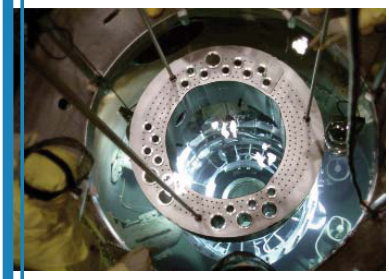
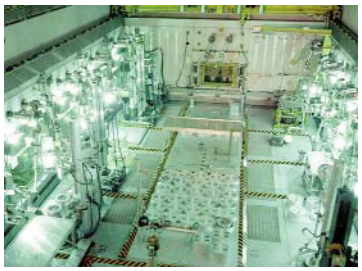
August 2011

*A Report to the Secretary of Energy*

# Review of Requirements and Capabilities for Analyzing and Responding to Beyond Design Basis Events

*Office of Nuclear Safety*
*Office of Health, Safety and Security*
*U.S. Department of Energy*

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# ACRONYMS

| | |
|---|---|
| AC | Alternating Current |
| ANL | Argonne National Laboratory |
| BDBE | Beyond Design Basis Event |
| CFR | Code of Federal Regulations |
| DC | Direct Current |
| DOE | U.S. Department of Energy |
| ETTP | East Tennessee Technology Park |
| EPHA | Emergency Planning Hazards Assessment |
| EU | European Union |
| HSS | Office of Health, Safety and Security |
| ICP | Idaho Cleanup Project |
| INL | Idaho National Laboratory |
| LANL | Los Alamos National Laboratory |
| LLNL | Lawrence Livermore National Laboratory |
| NBL | New Brunswick Laboratory |
| NNSS | Nevada National Security Site |
| NPH | Natural Phenomena Hazards |
| NRC | Nuclear Regulatory Commission |
| ORNL | Oak Ridge National Laboratory |
| PNNL | Pacific Northwest National Laboratory |
| SNL | Sandia National Laboratories |
| SRS | Savannah River Site |
| WIPP | Waste Isolation Pilot Plant |
| WVDP | West Valley Demonstration Project |
| Y-12 | Y-12 National Security Complex |

# EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) has established a rigorous nuclear safety regulatory infrastructure for the protection of workers, the public, and the environment. Part of this infrastructure includes processes for evaluating events to foster continuous improvement. In this spirit, DOE (including the National Nuclear Security Administration) took the following actions to review the safety of its nuclear facilities and identify opportunities for improvement in light of the March 2011 accident at the Fukushima Daiichi nuclear power plant:

- Issued Safety Bulletin 2011-01, *Events Beyond Design Safety Basis Analysis*, which requested DOE Program and Field Offices to review their nuclear facilities and report on (1) the analyses that have been performed for beyond design basis events and controls in place that could mitigate them, (2) the ability to safely manage their nuclear facilities during a total loss of power, (3) the operability of important safety systems, and (4) the readiness of emergency management plans and procedures.
- Conducted an analysis of DOE requirements and guidance for safety analysis, facility design, and emergency response as they relate to beyond design basis events.
- Performed a review of commercial nuclear power industry requirements and guidance related to beyond design basis events, including recent efforts by the U.S. Nuclear Regulatory Commission and the European Union to evaluate and enhance these requirements and guidance.
- Conducted a Nuclear Safety Workshop that was attended by senior nuclear safety managers and technical experts from DOE, other Federal agencies (such as the Nuclear Regulatory Commission, the Defense Nuclear Facilities Safety Board, and the Federal Emergency Management Agency), and the commercial nuclear power industry.

These actions focused on learning how DOE can better prepare to manage potential beyond design basis events (i.e., events more severe than the events that formed the basis of the design for DOE's nuclear facilities, such as extremely unlikely earthquakes). While DOE nuclear facilities significantly differ from commercial nuclear power reactors (particularly in regards to energy and decay heat removal needs during accidents), there are lessons from review of the accident at the Fukushima Daiichi nuclear plant. This report describes the opportunities for improvement identified by DOE's review and provides recommendations for short-term and long-term actions for improving DOE's nuclear safety.

## Insights and Opportunities for Improvement

1. DOE nuclear facilities have performed scheduled inspections and required maintenance to maintain their safety systems in an operable condition in accordance with technical safety requirements. These safety systems, which serve to prevent or mitigate design basis events, may also support the mitigation of beyond design basis events. However, additional reviews to evaluate the capabilities of safety systems to perform their safety function during beyond design basis events are warranted.

2. DOE's emergency management requirements and criteria provide the framework for evaluating and responding to design basis events and beyond design basis events. However, further planning is warranted for response to events that could have a significant and widespread impact on the site and the surrounding community emergency response infrastructure.

3. DOE has established requirements for analysis and control of accidents, including a requirement related to the safety analysis of beyond design basis events. However, while DOE has detailed criteria and guidance supporting implementation of requirements for design basis accidents, it does not have similarly detailed

criteria and guidance for beyond design basis events. Improvements in guidance and criteria for beyond design basis accidents are warranted in the following areas:

- Evaluation of more severe natural phenomena hazards and external events than is assumed in the safety analysis of design basis accidents.
- Evaluation of the potential for and impact of an extended total loss of onsite and offsite power.
- Evaluation of the failure of engineered controls that maintain important safety functions, such as energy removal or confinement, during beyond design basis events.
- Evaluation of accident management strategies (and the resources necessary for implementing such strategies) for beyond design basis events, including events that may affect multiple facilities.

In addition, although the focus of this review was on beyond design basis events, the review provided DOE an opportunity to ensure that its ongoing revision to DOE's natural phenomena hazards evaluation standard appropriately addresses lessons learned for evaluation of design basis natural phenomena events, in particular regarding evaluation of concurrent or cascading events.

## Recommendations for Actions to Improve Nuclear Safety

This review identified the following short-term and long-term actions for improving nuclear safety at DOE facilities:

1. Short-Term Actions

- Distribute this report to the Program and Field Offices and provide direction for implementing its recommendations. Provide briefings and training to field elements to support implementation of nuclear safety improvements discussed in this report.
- Update the DOE safety analysis, natural phenomena hazards, and emergency management requirements and guidance to reflect the opportunities for improvement described above, and perform a pilot application of revised requirements and guidance to gain insights on its application that can support finalization and subsequent implementation.
- Perform system walkdowns and evaluations at several DOE nuclear facilities to look for potential vulnerabilities to natural phenomena hazards. Capture the lessons learned from these walkdowns and evaluations in a DOE corporate lessons-learned document to support any additional walkdowns and evaluations which may be warranted at other DOE nuclear facilities.
- Improve planning for and conduct emergency management exercises using scenarios that include beyond design basis events that affect multiple facilities and cause the loss of onsite and offsite infrastructure (such as power and communication systems) and the loss of mutual aid resources.

