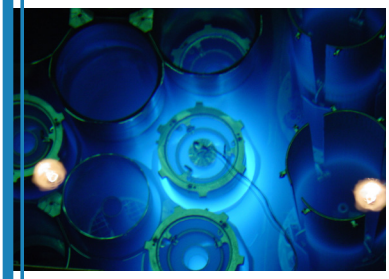
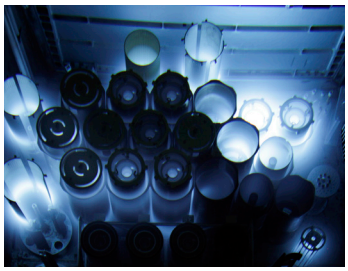
January 2013

A Report to the Secretary of Energy

Beyond Design Basis Event Pilot Evaluations

Results and Recommendations for Improvements to Enhance Nuclear Safety at Department of Energy Nuclear Facilities






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

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EXECUTIVE SUMMARY

In the six months after the March 2011 Fukushima Daiichi nuclear power plant accident in Japan, the U.S. Department of Energy (DOE) took several actions to review the safety of its nuclear facilities and identify situations where near-term improvements could be made. These actions and recommendations were addressed in an August 2011 report to the Secretary of Energy, *Review of Requirements and Capabilities for Analyzing and Responding to Beyond Design Basis Events*. Based on recommendations in the August 2011 report, DOE embarked on a project to develop and refine guidance that supports improvements in DOE's processes for analyzing and mitigating beyond design basis events (BDBEs), i.e., events such as earthquakes that are more severe than the events that formed the basis of the design for DOE's nuclear facilities. The results of this BDBE project and recommendations for further DOE actions are provided in this follow-on report.

The main activity of the BDBE project was the pilot application of guidance for evaluating the BDBE analysis and mitigation features at four DOE nuclear facilities representing a range of DOE sites, nuclear facility types/activities, and responsible program offices. The pilot evaluations focused on: (1) BDBE evaluations, as documented in the facility documented safety analysis (DSA); (2) potential BDBE vulnerabilities and margins to failure for facility safety features, as obtained from general area and specific system walkdowns and design document reviews; and (3) preparations made by facility and site emergency management programs to respond to severe accidents. The BDBE project also evaluated whether draft BDBE guidance on safety analysis and emergency management could be used to improve the analysis of, and preparations for, mitigating severe accidents and BDBEs. The pilot evaluation team paid close attention to related actions being pursued by the U.S. Nuclear Regulatory Commission, the U.S. commercial nuclear industry, and the international nuclear safety community to help refine the guidance for the pilot evaluations.

Results

The pilot results are provided in the three major areas reviewed: BDBE analysis, facility walkdowns, and emergency management.

BDBE Analysis

- The facilities participating in the pilot evaluations had previously evaluated BDBEs and established controls that would help manage BDBE risks in accordance with existing DOE requirements. Minor enhancements to these requirements were identified that could improve the linkage between the DSA assumptions and the conclusions about BDBEs and associated emergency response plans.

- The process used to perform BDBE evaluations during the pilots was useful in validating the existing facilities' BDBE accident analysis and facility-specific mitigation features. The pilot evaluation process also promoted effective exchanges of information among safety analysts, facility operations personnel, and site emergency management organizations.

- The benefits derived from the BDBE evaluation process are such that it should be applied to more of DOE's most hazardous facilities (i.e., potential to exceed the 25 rem evaluation guideline of DOE-STD-3009-94, *Preparation Guide for DOE Nonreactor Nuclear Facility DSAs*). In addition, some of the evaluations related to emergency planning and preparedness (such as evaluations of potential loss of infrastructure or severe accident impacts to multiple facilities at a site) can benefit all DOE sites.

- Minor updates to DOE standards and/or guides for safety analysis are needed to incorporate lessons learned from the pilot activities.

- The bounding BDBE verified at each facility was a seismic event. This conclusion was consistent with the DSAs.

Facility Walkdowns

- The walkdowns performed as part of the pilot evaluations did not identify any significant vulnerabilities in the safety equipment used to respond to BDBEs, but did identify opportunities for additional preparations that would enhance planned response actions.

- The walkdown guidance developed during the pilot evaluations provided a framework for conducting future system-specific walkdowns of critical structures, systems, and components in line with commercial nuclear industry practices.

Emergency Management

- DOE's emergency management requirements already dictate consideration of all potential severe accidents, including BDBEs. The pilot evaluations did not identify any significant issues and confirmed that the existing hazards survey/emergency planning hazards assessment process is sound.

- After the March 2011 accident at the Fukushima Daiichi plant, the DOE sites participating in the pilot evaluations all took proactive steps to improve emergency management capabilities for responding to severe events that could impact multiple facilities and the site's infrastructure.

- The draft emergency management approach for severe events used during the pilot evaluations was a good tool for enhancing the site's capabilities to plan and coordinate the responses to these events.

- The qualitative evaluation of severe accident impacts using a multi-discipline team (including facility operations personnel) was instrumental in developing an integrated response to BDBEs, including the important actions to be taken to stop progression of an accident or to safely shut down a facility.

Path Forward

As a result of the pilot evaluations and the reviews of efforts undertaken by the nuclear industry, recommendations for the Department's path forward include the following actions:

- Develop and issue an operating experience report that provides lessons learned from the pilot evaluations, along with the expectations and guidance for applying the BDBE pilot evaluation process to the small population of existing high hazard DOE facilities.

- Revise DOE safety directives and standards to require consideration of design options in new facilities to prevent/mitigate severe accidents and clarify safety analysis requirements and guidance for BDBEs at existing facilities (e.g., applicability of BDBE analysis, further discussion of preventive/mitigative safety features).

