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Office of Nuclear Material Safety and Safeguards: Spent Fuel Storage and Transportation

Norma Garcia Santos
Project Manager

Japan Lessons Learned

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Agenda

- Description
  - Roles and Responsibilities
  - Spent Fuel Storage systems
- Background
- Methodology
- Conclusions

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Description
SFST Roles and Responsibilities

- Licensing
  - Certificates of Compliance
    - Storage Systems - 10 CFR Part 72
    - Transportation Packages - 10 CFR Part 71
  - Independent Spent Fuel Storage Installation (ISFSI) Licensing - 10 CFR Part 72
    - General License (GL)
    - Specific License (SL)

- Oversight

	Lead
ISFSI	Regional Offices
Certificate Holders	Headquarters

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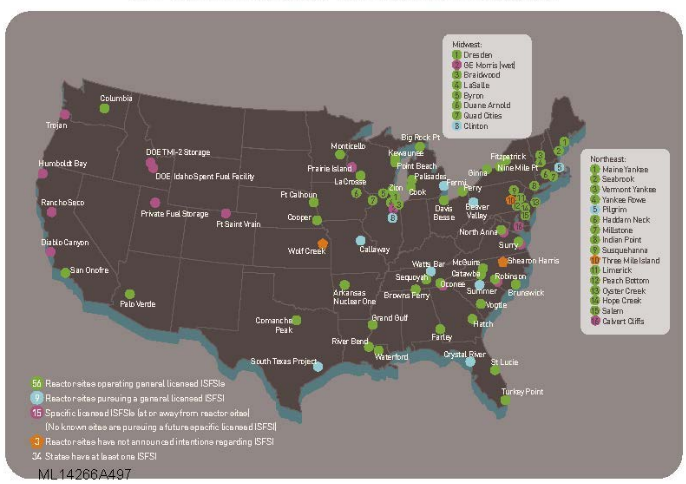
Background

U.S. Independent Spent Fuel Storage Installations



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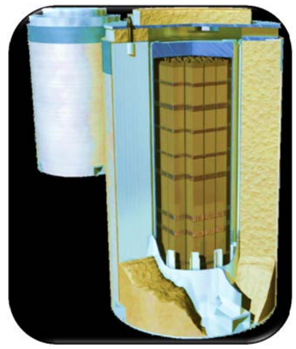
Background

Storage Cask Systems

Horizontal System



Vertical System

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Background

Pre-Fukushima

- ✓ Post-September 11, 2001 Assessments
- ✓ ISFSI Security Orders

Post-Fukushima

- ✓ G.E. Morris inspection (NRC Inspection Report 072-00001/11-01)
- ✓ Review the lessons learned of the Fukushima event as documented by the Near-Term Task Force

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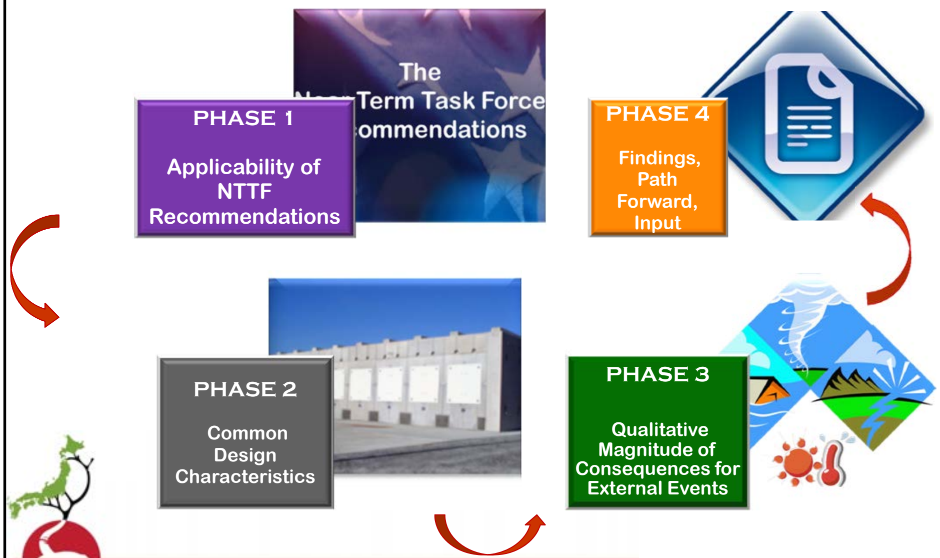
Methodology