2. Long-Term Actions

- Complete the revision of the safety analysis, natural phenomena hazards, and emergency management requirements and guidance, and conduct training to support proper and effective implementation.
- Evaluate the results of beyond design basis event safety analyses and the associated emergency response resource needs to determine the feasibility of DOE providing corporate emergency response resources to support site and facility responses to beyond design basis events.

- Conduct a follow-on Nuclear Safety Workshop to discuss lessons learned from implementing the above short-term and long-term actions and continuing efforts by the commercial nuclear power industry and its regulators to gather further lessons learned and make nuclear safety improvements based upon reviews of the accident at the Fukushima Daiichi nuclear power plant.

## Conclusions

Although DOE nuclear facilities differ from commercial nuclear power reactors, DOE can benefit from the lessons learned to date from the accident at the Fukushima Daiichi nuclear plant to improve nuclear safety at DOE facilities. While the evaluation of DOE site responses to DOE's Safety Bulletin confirmed that DOE has sound provisions in place to address beyond design basis events, additional actions should be taken to improve the criteria and guidance for evaluating beyond design basis events and to determine whether additional emergency response capabilities may be warranted. Implementing the short-term and long-term recommendations presented in this report would be useful in improving DOE's capabilities for mitigating and responding to beyond design basis events, and would provide greater assurance that DOE can protect the public in case of an extremely unlikely beyond design basis event at a DOE nuclear facility. DOE should continue to evaluate the activities by the commercial nuclear power industry and its regulators to gather further lessons learned and make nuclear safety improvements based upon reviews of the accident at the Fukushima Daiichi nuclear power plant.

# 1. INTRODUCTION

The U.S. Department of Energy (DOE) nuclear safety regulatory infrastructure includes processes for evaluating events to foster continuous improvement. While DOE nuclear facilities differ significantly from commercial nuclear power reactors (particularly in regards to energy and decay heat removal needs during accidents), there are lessons from review of the accident at the Fukushima Daiichi nuclear power plant. Therefore, DOE (including the National Nuclear Security Administration) took several actions to review the safety of its nuclear facilities and identify opportunities for improvement in light of the March 2011 accident at the Fukushima Daiichi plant. These actions focused on learning how DOE can better prepare to manage potential beyond design basis events (BDBEs); i.e., events more severe than the events that formed the basis of the design for DOE's nuclear facilities, such as extremely unlikely earthquakes. These actions included:

- Issuing Safety Bulletin 2011-01, *Events Beyond Design Safety Basis Analysis*, which requested DOE Program and Field Offices to review their nuclear facilities' capabilities to mitigate BDBEs;
- Conducting an analysis of DOE requirements and guidance for safety analysis, facility design, and emergency response as they relate to BDBEs;
- Performing a review of commercial nuclear power industry requirements and guidance related to BDBEs; and
- Conducting a Nuclear Safety Workshop to discuss the results from the above actions.

This report describes the opportunities for improvement identified in DOE's review, and provides recommendations for short-term and long-term actions for improving safety at DOE nuclear facilities.

# 2. REPORT OVERVIEW

This report begins with a high-level overview of DOE nuclear facilities and operations (Section 3). It then provides a summary of the analysis of the responses to Safety Bulletin 2011-01 for DOE's nuclear complex (Section 4); a review of DOE and commercial nuclear power industry requirements and guidance related to BDBEs (Section 5); and the results from DOE's June 2011 Nuclear Safety Workshop, which focused on BDBEs (Section 6). Based on the information from these analyses and reviews, the report then discusses the insights and opportunities for improvement (Section 7) and provides recommendations for short-term and long-term actions to improve nuclear facility safety (Section 8). Appendix A provides additional background and details on DOE's approach to nuclear safety.

**DOE Nuclear Facility Construction Project**

## 3. OVERVIEW OF DOE NUCLEAR FACILITIES AND OPERATIONS

DOE conducts three basic types of nuclear operations: nuclear weapons stockpile maintenance, research, and environmental remediation. The operations are performed in a variety of facilities, including nuclear reactors; weapons disassembly, maintenance, and testing facilities; nuclear material storage facilities; processing facilities; and waste disposal facilities. These facilities are located at national laboratories, cleanup sites, research and development sites, and manufacturing sites throughout the United States as shown in Figure 1.

Defense Waste Processing Facility at SRS

DOE categorizes nuclear facilities into three groups according to the level of hazard they present to the public and site workers, which depends primarily on the amount and type of nuclear materials present at the facility. Hazard Category 1 is the most hazardous group and includes facilities that have nuclear materials in a quantity or form that, if released, could have a significant impact on site workers and the public. Hazard Category 2 is the second most hazardous group and includes facilities that could have a significant impact on site workers outside the facility. Hazard Category 3 is the least hazardous group and includes facilities that can only have a significant impact on workers inside the facility. DOE also has "below Hazard Category 3" facilities called radiological facilities that contain very low levels of nuclear materials. DOE has two Hazard Category 1 facilities, 151 Hazard Category 2 facilities and nuclear operations, and 40 Hazard Category 3 facilities and nuclear operations. [1]

DOE has established a rigorous set of orders, standards, and guides that provide nuclear safety requirements and guidance for the design and operation of DOE's nuclear facilities. The overall safety policy and approach for meeting this policy is contained in DOE's Nuclear Safety Policy which states that "it is the policy of the Department of Energy to design, construct, operate, and decommission its nuclear facilities in a manner that ensures adequate protection of workers, the public, and the environment." An overview of these requirements and guidance is provided in Appendix A. An analysis of these requirements and guidance as they relate to BDBEs is provided in Section 5.1.

## 4. ANALYSIS OF SAFETY BULLETIN SUBMITTALS

The Secretary of Energy issued Safety Bulletin 2011-01 on March 23, 2011, to notify DOE managers of concerns related to the identification and mitigation of events that may fall outside those analyzed in the documented safety analyses for DOE nuclear facilities. The Safety Bulletin requested DOE managers and contractors evaluate nuclear facility vulnerabilities to BDBEs and to provide the result of the evaluations to the responsible Program Secretarial Officer and to the Chief Health, Safety and Security Officer. To assist with the evaluation, the Office of Health, Safety and Security (HSS) developed guidance to support implementation of the Safety Bulletin actions.

1 The source of the facility numbers is the DOE Safety Basis Report dated July 22, 2011. This report resides on DOE's publicly available Safety Basis Information System website (http://www.hss.doe.gov/nuclearsafety/ns/sbis/) and includes all of DOE's nuclear facilities and nuclear operations (such as the transportation of nuclear material).