- Consider developing a DOE counterpart to Severe Accident Management Guidelines or Extreme Damage Mitigation Guidelines found in the commercial nuclear industry.

- Finalize the emergency management approach for severe accidents/events, incorporating appropriate requirements and guidance into DOE's emergency management directives.

Conclusions

The pilot evaluations provided valuable perspectives and validation that BDBEs had been appropriately analyzed at the facilities visited. The pilot evaluations also confirmed that the existing DOE requirements for identifying and addressing BDBEs are adequate, but that some minor additional improvements to implementing guidance are warranted. The pilot evaluations served as an effective tool to further evaluate BDBEs and to obtain additional insights on potential means to ensure that the Department is prepared to respond to such events, particularly with respect to emergency management planning. The safety analysis guidance used and refined during the pilot evaluations was effective in supporting reviews of BDBEs at existing facilities and should be applied to DOE's existing high hazard facilities. The benefits include verification of safety analysis conclusions and development of insights that can improve planning for accident response actions.

ACRONYMS

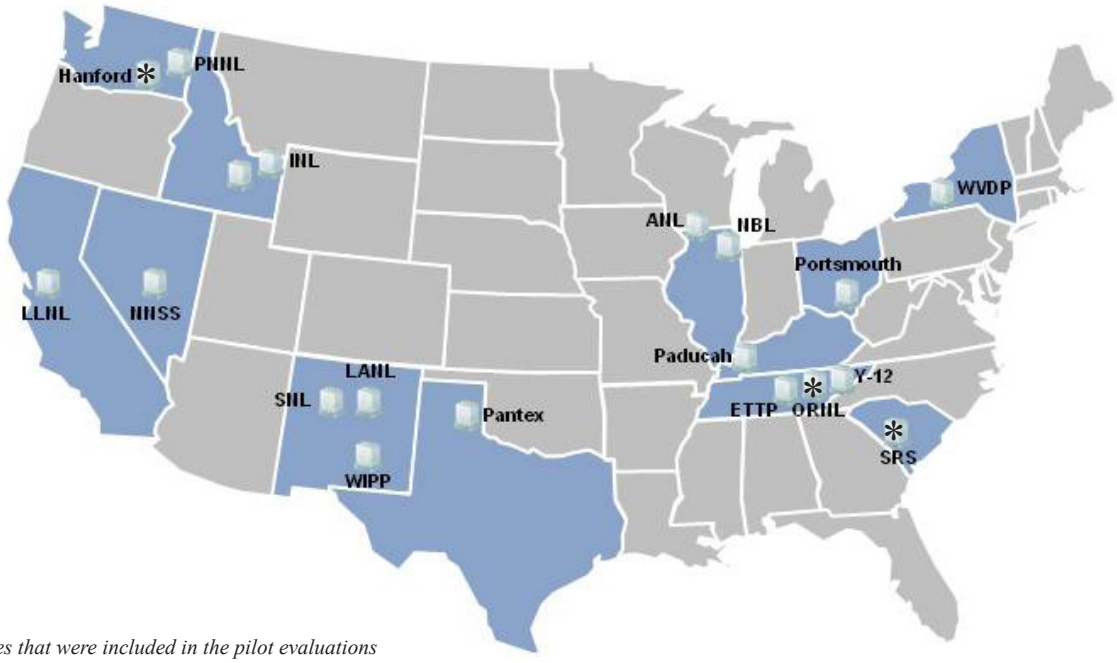
BDBE	Beyond Design Basis Event
CFR	Code of Federal Regulations
CSF	Critical Safety Function
DBE	Design Basis Event
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
EG	Evaluation Guideline
EPHA	Emergency Planning Hazards Assessment
EDMG	Extreme Damage Mitigation Guideline
HFIR	High Flux Isotope Reactor (at Oak Ridge National Laboratory)
NIMS	National Incident Management System
NNSA	National Nuclear Security Administration
NPH	Natural Phenomena Hazards
NRC	Nuclear Regulatory Commission
SAMG	Severe Accident Management Guideline
SRS	Savannah River Site
SSC	Structure, System, and Component
WESF	Waste Encapsulation Storage Facility (at Hanford Site)

Beyond Design Basis Event Pilot Evaluations: Results and Recommendations for Improvements to Enhance Nuclear Safety at Department of Energy Nuclear Facilities

1.0 INTRODUCTION AND PURPOSE

The U.S. Department of Energy (DOE) conducted a series of pilot evaluations to determine whether new guidance, developed for the analysis of beyond design basis events (BDBEs) and a new approach for emergency management of severe accidents (including BDBEs), provides an effective means for verifying that DOE nuclear facilities have adequate capabilities to protect against BDBEs. Figure 1 shows DOE's nuclear facilities.

These pilot evaluations were identified as short-term actions to be taken in response to DOE's August 2011 report to the Secretary of Energy, *Review of Requirements and Capabilities for Analyzing and Responding to BDBEs*. This follow-on report provides an overview of key activities related to development of BDBE safety analysis and emergency management guidance and the results of the pilot evaluations at the selected facilities.



* *Facilities that were included in the pilot evaluations*

ANL – Argonne National Laboratory
ETTP – East Tennessee Technology Park
*Hanford – Hanford Site
INL – Idaho National Laboratory
LANL – Los Alamos National Laboratory
LLNL – Lawrence Livermore National Laboratory
NBL – New Brunswick Laboratory
NNSS – Nevada National Security Site
*ORNL – Oak Ridge National Laboratory
Paducah – Paducah Gaseous Diffusion Plant
Pantex – Pantex Plant
PNNL – Pacific Northwest National Laboratory
Portsmouth – Portsmouth Gaseous Diffusion Plant
SNL – Sandia National Laboratories (New Mexico)
*SRS – Savannah River Site
WIPP – Waste Isolation Pilot Plant
WVDP – West Valley Demonstration Project
Y-12 – Y-12 National Security Complex

Figure 1. Locations of DOE Sites with Nuclear Facilities

2.0 BACKGROUND

In response to the March 2011 accident at the Fukushima Daiichi nuclear power plant, DOE took several actions to review the safety of its nuclear facilities and investigate how to better prepare for potential BDBEs, i.e., events more severe than those 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*[1], in March 2011, which requested DOE program and field offices to review their nuclear facilities' analyses for BDBEs, the controls in place that could mitigate BDBEs, and the readiness of their emergency management plans and procedures to respond to a BDBE

- Conducting an analysis, from April to July 2011, of DOE requirements and guidance for safety analysis, facility design, and emergency response related to BDBEs

- Performing a review, from April to July 2011, of commercial nuclear power industry requirements and guidance related to BDBEs

- Conducting a Nuclear Safety Workshop in June 2011 that was attended by senior nuclear safety managers and technical experts from DOE; other Federal agencies, such as the Nuclear Regulatory Commission (NRC), the Defense Nuclear Facilities Safety Board, and the Federal Emergency Management Agency; and the commercial nuclear power industry.

These efforts, as well as planned actions, are summarized in the aforementioned August 2011 DOE report to the Secretary of Energy, which identified the following short-term action recommendations:

- Update the DOE requirements and guidance on safety analysis, natural phenomena hazards (NPH), and emergency management to reflect the opportunities for improvement identified from industry and DOE field site interactions, and perform a pilot application of the revised requirements and guidance to gain insights to support finalization and subsequent implementation.

- Perform system walkdowns and evaluations at several DOE nuclear facilities to look for potential vulnerabilities to NPH, and capture the lessons learned from these walkdowns and evaluations in a DOE corporate lessons-learned document to support any additional walkdowns and evaluations that may be warranted at other DOE nuclear facilities.

- Improve the planning for and conduct emergency management exercises using scenarios involving BDBEs that affect multiple facilities and that cause the loss of onsite and offsite infrastructure (such as power and communication systems) and the loss of mutual aid resources.

3.0 PILOT EVALUATIONS OF SAFETY ANALYSIS, NPH, AND EMERGENCY MANAGEMENT GUIDANCE

The Office of Nuclear Safety within the DOE Office of Health, Safety and Security and the Office of Emergency Operations within the National Nuclear Security Administration (NNSA) formed a team to work with program

1 This Safety Bulletin and other reference material in this report can be found via links provided on the Office of Nuclear Safety web site at www.hss.doe.gov/nuclearsafety/

and field offices and site management and operating contractors to perform pilot evaluations to support implementation of the recommendations described in the August 2011 report to the Secretary of Energy. The pilot evaluation team, composed of experts in safety analysis, structural engineering, operations, and emergency management, developed draft guidance related to safety analysis, system walkdowns, and emergency management. This guidance was refined during each pilot evaluation. Appendix A lists the team members supporting the pilot evaluations.

High Flux Isotope Reactor at Oak Ridge National Laboratory

Team members met with staff from the NRC and the Institute of Nuclear Power Operations to discuss actions being taken in the nuclear industry, both nationally and internationally, to enhance capabilities for responding to BDBEs. Section 4 provides an overview of these actions and how they relate to DOE's ongoing BDBE evaluation activities.

A DOE technical report, *Technical Details on BDBE Pilot Evaluations*, describes the safety analysis, walkdown, and emergency management guidance that was used, including any refinements that were made as a result of lessons learned during the pilot evaluations. That technical report also discusses the detailed results of the pilot evaluations and forms the basis for the content of this summary report.

In September 2012, DOE conducted a second Nuclear Safety Workshop, which again was attended by senior nuclear safety managers and technical experts from DOE and other Federal agencies, to support development of the recommendations identified in this summary report.

3.1 Overview of Pilot Evaluations

Based on consultation with DOE program offices, four facilities (listed in Table 1) were selected to participate in the pilot evaluations. The objective was to evaluate a spectrum of DOE facilities (e.g., reactor, waste storage, and materials processing) across different program offices, focusing on those facilities with the highest hazards.

Table 1. Facilities Participating in BDBE Pilot Evaluations

Facility	Program Affiliation/Site	Hazard Category[2]	Mission
High Flux Isotope Reactor (HFIR)	Office of Science – Oak Ridge National Laboratory	1	Research Reactor
Waste Encapsulation Storage Facility (WESF)	Office of Environmental Management – Hanford Site	2	Storage of Cesium and Strontium Capsules
H-Area Tank Farm	Office of Environmental Management – Savannah River Site (SRS)	2	High-level Waste Storage
Tritium Facilities	NNSA – SRS	2	Tritium Recovery

2 DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*

At each facility, the team:

- Reviewed existing documentation for design basis event (DBE) analyses, BDBE analyses, associated controls discussed in the documented safety analysis (DSA), and any additional information provided by the facility in response to DOE Safety Bulletin 2011-01
- Performed a general walkdown of the facility
- Identified critical safety functions (CSFs) and performed a qualitative analysis of the impacts of potential BDBE NPH events on those functions
- Evaluated the impact of an extended station blackout
- Performed detailed walkdowns of selected safety structures, systems, and components (SSCs) identified as potentially vulnerable to BDBEs
- Evaluated emergency management planning and capabilities, including:
    - The link between BDBE scenarios from the DSA documentation and the emergency management technical planning bases
    - The emergency management program's ability to protect workers and recommend protective actions for the general public in case of severe events
    - The emergency response organization's ability to perform critical functions when supporting services (communications, power) are not available.

The team also evaluated a variety of BDBE NPH threats, including seismic events, floods, wildfires, lightning, wind, tornadoes, snow and ice, and ash fall, as well as manmade threats, such as aircraft crashes.