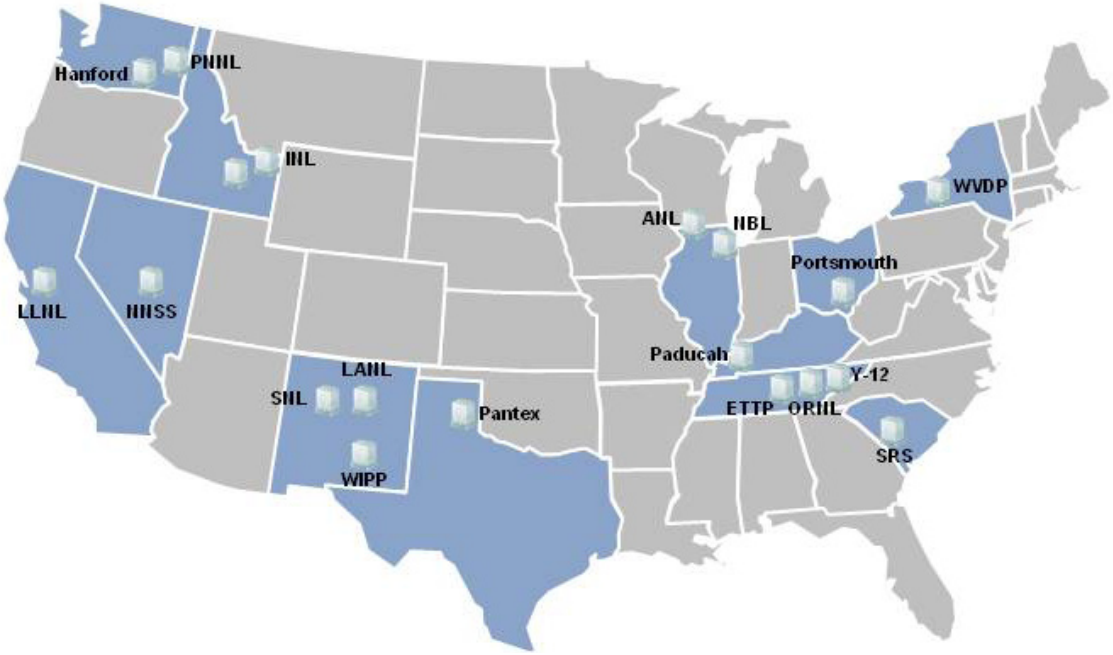


**Figure 1. Locations of DOE Sites with Nuclear Facilities**
(See page i of this report for a list of acronyms)

## 4.1 Responses to Action 1 – Analysis of BDBEs

Action 1 requested the following information:

*Review how BDBEs have been considered or analyzed in accordance with DOE's Nuclear Safety Regulation [Title 10 Code of Federal Regulations (CFR) Part 830, Nuclear Safety Management] and any controls that have been put in place that could prevent or mitigate them.*

The responses provided data on the spectrum of BDBEs that were analyzed for each facility, including natural phenomena hazards (NPH) events, such as seismic events, flooding, and tornados, and external hazards, such as aircraft crashes. The potential effects of the BDBEs on the nuclear facilities included loss-of-coolant and loss-of-confinement accidents, loss of fuel pool water, and the inability to shut down a reactor. Furthermore, the responses indicated some of the capabilities that facilities have implemented to mitigate a BDBE.

However, the responses indicated that there were several limitations in facility analyses of BDBEs including:

- The range of BDBEs that the facility analyzed was not clearly defined or justified.
- The analyses did not discuss the potential impact of cascading events from a common initiator, such as a seismic event leading to the failure of nearby dam(s).
- The analyses did not fully consider the potential for and effects of similar, concurrent events in adjacent facilities, such as fires in neighboring facilities.
- The analyses did not fully evaluate hydrogen generation from all materials that may react with water to release hydrogen.

These limitations can be attributed to the lack of detailed guidance in DOE standards for considering the need for and conducting an analysis of BDBEs.

Although not specifically related to BDBEs, some of the responses did note that significant efforts had been made to improve facility seismic capabilities in response to new information regarding ground motion levels that could adversely impact a facility.

## 4.2 Responses to Action 2 – Ability to Manage a Total Loss of Power

Action 2 requested the following information:

*Discuss the ability to safely manage a total loss of power event including a loss of backup capabilities.*

The responses discussed the ability of the nuclear facilities to withstand a loss of alternating current (AC) power. For all facilities covered by the Safety Bulletin, the responses indicated that either the facility did not need AC power in order to prevent or mitigate an accident or the total loss of AC power would not affect the facility's capability to mitigate the accident and protect public safety. Similarly, the responses indicated that for most facilities, the loss of direct current (DC) power from batteries and generators would not affect the facility's ability to mitigate the accident.

However, some facilities had not considered the loss of DC power as a part of the loss of all electrical power in their safety analyses or as part of their response for this action – possibly because DOE has typically defined a loss of power event as the loss of AC power only. The facilities that addressed the loss of DC power in their submittals described how the loss of DC power could be safely managed, but they provided few details on the effects and did not address the potential consequences. For example, the submittal for one of the Hazard Category 1 reactors noted that DC power was only needed for a short period (less than two hours) to power the water circulation pumps that remove decay heat immediately following reactor shutdown; however, the potential consequences of losing DC power during that short period were not discussed. As was found with the review of responses to Action 1, the shortcomings identified are attributable to the lack of detailed guidance in DOE Directives (as discussed further in Section 5.1) for evaluating BDBEs (such as an event involving failure of safety systems relied on for preventing or mitigating an accident).

## 4.3 Responses to Action 3 – Confirm Safety Systems Operability and Maintenance

Action 3 requested the following information:

*Confirm safety systems are being maintained in an operable condition in accordance with technical safety requirements.*

**Hanford Site's Waste Treatment and Immobilization Plant**

The submittals indicated that safety systems are maintained in an operable condition and that scheduled inspections and maintenance are performed as required. In most cases, the responses were based upon review of maintenance and test data. In response to the Safety Bulletin, some sites also performed walkdowns and evaluation of the safety systems to look for potential susceptibilities to NPH and other external hazards. The Safety Bulletin action focused on confirming that the safety systems would function as intended under design basis conditions, rather than on the survivability of safety systems during a BDBE. A recommendation on expanding safety system walkdowns to include the potential effect of BDBEs is discussed in Section 8.1.5 of this report.

## 4.4 Responses to Action 4 – Confirm Emergency Management Program Operability and Maintenance

Action 4 requested the following information:

*Confirm emergency plans, procedures, and equipment are current, functional, and have been appropriately tested, including plans and procedures for response to natural phenomena events that could have sitewide impacts or impacts on regional support infrastructure.*

The submittals indicated that sites have established emergency management programs in accordance with DOE Order 151.1C, *Comprehensive Emergency Management System*. The responses also provided valuable insights into the likely response to a BDBE.