The process for performing these reviews evolved based on the lessons learned at each facility. The team captured the lessons learned in the draft guidance for BDBE safety analysis evaluation supporting the pilot evaluations and the draft guidance developed to enhance emergency management response to BDBEs.

3.2 Results of Pilot Evaluations

3.2.1 Evaluation of BDBEs in DSAs

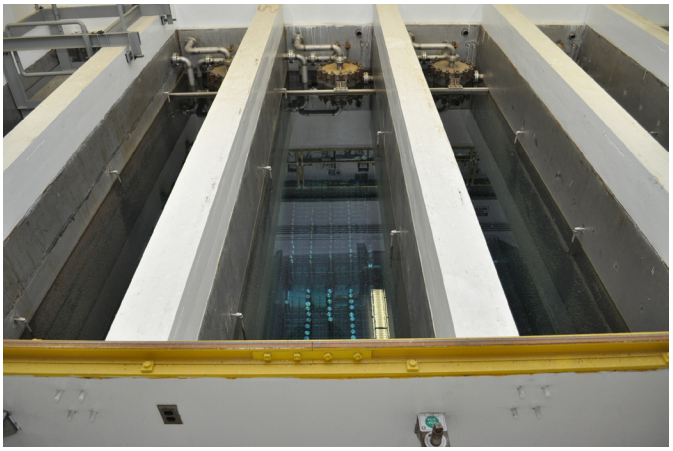
3.2.1.1 BDBE Analysis Process

The team began its evaluation by reviewing the facility's BDBE analysis documentation in the facility DSA and the facility's response to Safety Bulletin 201101. The team then evaluated what additional analysis and benefits might be obtained by applying the new BDBE guidance developed for these pilot reviews. The new BDBE guidance begins with the identification of CSFs that prevent a significant release of radioactive material. Although the term CSF is not explicitly used in DSAs, the concept is commonly used in the commercial nuclear reactor community and the team considered it to focus BDBE evaluations. The CSFs for non-reactor facilities can vary, but they are typically related to confinement of radioactive material, prevention of energetic reactions (e.g., explosions) that could cause the rapid dispersion of radioactive material, and removal of energy (e.g., from fires) that can cause the dispersion of radioactive material.

The team, along with knowledgeable facility personnel, then performed a qualitative evaluation of a broad list of BDBEs, using a simple "what-if" type of brainstorming session that is a commonly accepted hazard evaluation technique. The potential impacts of the failure of CSFs and associated consequences were also

estimated. This effort provided information on the types of BDBEs that could have a significant impact on the CSF, thereby identifying the BDBEs of concern. Where the loss of a CSF indicated the potential to exceed the offsite evaluation guidelines (EGs) for the release of radioactive materials established for accident analysis, the team performed a more detailed assessment to evaluate the margin to failure of the relevant SSCs. For NPH events, the team carried out this assessment by evaluating the system's response to an event with a higher stress level than the original design or evaluation basis. For example, for a facility designed to meet a Performance Category 3 event[3], the next higher stress level event would be a Performance Category 4 event. The major input to this process was each facility's safety analysis performed for design basis (or evaluation basis) accidents. Due to limited time, the pilot evaluation team did not perform a full margins assessment, but certain elements of the approach were applied during the pilot evaluations using a technique developed by the Electric Power Research Institute and endorsed by the NRC. This approach yielded insights into the margin to failure associated with the design of a particular structure or piece of equipment.

The BDBE evaluation process guidance also included the option to perform a quantitative risk assessment, similar in concept to long-term actions being considered by the NRC for commercial nuclear power plants. The quantitative risk assessment would provide insights into the level of protection provided by the primarily deterministic process that DOE facilities use in developing DSAs, including any residual risk from BDBEs. However, given the complexity and the time-consuming and resource-intensive nature of the analyses, and the lack of risk data, a formal probabilistic risk assessment would probably not be a viable approach for a DOE non-reactor facility and was not pursued as part of the pilot evaluations. The final step in the BDBE analysis process was to document the results and determine whether any potential changes should be made in the facility design or in the facility or site emergency management programs. The team performed a cost-benefit analysis for any identified resource-significant design improvements.



Interior and Aerial Views of the Hanford Site Waste Encapsulation Storage Facility

3.2.1.2 BDBE Analysis Results

The team found that the BDBE analyses in the DSAs for the facilities were consistent with the requirement in 10 Code of Federal Regulations (CFR) 830.204(b)(3) that requires, as part of DSAs, the consideration of need for analysis of accidents that may be beyond the design basis of the facility. The team also found that for some older facilities, the design had evolved as a result of new requirements and data, particularly in relation to NPH. As part of the design evolution, the additional stresses that led to the new requirements and standards were determined and then evaluated against the original design to determine the facility's capability to withstand the additional stresses. Periodic review of original designs against new information that may suggest previously-unidentified vulnerabilities is a very important element of the DOE safety analysis processes, and it is also a lesson learned from the Fukushima Daiichi accident.

3 DOE-STD-1020-2002, *Natural Phenomena Hazards Analysis and Design Criteria for Department of Energy Facilities*, provides definitions of the Performance Categories

The team found that the reviewed facilities' BDBE analyses and capabilities were appropriate. The BDBE evaluation process provides a good framework for enhancing DSAs because of its structured process for screening out certain natural phenomena initiators and focusing on BDBEs that are deemed physically possible. Qualitative evaluations identified the consequences of equipment failures related to one or more CSFs. Based on this process and the information in the DSAs, the team determined that the bounding accident at each facility was a seismic event, consistent with the facilities' conclusions in their DSAs.

Although the seismic event would result in the greatest potential damage at all facilities, the team concluded that there was value in evaluating a range of BDBEs and describing the possible impacts in the DSA. Because the extent of damage to the facility and surrounding area may be different for each facility and type of BDBE, capturing these details in the DSA and identifying the appropriate follow-on mitigation actions for each type of facility and BDBE is beneficial, especially for supporting emergency preparedness activities. For example, WESF faces unique and different challenges from flood (which could result in loss of power and ventilation that makes hydrogen buildup inside the building a concern) and seismic BDBEs (where loss of heat removal and shielding are concerns).

The team's qualitative evaluations identified some facility features that could be important in mitigating BDBE effects. The ability of these features to survive the BDBE was further investigated using the margins assessment approach, supported by system-specific walkdowns (described in Section 3.2.2).

The team evaluated new methods for capturing the results of BDBE analyses in the DSAs and for capturing the additional analyses performed during the pilot evaluations, including any new insights. Of particular importance was how to document facility features that could help mitigate BDBEs but are not identified in the DSA as safety features that could mitigate DBEs. The team concluded that existing safety analysis directives should be revised to clarify expectations for the DSA to identify these features, although such features would not need to be formally designated as safety significant or safety class solely because of the BDBE analysis.

During the development and conduct of the BDBE pilot evaluations, the team considered whether additional DOE facilities should apply the new BDBE guidance. The team concluded that hazard category 1 and 2 facilities with a DSA indicating unmitigated accident consequences greater than the 25 rem EG of DOE-STD-3009-94, *Preparation Guide for DOE Nonreactor Nuclear Facility DSAs*, would benefit from applying the new BDBE guidance. Many of DOE's hazard category 2 facilities do not have sufficient quantities and/or types of radioactive material to produce a release that could significantly impact public safety. The new approach to evaluating BDBEs will be included in future guidance and operating experience report recommendations, and existing safety analysis directives should be revised to clarify whether and how a given facility will need to conduct BDBE analysis (i.e., applicability criteria) for both nuclear safety and emergency preparedness purposes.

3.2.2 Walkdowns

3.2.2.1 Walkdown Process

The members of the team conducted an initial walkdown of the facility to familiarize themselves with the site characteristics (e.g., site elevation relative to nearby bodies of water, potential for wildland fires, nearby facilities) and to provide a view of the facility's potential vulnerabilities from a BDBE. Insights from this walkdown, together with the document reviews and qualitative evaluations discussed in Section 3.2.1.1, allowed the team to rule out certain accident scenarios such as severe flooding, based on the facility's elevation. The walkdown also allowed the team's seismic experts to become familiar with the structures and potential seismic interactions that might impact the validity of its BDBE analysis.

The team developed guidance for performing system-specific walkdowns that support the margin-to-failure analysis for selected SSCs. This process uses subject matter experts to perform an analysis that

identifies and ranks SSCs based on their vulnerability to failure, up to and including the bounding BDBE. This process also includes detailed, focused walkdowns for a sample of the SSCs with the smallest margin to failure for stresses beyond that produced by a DBE.

H-Area Tank Farm at Savannah River Site

The team, consisting of personnel with experience in systems/process engineering, seismic engineering, and facility operations/maintenance, conducted the walkdowns using techniques and checklists based on those in DOE/EH-0545, *Seismic Evaluation Procedure for Equipment in DOE Facilities*. The primary focus of the walkdowns was to determine the stability and anchorage of equipment, adverse seismic interactions, leak tightness and sealing (in situations where flooding was a concern), and modes of failure for other NPH that could impact the survivability of the SSC and the effect its failure might have on post-event operator mitigative actions or emergency response.

3.2.2.2 Walkdown Results

The team conducted a variety of walkdowns during the pilot evaluations, including general area tours and focused reviews of specific SSCs. No significant vulnerabilities were identified during the pilots that would compromise the SSC capabilities described in the DSAs. The walkdowns were useful in supporting the BDBE analysis, as discussed in Section 3.2.1.

The system-specific walkdowns at each pilot site yielded the following results:

- At HFIR, the team conducted a walkdown of a sample of components with the smallest margin to failure using techniques and checklists based on those in DOE/EH-0545. The walkdown confirmed that the margin to failure in the facility analysis was correct and established confidence in the design, installation, and maintenance of equipment. Through the walkdowns, the team identified areas that might warrant further review to determine whether a BDBE might impact any CSFs.

- At the WESF, the components that could compromise the ability to perform CSFs during a BDBE were located in a high radiation area and not available for walkdown. The walkdown did identify an opportunity to consider operator actions that could mitigate radiation exposure to emergency response personnel by removing abandoned piping and components that might require clearing after a seismic event to allow the addition of water to the capsule pools.

- At the SRS H-Area Tank Farm, the team selected the portable emergency ventilation equipment and its storage building for a walkdown based on its recognized importance in preventing the buildup of an explosive concentration of hydrogen in certain tanks after a DBE or BDBE that disrupts normal ventilation. The walkdown confirmed that the building housing the equipment was robust and would likely survive a BDBE seismic event or severe wind event. Based on the results of the walkdown, the team discussed with the facility staff measures that might improve facility personnel's ability to provide the required ventilation after a BDBE.

- At the SRS Tritium Facilities, the DBE assumed a complete structural and containment failure and the unmitigated release of the entire inventory of radioactive material. Although this scenario is highly improbable, it serves as the bounding case, and the consequences from this release do not exceed the EG at the site boundary. As a result, no SSCs were identified for further walkdown.

Several key lessons were learned during the development and implementation of the walkdown guidance. Team members conducting the walkdowns must be thoroughly familiar with the safety basis documents in order to evaluate the equipment and systems that impact the CSFs. Personnel conducting the walkdowns must also be skilled in observation techniques and using walkdown checklists, particularly for seismic-related observations. Further, using personnel with experience in systems/process engineering, seismic engineering, and operations/maintenance improved walkdown quality.