While some sites indicated that a BDBE could overwhelm their initial emergency response capabilities, they generally did not explain the limitations in these capabilities. In addition, it was evident that some facilities do not follow the guidance provided in DOE Guide 151.1-2, *Technical Planning Basis Emergency Management Guide*, which states that BDBEs, such as "extreme" NPH events and malevolent acts, should be analyzed when developing hazards surveys and emergency planning hazards assessments (EPHAs). These documents form the technical basis for site and facility emergency management programs and indicate what emergency response capabilities are needed. The review team identified the following additional uncertainties in the emergency management programs:

- The effects of simultaneous events at multiple facilities at a site have not been fully evaluated.
- The potential damage to site and community infrastructure from a BDBE has not been fully evaluated, including the impact of a total loss of power and damage to the infrastructure for communication systems.
- Site plans have not been integrated with surrounding community plans for events that would affect the entire area.
- Emergency exercises have not included the response to extreme NPH events, situations where mutual aid support is degraded, and/or simultaneous events at multiple facilities.

# 5. REVIEW OF DOE AND COMMERCIAL NUCLEAR POWER INDUSTRY REQUIREMENTS AND GUIDANCE FOR BDBEs

Sections 5.1 to 5.3 provide an overview of the applicable DOE and commercial nuclear power industry requirements and guidance, as well as applicable recommendations from the Nuclear Regulatory Commission's (NRC's) task force review of the Fukushima Daiichi accident and the new European Union (EU) guidance developed in response to the events at Fukushima Daiichi.

## 5.1 DOE Requirements and Guidance

### 5.1.1 Safety Analysis Requirements and Guidance

DOE safety analysis requirements and guidance specify that the entire spectrum of potential accidents be evaluated for nuclear facility operations – including evaluation of internal operational events, NPH events, and external events (such as an airplane crash) – to determine the consequences of an accident. The consequence results are then used to determine the type and design of safety systems needed to prevent or mitigate a release of radioactive material. For internal operational events, DOE nuclear facilities evaluate all physically possible events without regard to their likelihood. In many cases, this approach results in consequences being calculated for scenarios in which all of the hazardous material in the facility is assumed to be released, without taking any credit for mitigation from the facility structure. However, for NPH events and external events, DOE nuclear facilities consider the likelihood of the event as part of the process in determining the facility design basis. For example, DOE will design a Hazard Category 2 facility to withstand the maximum seismic event that is predicted to occur once in 2500 years and an external event that is predicted to occur once in a million years.

For design events, DOE's NPH design guide (DOE Guide 420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Nonnuclear Facilities* ) also provides guidance for considering potential

damage and failure of structures, systems, and components due to both direct natural phenomena effects (including common cause) and indirect natural phenomena effects due to the response of other structures, systems, and components (interaction) including natural phenomena-induced fires.

DOE Nuclear Packaging Operation

In regard to BDBEs, the safety analysis requirements in Title 10 CFR Part 830, *Nuclear Safety Management*, and in the safety analysis development standard used for most DOE nuclear facilities (DOE-STD-3009-94, *Preparation Guide for DOE Nonreactor Nuclear Facility Documented Safety Analyses*) require that the site/facility consider the need for analysis of accidents that may be beyond the design basis of the facility in order to provide a complete perspective on the risk associated with operating the facility. DOE provides no amplifying requirements or guidance regarding how "the need for analysis of accidents" is to be considered or documented. DOE also has a safety analysis guide (DOE Guide 421.1-2, *Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 CFR 830*) that provides general guidance supporting the development of safety analyses, but it does not provide guidance on the analysis or consideration of BDBEs. In regards to seismic performance, DOE standards for seismic design have sufficient conservatism, in general, to achieve less than 10 percent probability of unacceptable performance for ground motion equal to 150 percent of design basis ground motion (a list of these Standards is included in Appendix A).

### 5.1.2 Emergency Management Requirements and Guidance

DOE's approach to emergency management is founded on the principle that no matter how sound the fundamental safety programs and controls might be at DOE's facilities, events may sometimes happen that could affect the health and safety of people and/or the environment. This principle expresses DOE's position that if safety systems fail, the affected DOE site must be prepared to take emergency response actions to limit or prevent adverse health and safety effects to workers, the public, and the environment. Putting this principle into action requires that DOE sites undertake emergency response planning for all possible events, including those that are beyond the design basis of the safety systems (i.e., BDBEs).

DOE Order 151.1C requires that the release or loss of control of hazardous materials be quantitatively analyzed in an EPHA. DOE Guide 151.1-2 provides guidance on preparing EPHAs and states that EPHAs should analyze the set of events and conditions that represents the full spectrum of possible events, ranging from low-consequence, high-probability events to high-consequence, low-probability events; these include BDBEs and extreme malevolent events, such as a terrorist attack, which typically represent the upper end of the consequence spectrum. In addition, scenarios analyzed in the EPHA should represent both the success and the failure of control measures and safety systems (e.g., fire suppression systems, air filters, and security systems). Further, the guide states that emergency events or conditions should not be excluded from EPHA analysis solely because the calculated probability of occurrence is low or the event is designated as "incredible" or "beyond extremely unlikely."

## 5.2 Commercial Nuclear Power Industry Requirements and Guidance

### 5.2.1 Severe Accident Mitigation Guidelines

After the Three Mile Island reactor accident in 1979, the commercial nuclear power industry voluntarily developed guidance for severe accident mitigation that addresses severe reactor events, such as those involving multiple failures of safety equipment or unanticipated accidents that lead to significant degradation of the reactor core. The guidelines state that severe accidents should be evaluated to identify reasonable measures

for prevention or mitigation, based on realistic or best-estimate assumptions, methods, and analytical criteria regarding specific severe accidents.

### 5.2.2 BDBE Mitigation Requirements

After the terrorist attacks of September 11, 2001, the NRC added new requirements to 10 CFR Part 73 Appendix C, *Nuclear Power Plant Safeguards Contingency Plans*, to address such BDBEs as deliberate aircraft crashes. In addition, the NRC issued Order EA-02-026, *Order for Interim Safeguards and Security Compensatory Measures*, which modified the operating licenses for commercial nuclear power reactors and required new interim safeguards and security compensatory measures. This order also requires licensees to adopt strategies, using readily available resources, to maintain or restore cooling and containment of the reactor core and spent fuel pool and to handle the loss of large areas of the facility to large fires and explosions from any cause, including aircraft impacts. Subsequently, the NRC added provisions to 10 CFR 50.54, *Conditions of Licenses*, that require licensees to develop strategies for fighting fires, mitigating fuel damage, and minimizing radiological releases when large areas of the plant are affected by explosions or fire.