Both the initial and detailed walkdowns provided valuable insight into the facilities' operations and confidence that SSCs supporting the CSFs will remain viable after a BDBE.

3.2.3 Emergency Management

In late 2011, NNSA's Office of Emergency Operations developed a draft emergency management approach, based on lessons learned from the Fukushima nuclear accident. The draft document was informally coordinated with Federal points of contact at the DOE program and field offices. After comments were received in early 2012, the draft approach was revised and again informally coordinated with the Federal points of contact and used as the basis for the pilot evaluations.

The team used the draft emergency management approach for severe events (see Appendix C of DOE technical report, *Technical Details on BDBE Pilot Evaluations*), which will be incorporated into revisions of the DOE emergency management directives. Although the pilot evaluations are generally focused on BDBE events at nuclear facilities, the emergency management portion focused on severe events that could affect radiological, chemical, and other hazardous facilities that could pose a threat to the life and safety of onsite personnel.

3.2.3.1 Emergency Management Review Process

During the pilot evaluations, the emergency management team members participated in the development of severe event scenarios that impacted CSFs. Once the CSFs were identified, the emergency management team members branched off to interview facility and site personnel responsible for planning for emergencies. The first interview objective was to confirm that the existing emergency management program technical planning bases – hazards survey and emergency planning hazards assessment (EPHA) – addressed the CSF scenarios. The second objective was to determine whether the existing facility/site emergency program had robust capabilities that would allow a flexible and effective emergency response to severe events, which dominate the low-probability, high-consequence end of the spectrum of events required to be addressed by the emergency management program. Answers obtained during the interviews regarding these objectives were confirmed through checks of existing program documentation. The final interview objective was to discuss with facility/site personnel their preferences for changes in requirements/guidance that allow alternate courses of action in response to emergencies existed.

3.2.3.2 Emergency Management Review Results

Technical Planning Bases

The team found that the existing technical planning bases and the hazards surveys/EPHAs at the facilities/sites encompassed the DSA BDBE scenarios for each facility. Since current emergency management requirements and guidance address using the DSA as a source of information for the hazards survey/EPHA process, this result was expected. The team also found that those scenarios identified during the review of the CSF process

were also addressed within the hazards survey/EPHA process. In several situations, the information used to frame the CSF discussion was found in the existing hazards survey or EPHA for the facility.

Existing DSAs generally cover only one, or a few, BDBE scenarios. Although there may be coordination between facility safety analysts and emergency management analysts, the emergency management analysts currently develop information on the failure of barriers and hazardous material controls. An expansion of the coverage of BDBE events in the DSA, or information obtained by facilities/sites using the structured BDBE evaluation, will provide more detailed information about barrier failures, or the loss of controls, because of the greater expertise of the safety analysts. Expanded information will allow a better focus for emergency planning efforts.

Although expansion of BDBE coverage in the safety analysis process will benefit emergency management, the team confirmed that the existing hazards survey/EPHA process is sound. Every severe event scenario identified by the team during a discussion of CSFs was found to be addressed in the hazards survey or EPHA. Thus, the hazards survey/EPHA process, addressing a spectrum of scenarios from low-consequence/high-probability events to BDBE scenarios that are included in the high-consequence/low-probability end of the spectrum, provides a sound foundation for the emergency management program to protect the health and safety of workers and the public.

Facility Safety/Conduct of Operations

As the team examined the flow of information from the safety basis to the emergency management technical planning bases, the team discovered a gap in the information flow. Each facility had procedures on how to operate the facility within the safety basis, and the emergency management program addressed situations where facility controls fail and when the safety basis or design of the facility is exceeded. However, DOE has no counterparts to the Severe Accident Management Guidelines (SAMGs) or Extreme Damage Mitigation Guidelines (EDMGs) found in commercial nuclear industry.

SAMGs and EDMGs use information about BDBE scenarios in order to mitigate the event to protect the facility and prevent the progression of an event. Although the actions addressed in SAMGs or EDMGs may be executed during an emergency, they fall outside the DOE emergency management program, which focuses on protecting the workers and the public from the effects of hazardous materials released to the environment. Steps to limit the progression of a severe event scenario, including a BDBE scenario, or to safely shut down a facility so workers can "walk away" from the facility, leaving it in a safe configuration, fall within the purview of the facility safety/conduct of operations program. This programmatic alignment appears to be an area where improvements can be made, whether improving the information that flows from the safety analyst to the facility safety/operations staff or improving the ability of the facility safety/operations staff to take actions to mitigate the progression of an event.

High-level Waste Tank

Incident Command/Unified Command

Each of the facilities/sites that were part of the pilot evaluation program used the National Incident Management System (NIMS) as the foundation for responding to the event. NIMS is a comprehensive, national approach to incident management that is applicable at all jurisdictional levels and across functional disciplines and is scalable to the magnitude of the incident. Unified Command, which is part of NIMS, provides the framework for multiple jurisdictions to establish a common set of objectives for each operating

period during the response. The regular use of the NIMS Incident Command and Unified Command, during incidents at facilities/sites and during exercises, including those with offsite partner agencies, provides both familiarity and flexibility, if response is needed for a severe event. Forming a Unified Command during a catastrophic event will allow the most efficient use of limited resources to accomplish the National Response Priorities established by 40 CFR 300.317, *National Response Priorities*, including: protect safety of human life; stabilize the situation to prevent it from worsening; and minimize adverse impacts to the environment.

Response Asset Prioritization

Each of the pilot sites/facilities identified resources necessary to respond to the scenarios included in their technical planning bases (hazards surveys and EPHAs). There was coordination with offsite agencies for mutual sharing of capabilities, and appropriate agreements were in place. None of the pilot sites, and the majority of the other DOE emergency management personnel later polled, was in favor of establishing a DOE pool of emergency response equipment. In their opinion, the National Response Framework/NIMS Unified Command System was a more economical and prudent approach, since resources would be allocated according to 40 CFR 300.317 after a severe event affecting a large area.