### 5.2.3 BDBE Analysis Requirements

After the Fukushima Daiichi accident, the NRC issued Information Notice 2011-05, *Tohoku-Taiheiyou-Oki Earthquake Effects on Japanese Nuclear Power Plants*, to its reactor licensees. The notice states that the NRC is assessing the implications of beyond design basis NPH and is developing a Temporary Instruction to guide NRC staff in performing independent assessments of nuclear power plant readiness to address beyond design basis NPH. Furthermore, Chapter 19 of Regulatory Guide 1.206, *Combined License Applications for Nuclear Power Plants*, requires licensees of future nuclear power reactors to perform a probabilistic risk assessment that includes analysis of BDBEs.

The NRC regulates fuel cycle facilities (i.e., facilities that produce or dispose of nuclear reactor fuel) under 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*. These facilities are less hazardous than nuclear power reactors and are similar to DOE Hazard Category 2 facilities. The fuel cycle facility regulations require that as part of the licensing process, licensees are to consider accidents, including BDBEs, that may result in high consequences for workers or the public and to demonstrate that safety equipment appropriately reduces the consequences. The NRC is examining the implications of the events in Japan and reviewing whether changes are needed in this regulation.

### 5.2.4 NRC Near-Term Task Force Report on the Fukushima Daiichi Accident

The NRC recently issued *Recommendations for Enhancing Reactor Safety in the 21st Century – the Near-Term Task Force Review of Insights from the Fukushima Daiichi Accident*, which summarizes the Task Force's systematic and methodical review of the NRC processes and regulations to determine whether additional improvements are warranted and to recommend changes in policy direction. The Task Force proposed improvements in five major areas:

- Clarifying the regulatory framework
- Ensuring protection
- Enhancing mitigation
- Strengthening emergency preparedness
- Improving the efficiency of NRC programs.

The Task Force stated that a "patchwork of regulatory requirements" developed "piece-by-piece over the decades" should be replaced with a "logical, systematic and coherent regulatory framework" to further bolster reactor safety in the United States. In recommending a more "coherent regulatory framework for adequate protection that appropriately balances defense-in-depth and risk considerations," the Task Force

recommended that the NRC consider implementing 12 recommendations. Several of these recommendations are similar to actions that DOE is currently considering, including:

- Requiring licensees to reevaluate and upgrade as necessary the design basis seismic and flooding protection of structures, systems, and components for each operating reactor (NRC Recommendation #2)
- Evaluating potential enhancements of the capability to prevent or mitigate seismically induced fires and floods (NRC Recommendation #3)
- Strengthening station blackout mitigation capability at all operating and new reactors for design basis and beyond design basis external events (NRC Recommendation #4)
- Identifying insights about hydrogen control and mitigation inside containment or in other buildings as additional information is revealed through further study of the Fukushima Daiichi accident (NRC Recommendation #6)
- Enhancing spent fuel pool makeup capability and instrumentation for the spent fuel pool (NRC Recommendation #7)
- Strengthening and integrating onsite emergency response capabilities, such as emergency operating procedures, severe accident management guidelines, and extensive damage mitigation guidelines (NRC Recommendation #8)
- Requiring that facility emergency plans address prolonged station blackout and multi-unit events (NRC Recommendation #9)
- Pursuing additional emergency preparedness topics related to multi-unit events and prolonged station blackout (NRC Recommendation #10).

The NRC Task Force also discussed improvements that should be made to re-evaluate and upgrade seismic and flooding protection of structures, systems, and components to current requirements. DOE already has in place requirements for re-evaluating NPH hazards every 10 years and is in the process of updating its standard (DOE-STD-1020-2002, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*) that guides these efforts. DOE will continue to follow the NRC actions relative to this effort to look for further lessons learned and opportunities for improvement.

## 5.3 EU Guidance in Response to the Fukushima Daiichi Accident

In response to the accident at the Fukushima Daiichi nuclear power plant, the EU performed a review to look for potential improvements for addressing BDBEs, caused by NPH or malevolent acts, that could affect nuclear power plants. The EU concluded that the safety of all EU nuclear power plants should be reviewed using comprehensive and transparent risk and safety assessments or "stress tests." These tests are defined as targeted reassessments of the safety margins of nuclear power plants for extreme events, regardless of the probability of occurrence, that challenge the plant's safety systems. The stress tests will evaluate the severe-accident management measures currently in place to mitigate loss of core cooling, fuel damage, breach of the reactor vessel, and protection of containment integrity. The testing process will also evaluate corresponding measures for dealing with loss of cooling in the spent fuel pool. The accident management measures will be evaluated for the extreme circumstances that occurred at Fukushima Daiichi; i.e., extensive destruction of plant infrastructure, unavailability of power and instrumentation, and inability to perform work due to accident conditions, such as high dose rates and extensive contamination at the site. The reactor licensees will perform the stress tests, and the appropriate regulatory bodies will independently review the results. The stress test reports will describe the effectiveness of the measures taken and the response initiated at the plant, noting any potential weak points such as significant flooding at the plant or the depletion of batteries if power is lost.

# 6. RESULTS FROM THE NUCLEAR SAFETY WORKSHOP

## 6.1 Workshop Purpose

On June 6-7, 2011, DOE sponsored a Nuclear Safety Workshop to (1) gather insights into lessons to be learned from the accident at the Fukushima Daiichi nuclear plant, (2) further examine the responses submitted for Safety Bulletin 2011-01 for lessons learned, and (3) begin developing recommendations for actions to further improve DOE nuclear safety. The workshop brought together high-ranking officials and technical experts from the DOE nuclear community to discuss how organizations could enhance and improve nuclear safety at their sites. In addition to the DOE nuclear community, representatives from the U.S. nuclear community attended the workshop, including the NRC, the Environmental Protection Agency, the Department of Homeland Security, the Institute of Nuclear Power Operations, the Defense Nuclear Facilities Safety Board, the Chemical Safety Board, and the Blue Ribbon Commission on America's Nuclear Future.

## 6.2 Workshop Overview

The first day of the workshop explored the accident at the Fukushima Daiichi nuclear power station in Japan and the organizational insights that DOE could gain from this tragic accident. Senior Departmental leaders shared their vision of how DOE is moving forward to improve its nuclear safety, and a panel of senior managers discussed the DOE nuclear safety culture, highlighting the importance of maintaining a strong, integrated safety management approach. The first day also included technical presentations on the Fukushima Daiichi accident by a Defense Nuclear Facilities Safety Board member, a senior vice president from the Institute of Nuclear Power Operations, an NRC commissioner, a senior scientific advisor to the Secretary of Energy, and an internationally recognized expert in NPH.

**DOE Senior Management Panel**

The second day of the workshop featured three technical breakout sessions that focused on DOE's evaluation of BDBEs, NPH, and emergency management. The purpose of these breakout sessions was to conduct a guided discussion of DOE nuclear facilities' potential vulnerabilities to a BDBE and determine whether DOE needed to perform additional actions to explore or address those vulnerabilities.

## 6.3 Technical Breakout Session Results

### 6.3.1 BDBE Breakout Session

This breakout session identified a number of strengths and weaknesses in DOE's current processes for evaluating BDBEs. The strengths included the fact that DOE does have a requirement for considering the need for evaluation of BDBEs, and that some facilities have performed this evaluation. The participants agreed that although the analysis of BDBEs may be performed as part of the documented safety analysis, much of the information from that analysis would likely be used to identify accident management strategies and would be best captured in an emergency management document. Some information that may be useful would include time dependencies associated with safety equipment, such as how quickly a pump would need to begin operating or how long it would need to operate. The participants noted a number of weaknesses, including the lack of a clear definition of what constitutes a BDBE, the limitation of some BDBE analyses to the immediate facility rather than multiple facilities that would be affected, and an incomplete understanding of the potential impacts from external facility events. Other areas noted as needing additional analysis included the impact of the failure of engineered controls that maintain important safety functions (such as energy

removal or confinement) during an accident; the identification of safety systems beneficial for mitigating a BDBE and the survivability of these safety systems following a BDBE; and the ability to compensate for the loss of shared infrastructure following a BDBE.

Several actions were recommended during the breakout session: (1) revising DOE-STD-1189-2008, *Integration of Safety into the Design Process*, to more fully address BDBE analyses; (2) revising DOE-STD-3009-94 to clarify expectations for analyzing impacts from nearby facilities following a BDBE; and (3) better integrating the expectations for accident analysis and emergency response.

### 6.3.2 NPH Breakout Session

The discussion in the NPH breakout session identified several areas warranting further study. The participants noted a lack of clarity concerning what constitutes significant new data, models, or methods for quantifying NPH, or when an updated assessment review of NPH is warranted. Another area of concern was whether the probabilities and consequences of NPH accident analyses are equivalent to or consistent with other types of accident analyses. The participants also noted that NPH, particularly earthquakes, are not always appropriately considered as events that will affect an entire site or as events with cascading impacts (such as an earthquake causing a tsunami, which causes damaging and sustained flooding).

Several actions were recommended to improve the analysis of and planning for NPH: (1) the ongoing revision of DOE-STD-1020-2002 needs to include criteria for determining whether an existing seismic study is adequate or an updated assessment is necessary; (2) DOE Order 420.1B, *Facility Safety*, should clarify that an NPH assessment review is to be performed every 10 years or when significant changes in data, models, or methods occur; and (3) analyses of potential impacts from an NPH need to consider the possible cascading events and sitewide impacts.

### 6.3.3 Emergency Management Breakout Session

The emergency management breakout session identified a number of topics that warrant further consideration. The participants noted that current emergency planning guidance focuses on facility hazards and the capabilities needed for an emergency response at a single facility, rather than the response to a BDBE that simultaneously affects multiple facilities, results in the long-term loss of power, and limits the availability of regional resources. Another area of concern involved the interfaces among emergency management, security, and continuity-of-operations activities during a BDBE, given the magnitude of the event and the protracted nature of the response. The participants also observed that emergency management exercises do not typically test the limits of a site's emergency plan, particularly for sitewide, regional, or simultaneous events.

The recommended actions to improve emergency management focused on three main areas: (1) revising the Emergency Management Guides to provide expanded planning guidance for BDBEs, with an emphasis on simultaneous emergencies at multiple facilities; (2) identifying ways to improve the interface among emergency management, security, and continuity-of-operations activities during a protracted response to a BDBE; and (3) conducting drills at DOE sites to examine the emergency response to a BDBE that affects multiple facilities.

## 7. SUMMARY OF INSIGHTS AND OPPORTUNITIES FOR IMPROVEMENT

The review provided DOE with insights and opportunities for improvement based on the analysis of site responses to the Safety Bulletin, the review of the DOE and commercial nuclear power industry requirements and guidance related to BDBEs, and the results of DOE's Nuclear Safety Workshop.

## 7.1 Safety System Operability

DOE sites maintain the safety systems at DOE nuclear facilities, ensure that the systems are operable, and perform scheduled inspections and required maintenance. In addition, sites perform walkdowns of the safety systems to evaluate their material condition. However, the responses to the Safety Bulletin, for the most part, did not indicate that sites had performed walkdowns specifically targeted at looking for potential susceptibilities to NPH and other external hazards following issuance of the Safety Bulletin.

Walkdowns of safety systems should be performed to identify unforeseen susceptibilities to the effects of BDBEs, particularly the impacts from NPH. Given the information from the Fukushima Daiichi nuclear power plant accident, walkdowns would provide valuable insight into potential weaknesses that may not have been previously considered.

## 7.2 Emergency Management Program

DOE's emergency management requirements and guidance (see Section 7.3) provide the framework for evaluating and responding to design basis events and BDBEs. In addition, DOE sites appropriately perform reviews and exercises to ensure that their emergency management programs can be effectively implemented. However, further planning is warranted for response to events that could have a significant and widespread impact on the site and surrounding community emergency response infrastructure. Considerations for emergency management planning criteria and guidance are further discussed in Section 7.3.3 below.

## 7.3 DOE Requirements and Guidance on BDBE Analysis

As discussed in Section 5, 10 CFR Part 830, DOE-STD-3009-94, and DOE Order 151.1C require consideration of BDBEs. However, these documents do not address the specific types of BDBEs that should be analyzed or provide detailed guidance on how the results of the analyses are to be used, as noted in Section 4. Additionally, DOE does not provide detailed expectations regarding the mitigation of severe accidents and BDBEs, differing in this way from the guidance and requirements issued by the NRC or the stress tests initiated by the EU, as discussed in Section 5. Further, the Nuclear Safety Workshop confirmed many of the items noted in the Safety Bulletin analyses discussed in Section 4 and identified additional areas where further requirements and guidance are warranted.

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The Safety Bulletin responses and Nuclear Safety Workshop results indicate that revisions are warranted for the safety analysis standards and guide (DOE-STD-3009-94, DOE-STD-1189-2008, and DOE Guide 421.1-2) and the emergency management order and guide (DOE Order 151.1C and DOE Guide 151.1-2). These revisions should clarify the expectations for analyzing and mitigating BDBEs and improve the integration of BDBE requirements and guidance among these documents. Additionally, the NPH standard (DOE-STD-1020-2002) and DOE Order 420.1B should be revised to clarify when an updated NPH assessment is necessary. The specific areas identified as warranting additional criteria and guidance are discussed in the following sections.