Improved Coordination with Offsite Organizations

Each of the pilot sites had active programs to engage with their offsite partner agencies. However, DOE's efforts to improve the ability to address severe events do not have the same priority within their offsite partner agencies, and some important planning details for the severe events have not been established between the sites and offsite partner agencies. Existing networks and partnerships will be useful in sharing DOE's lessons learned with offsite agencies.

Communications Systems

Each of the pilot facilities/sites had extensive communications systems that provided multiple means to communicate with site facilities, response forces, and local agencies. Backup power for these systems was found to be available, as appropriate. Sites had considered the possibility of a need to use portable public address systems (vehicle mounted or "bull horns") and runner systems if electronic systems failed.

Protective Actions/Protective Action Recommendations

The existing DOE emergency management system requires facilities/sites to develop pre-planned initial protective actions for workers and pre-planned initial protective action recommendations to offsite agencies to consider for protecting the public in each of the scenarios addressed in the EPHA. For workers, the pre-planned initial protective action also promotes accountability and communicates the controlled implementation of other protective actions, such as evacuation. None of the pilot sites had established sitewide evacuation plans that were coordinated with offsite agencies. Each of the sites had experience in evacuating large areas of their site in response to severe weather and coordinating this evacuation with local agencies. However, all agreed that coordinated planning with offsite agencies would be beneficial.

Events Impacting Multiple Facilities

As noted in the August 2011 report to the Secretary, this is an area that has been not been appropriately addressed because the focus has been on individual facility response. Each of the pilot sites had begun efforts to improve planning for events that have multiple impacts. Substantial improvement will require a sustained effort over the long term.

Drills and Exercises

The best emergency response framework in the world will work only if people are familiar with the framework, emergency plans, and emergency plan implementation procedures and are comfortable using the tools available to address situations that happen "off script." Each of the pilot facilities/sites has begun to expand its drill and exercise programs to encompass NPH and events that impact multiple facilities. Some

of the drills and exercises are designed to identify areas or issues that can then be addressed by planners. As improvements are made, the exercise program will be used to validate the readiness of the facility and site emergency response organization to respond to severe events and protect the health and safety of DOE workers and the public.

4.0 INSIGHTS GAINED FROM NRC AND THE NUCLEAR COMMUNITY

Although the NRC and the commercial nuclear community (including power reactor owners and industry groups, such as the Nuclear Energy Institute, the American Nuclear Society, the Institute of Nuclear Power Operations and the Electric Power Research Institute) have focused their improvement efforts on commercial power reactors, the team found it useful to evaluate their efforts to determine whether DOE's efforts were in line with industry efforts and to gain insights on methods for performing BDBE evaluations and on additional efforts that might be warranted at DOE facilities.

The following sections address this evaluation. Appendix D of DOE Technical Report, *Technical Details on BDBE Pilot Evaluations*, provides additional details of the nuclear industry efforts.

4.1 Immediate Efforts

DOE's immediate efforts paralleled those of the nuclear industry in order to quickly ascertain whether there were some unanticipated vulnerabilities to BDBEs that should be addressed. Both DOE and the U.S. nuclear industry performed the following type of evaluations:

- Verification of the existence of the capability to mitigate conditions that result from BDBEs (in particular, beyond design basis flooding and seismic events)
- Verification of the existence of the capability to mitigate station blackout conditions
- Performance of walkdowns and inspections of safety systems
- Evaluations of the readiness and capabilities of emergency management plans and equipment.

4.2 Near-Term Efforts

Both the NRC and DOE performed an analysis of their regulatory frameworks to identify where improvements can be made in light of lessons learned from the Fukushima Daiichi accident.

The NRC issued a July 2011 report, *Near-Term Report and Recommendations for Agency Actions Following the Events in Japan*, that identified near-term recommendations for:

- Seismic and flood hazard reevaluations
- Seismic and flood walkdowns
- Station blackout regulatory actions
- Strengthening and integrating of emergency operating procedures, SAMGs, and EDMGs
- Emergency preparedness regulatory actions.

The NRC is in the process of implementing these recommendations via information requests, orders, and proposed rulemakings. The timeframe for industry performing the analysis is one to seven years, depending

upon the complexity of the action. The nuclear industry supported implementation of some of these actions by developing guidance for flood and seismic walkdowns. The team reviewed this information and incorporated insights into the BDBE guidance for the pilots.

In its August 2011 report to the Secretary, the Department recommended evaluating improvements in its guidance and other regulatory documents relative to BDBEs, as well as evaluating other corporate actions DOE could take to improve its capabilities to respond to BDBEs. Since issuing that report, DOE has developed draft guidance for both BDBE evaluations and emergency management improvements and has piloted this guidance. DOE is in the process of formulating long-term actions.

4.3 Long-Term Efforts

The NRC and the nuclear industry will continue to implement many of the near-term recommendations over the next seven years. In addition, the NRC is evaluating whether additional regulatory infrastructure changes are appropriate (for example, implementing some of the recommendations provided in NUREG-2150, *A Proposed Risk Management Regulatory Framework*).

As part of the pilot process, DOE is evaluating long-term efforts to:

- Issue an operating experience document requiring high hazard nuclear facilities to perform BDBE evaluations similar to the pilots to confirm documentation of facility-specific BDBE evaluations, gain further confidence on BDBE capabilities, and identify enhancements both at the facility and site level.

- Update the DSA and emergency management guidance to capture any improvements for use at new facilities and to support continued application at existing facilities/sites.

5.0 SUMMARY OF RESULTS AND RECOMMENDATIONS

5.1 Results

The pilots provided useful insights and recommendations on how to effectively evaluate and mitigate the effects of a spectrum of severe accident stresses on a facility's CSFs.