### 7.3.1 Evaluation of Severe NPH and External Events

Based on the Safety Bulletin responses and Nuclear Safety Workshop results, criteria and guidance should be revised to clearly describe and justify the range of BDBEs to be analyzed. In addition, the design basis analysis guidance should address cascading events across an affected region (e.g., a seismic event causing the failure of a nearby dam) and simultaneous events in adjacent facilities (e.g., fires in neighboring facilities); these are critical considerations for a thorough analysis of BDBEs. Furthermore, the criteria and guidance for analyzing hydrogen generation and/or explosions should be broadened to include all materials that can react

with water to create hydrogen. Finally, the design basis analysis should evaluate the impact of BDBEs on a facility's safety systems in order to clarify the design margins of the safety systems, the time dependencies associated with operation of the safety systems, and the likelihood that the safety systems would be able to provide some mitigation of the impacts of a BDBE.

### 7.3.2 Analysis of a Total Loss of Power

Based on the Safety Bulletin responses and Nuclear Safety Workshop results, criteria and guidance should be revised to ensure that sites identify their critical safety systems or functions that depend on either AC or DC power to operate. In addition, a site's design basis analysis should include the alternatives for supplying the needed power and performing critical safety functions, such as portable pumps, generators, or compressors and the associated transportation, setup, fuel, and connection devices necessary for operation. Also, sources for these items should be identified, both those that are available locally and those that would be available from a location unaffected by the BDBE. Further, the criteria and guidance should be expanded to address the possibility of using standardized external facility power connections to allow quick access to temporary power.

### 7.3.3 Analysis of Emergency Planning Needed to Respond to BDBEs

Based on the Safety Bulletin responses and Nuclear Safety Workshop results, criteria and guidance on analyzing BDBEs in hazards surveys and EPHAs should be enhanced to better define the emergency planning concepts. Additionally, existing criteria and guidance should be expanded to include an analysis of the potential impact of simultaneous events at multiple facilities resulting from a common accident initiator. Consideration should also be given to the potential unavailability of site and community infrastructure, such as power and communication systems, and the alternative means of providing these vital safety or emergency response resources. In addition, the criteria and guidance should be expanded to address coordination of site, facility, and community emergency plans, as well as integration of the site's emergency management, security, and continuity-of-operations activities. The scope of exercises should be expanded to include responses to BDBEs, including scenarios where mutual aid is unavailable and/or simultaneous events occur at multiple facilities on a site.

# 8. SUMMARY OF RECOMMENDATIONS

The review team developed several short-term and long-term recommendations based on their analysis of the Safety Bulletin submittals, review of applicable requirements and guides, and the results of the Nuclear Safety Workshop.

## 8.1 Recommendations for Short-Term Actions

### 8.1.1 Distribute Report

Distribute this report to inform the Program and Field Offices of its analysis and insights and provide direction for implementing its recommendations. HSS will work with the Program and Field Offices to develop a strategy for implementing the recommendations, including providing briefings and training to Field Office personnel.

### 8.1.2 Update the DOE Safety Analysis Guide and Standards

Initiate revisions of DOE Guide 421.1-2, DOE-STD-3009-94, and DOE-STD-1189-2008 to include criteria and guidance relative to BDBEs for:

- Evaluation of severe NPH and external events including safety systems' susceptibility to impacts from BDBEs.

- Evaluation of the potential for and impact of an extended total loss of onsite and offsite power.
- Evaluation of failure of engineered controls that maintain important safety functions, such as energy removal or confinement, during BDBEs.
- Integration of BDBE requirements and guidance with DOE Order 151.1C and DOE Guide 151.1-2.

HSS is developing a revision of DOE Guide 421.1-2 to include guidance on these topics. The draft guide is currently undergoing DOE-wide review. Following the comment resolution process, HSS will work with the Program and Field Offices to perform a pilot study of the guide to obtain insights on any implementation issues and ensure the effectiveness of the guide before issuing it.

### 8.1.3 Update the DOE Emergency Management Order and Guide

Initiate revisions of DOE Order 151.1C and DOE Guide 151.1-2 to include criteria and guidance for:

- Analyzing the emergency planning needed to respond to BDBEs.
- Integrating the analysis of BDBEs performed as part of the documented safety analysis into emergency planning.
- Planning for the response to simultaneous accidents at multiple facilities.
- Planning for the response when support services may not be available.
- Coordinating site, facility, and community emergency plans.
- Integrating the site's emergency management, security, and continuity-of-operations activities.
- Integrating BDBE requirements and guidance with DOE Guide 421.1-2, DOE-STD-3009-94, and DOE-STD-1189-2008.

### 8.1.4 Update the DOE NPH Requirements and Guidance

As part of the ongoing revisions of DOE Order 420.1B and DOE-STD-1020-2002, include lessons learned from the Fukushima Daiichi event relative to analysis and design for design basis events and well as BDBEs, in particular regarding evaluation of potentially concurrent or cascading events.

### 8.1.5 Enhance the Safety System Walkdown Process

Perform a series of pilot safety system walkdowns and evaluations at several Hazard Category 1 and 2 facilities to assess potential susceptibilities to NPH and external BDBEs. Capture the results in a corporate lessons-learned document that discusses successful methods for performing safety system walkdowns and evaluations.

### 8.1.6 Conduct Emergency Drills and/or Exercises for BDBEs

Conduct emergency drills and exercises at DOE sites with nuclear facilities, focusing on BDBEs. Scenarios should include events that impact multiple facilities and can cause the loss of infrastructure capabilities (such as onsite and offsite power, communications, and roadways) and the unavailability of mutual aid.

## 8.2 Recommendations for Long-Term Actions

### 8.2.1 Issue and Implement Revisions of the DOE Orders, Guides, and Standards for Safety Analysis, Emergency Management, and NPH

Complete the revision of DOE Orders 151.1C and 420.1B; DOE Guides 151.1-2 and 421.1-2; and DOE-STD-3009-94, DOE-STD-1189-2008, and DOE-STD-1020-2002. Develop an implementation strategy for each

document with the Program Offices, Field Offices, and the National Nuclear Security Administration's Office of Emergency Operations. The implementation strategy should include the development and conduct of training.

### 8.2.2 Evaluate the Necessity for Providing Additional Corporate Emergency Response Resources to Support Mitigation of BDBEs

The National Nuclear Security Administration's Office of Emergency Operations, in coordination with the Program and Field Offices responsible for nuclear facilities, should study whether enhanced emergency response resources are necessary to support the effective maintenance of critical safety systems and implementation of facility emergency plans. This study should include the ability to deliver equipment to the site under conditions involving significant natural events where degradation of infrastructure or competing priorities for response resources could delay or prevent the arrival of offsite aid. This study should also include lessons learned as part of the implementation of the new guides and standards and emergency response exercises regarding mitigation of BDBEs.