5.1.1 BDBE Analysis

- The facilities participating in the pilot evaluations had previously evaluated BDBEs and established controls that would help manage BDBE risks in accordance with DOE requirements. The method of the analysis was sufficient to identify the primary BDBEs of concern, although some enhancements could be made to make these analyses more systematic and to better document the results.

- The bounding BDBE at each pilot facility was a seismic event. However, there was value in evaluating a range of BDBE types, their impacts, and potential mitigation options. Evaluating a range of BDBE types has the potential to improve DOE programs by providing more detailed information to the emergency management program, which should improve planning for the scenarios that are already included in the emergency management technical planning bases (the hazards survey and EPHA) and could improve the ability of facility operations staff to better respond to BDBE scenarios, thereby limiting damage to the facility.

- The draft guidance for performing a structured BDBE evaluation during the pilots was useful in validating the appropriateness of the facilities' existing BDBE accident analyses and facility-specific

mitigation features. It promoted effective exchanges of information from safety analysts to facility operations personnel and site emergency management organizations, and allowed clear definition of responsibilities for each. These information exchanges are important for enhancing abnormal and emergency operating procedures for BDBEs.

- Existing DOE standards and/or guides for safety analysis were found to be largely sufficient for BDBE evaluation. However, the following minor improvements were identified during the pilots:

    - The scope of facilities to which further BDBE analysis is applied, consistent with the process used in the pilots, should be limited to DOE's most hazardous facilities. Given the existing threshold established in DOE-STD-3009 for classification of controls required for public protection, it is proposed the targeted population of facilities be limited to those with the potential to exceed the 25 rem public EG (in worst case accidents). This criterion should be further evaluated and clarified in safety analysis directives in light of the specific requirement in 10 CFR 830 for "consideration of the need" for BDBE analysis and in support of sitewide emergency preparedness for sites with multiple nuclear facilities.
    - Although it is not recommended that the current safety classification (i.e., safety significant or safety class) be identified solely on the basis of BDBE assessment results, corresponding BDBE-related safety features should be identified in the DSA to provide for defense in depth in order to ensure a higher degree of configuration control and maintenance than is applied to general plant equipment.
    - For new facilities, guidance is needed that promotes consideration of design options that may enhance BDBE mitigation.

5.1.2 Facility Walkdowns

- The walkdowns did not identify any significant vulnerabilities in safety equipment with respect to BDBEs. The walkdowns did identify some opportunities for additional preparations to enhance the response to BDBEs.

- The walkdown guidance developed during the pilots provided a good framework for conducting more detailed system-specific walkdowns of critical SSCs for safety margins assessments that are in line with commercial nuclear industry practices.

5.1.3 Emergency Management

- DOE's emergency management requirements already call for consideration of all potential severe accidents, including BDBEs. The CSF approach to BDBE analysis used by the team did not identify any new BDBEs, confirming that DOE's existing hazards survey/EPHA process is sound.

- After the March 2011 accident at the Fukushima Daiichi plant, the DOE sites participating in the pilots all took some proactive steps to improve emergency management in such areas as:

    - Responses to severe events that could impact multiple facilities
    - Responses under conditions where infrastructure is impacted.

- The draft emergency management approach for severe events focused attention on analyzing severe events, as well as planning and coordination of responses to them.

- To provide for a more integrated response to BDBEs, facility operations personnel should be included on the team. The pilot process did not examine facility operator actions, moving from safety analyses

and walkdowns to examination of the emergency program. Actions taken to stop an accident progression or safely shut down a facility in a BDBE scenario are just as important as those taken to protect workers and the public from the impact of a hazardous material release.

5.2 Recommendations

As a result of the pilot evaluations and the evaluations of efforts undertaken by the nuclear industry, recommendations for the Department's path forward include the following actions:

- Develop and issue an operating experience report that provides lessons learned from the pilot evaluations, along with expectations and guidance for applying the BDBE pilot evaluation process to subset of existing DOE hazard category 1 and 2 nuclear facilities with DSAs indicating that the unmitigated accident analysis results in radiological release consequences exceeding the 25 rem EG.

- Develop and incorporate improvements, commensurate with pilot results and conclusions, into existing DOE safety analysis directives and standards, specifically DOE-STD-3009 and DOE-STD-1189.

- Consider developing a DOE counterpart to SAMGs or EDMGs found in the commercial nuclear industry.

- Finalize the emergency management approach for severe events, incorporating appropriate requirements and guidance into DOE's emergency management directives.

6.0 CONCLUSIONS

The pilot evaluations confirmed that the primary BDBE threats had been identified and analyzed at the facilities reviewed, and no significant threats to public safety were identified. Protective measures were established in response to the BDBE threats. These measures were appropriate in light of the conclusions at many of the facilities that safety features may not survive severe accidents that develop stresses beyond the design basis.

The pilots validated the process and guidance developed for performing BDBE evaluations at the selected DOE nuclear facilities. At each facility, benefits gained by applying the pilot's BDBE evaluation process included: (1) confirming that primary BDBE threats are identified and analyzed; (2) providing added assurance that facilities are prepared to safely respond to BDBE threats; (3) providing important opportunities for key facility personnel to review BDBE preparations; and (4) identifying enhancements to facility design, procedures, training, or documentation.

To extend these benefits to other DOE facilities and ensure that the conclusions reached during the pilot remain valid, DOE determined that the pilot evaluation process should be applied to the most hazardous DOE facilities not included in the pilots. This application will confirm that DOE's safety posture relative to BDBEs is sound and will substantiate the current basis and plans for minor revisions to existing DOE safety analysis and emergency management directives and standards.

Appendix A
Pilot Evaluation Team Members

The core team was composed of the following individuals:

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