### 8.2.3 Conduct a Follow-on Nuclear Safety Workshop

In the spirit of continuous improvement, conduct another Nuclear Safety Workshop to discuss the results of completed short-term and long-term actions and efforts by the commercial nuclear power industry and its regulators to gather further lessons learned and make nuclear safety improvements based upon reviews of the accident at the Fukushima Daiichi nuclear power plant.

## 9. CONCLUSIONS

DOE nuclear facilities differ from the commercial nuclear power industry, but can still benefit from the lessons learned from the accident at the Fukushima Daiichi nuclear plant to improve nuclear safety at DOE facilities. While the responses to the Safety Bulletin confirmed that DOE has sound provisions in place to address BDBEs, additional actions should be taken to improve the criteria and guidance for evaluating BDBEs and to determine whether improvements in emergency response capabilities may be warranted. Implementing the short-term and long-term recommendations would be useful in improving DOE's capabilities for mitigating and responding to BDBEs, and would provide greater assurance that DOE can protect the public in case of an extremely unlikely and severe event at a DOE nuclear facility. DOE should continue to evaluate the activities by the commercial nuclear industry and its regulators to gather further lessons learned and make nuclear safety improvements based upon reviews of the accident at the Fukushima Daiichi nuclear power plant.

# APPENDIX A
# DOE's Nuclear Safety Approach

## Nuclear Safety Policy

It is the U.S. Department of Energy's (DOE's) policy to design, construct, operate, and decommission its nuclear facilities in a manner that ensures adequate protection of workers, the public, and the environment (DOE Policy 420.1, *Department of Energy Nuclear Safety Policy*).

In implementing this Policy, DOE has established a Federal regulation and DOE Directives (Orders, Manuals, Standards, and Guides) for:

- **Safety Analysis:** Performing analysis of hazards and potential accidents in order to identify safety controls.
- **Design:** Designing nuclear facilities to rigorous safety standards that require multiple layers of protection against the release of hazardous materials.
- **Personnel and Procedures:** Operating and maintaining its facilities with highly qualified and trained personnel using well-defined procedures.
- **Quality Assurance:** Requiring a strong quality assurance program to ensure that all aspects of facility safety, from design calculations, equipment procurement, and facility construction to operations and maintenance, are properly implemented.
- **Emergency Response:** Establishing emergency plans and procedures and routinely exercising these procedures to train and prepare for emergencies.
- **Integrated Safety Management:** Integrating safety into work planning and execution at all levels and establishing a strong safety culture.
- **Oversight:** Implementing a comprehensive oversight program to confirm that design, construction, operations, and decommissioning are conducted in a manner that protects the public, workers, and the environment.

## DOE Safety Requirements

Nuclear safety requirements are contained in Title 10 Code of Federal Regulations (CFR) Part 830, *Nuclear Safety Management*, and DOE Orders that cover the areas described above.

## DOE Nuclear Safety Guides and Standards

DOE uses a variety of standards and guides to support implementation of its nuclear safety requirements. These include:

- **Safety Analysis Guide and Standards:** Provide standardized and appropriate approaches for analyzing potential nuclear accidents and establishing controls to prevent them.
- **Natural Phenomena Hazards Guide and Standards:** Provide standardized and appropriate approaches for analyzing hazards and establishing designs to protect nuclear facilities from the effects of earthquakes, tornadoes, etc.
- **Facility Safety Guide and Standards:** Address defense-in-depth and reliable design of safety systems to ensure that multiple layers of protection are part of the safety design of DOE nuclear facilities.

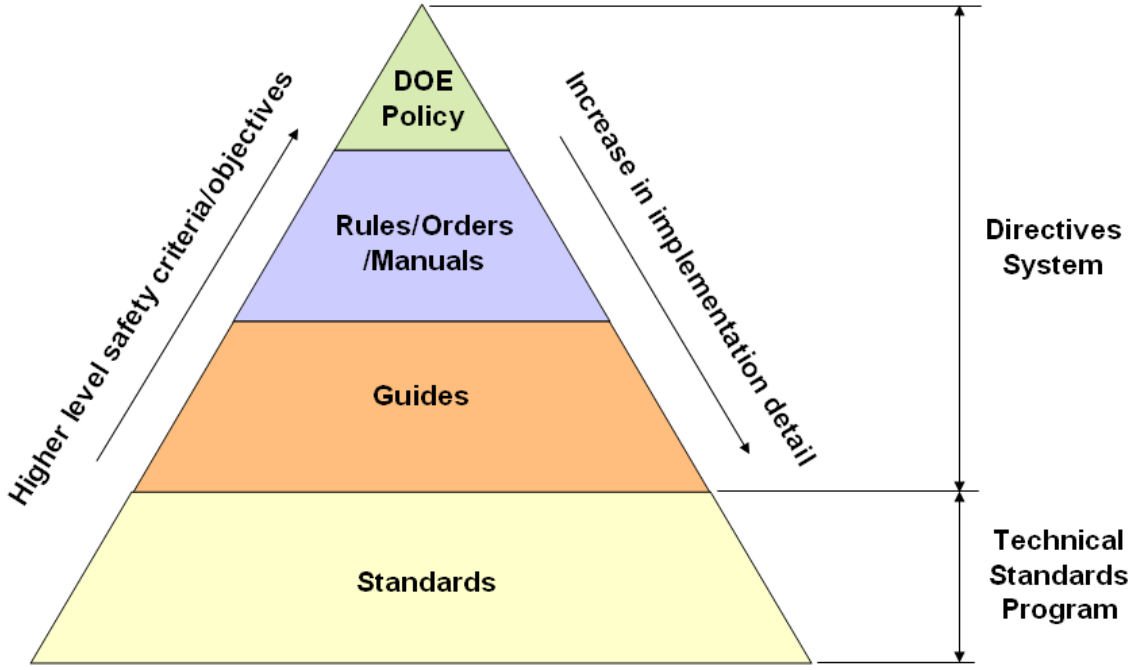


**Figure 2. DOE Regulatory Structure**

## List of DOE Nuclear Safety-Related Directives Referred to in this Report

DOE Order 151.1C, *Comprehensive Emergency Management System*.

DOE Order 420.1B, *Facility Safety*.

DOE Guide 151.1-2, *Technical Planning Basis Emergency Management Guide*.

DOE Guide 421.1-2, *Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 CFR 830*.

DOE Guide 420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear and Non-Nuclear Facilities*.

DOE-STD-1020-2002, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*.

DOE-STD-1021-93, *Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems, and Components*.

DOE-STD-1022-94, *Natural Phenomena Hazards Site Characterization Criteria*.

DOE-STD-1023-95, *Natural Phenomena Hazards Assessment Criteria*.

DOE-STD-1189-2008, *Integration of Safety into the Design Process*.

DOE-STD-3009-94, *Preparation Guide for DOE Nonreactor Nuclear Facility Documented Safety Analyses*.