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Conclusions

Low (green) – No radiation-related deaths or injuries expected; no offsite contamination.

Medium (Yellow) – Few radiation-related deaths or injuries; little to no offsite contamination.

High (Red) – Significant radiation-related deaths and/or injuries and significant offsite contamination or property damage.

QUALITATIVE EVALUATION (Low, Medium, or High)

System Orientation	Closure type	Vented	Seismic	Flooding	High Winds	Tornado Missiles	Ice & Snow Loads	Extreme Fires	LOOP	Drought	Extreme T
Vertical	Bolted	N	Low	Low	Low	Low	Low	Low	Low	Low	Low
Vertical	Welded	Y	Low	Low	Low	Low	Low	Low	Low	Low	Low
Horizontal	Welded	Y	Low	Low	Low	Low	Low	Low	Low	Low	Low
Vertical Underground	Welded	Y	Low	Low	Low	Low	Low	Low	Low	Low	Low

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Preliminary Conclusions

- No additional analysis or regulatory action is needed
  - Existing regulatory framework is adequate
  - No identified safety concerns.

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BACKUP SLIDES

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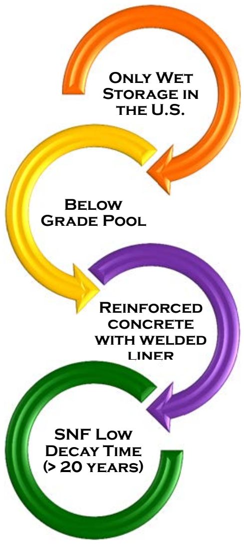
G.E Morris



NRC Inspection Report 072-00001/11-01, dated 3/13/2011

- After the Fukushima Dai-ichi event
- Considered station blackout, seismic, tornado, flood, and fire events
- Drained water scenario…fuel melt is not expected to occur -limited fuel decay heat load

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Recommendations – ISFSIs Applicability

Recommendations		Review Result
1	**Establishing a logical, systematic, and coherent regulatory framework** for adequate protection that appropriately balances **defense-in-depth and risk considerations**.	No Action
2	Require licensees to **reevaluate and upgrade** as necessary the **design-basis seismic and flooding** protection of structures, systems and components (SSCs).	Not Applicable
3	As part of the longer term review, evaluate potential **enhancements to the capability to prevent or mitigate seismically induced fires and floods**.	No Action
4	**Strengthen station blackout mitigation (SBO) capability** at all operating and new reactors for design-basis and beyond-design-basis external events.	No Action
5	**Require reliable hardened vent designs** in boiling-water reactor (BWR) facilities with Mark I and Mark II containments.	Not Applicable
6	As part of the longer term review, **identify insights about hydrogen control** and mitigation inside containment or in other buildings as additional information is revealed through further study of the Fukushima Dai-ichi accident.	Not Applicable
7	**Enhance spent fuel pool makeup capability and instrumentation** for the spent fuel pool.	No Action
8	**Strengthen and integrate onsite emergency response capabilities** such as EOPs [emergency operating procedures], SAMGs [severe accident management guidelines], and EDMGs [extensive damage mitigation guidelines].	Not Applicable
9	Require that facility emergency plans address **prolonged SBO and multiunit events**.	No Action
10	As part of the longer term review, pursue additional **emergency plan (EP) topics related to multiunit events and prolonged SBO**.	No Action
11	As part of the longer term review, pursue **EP topics related to decision-making, radiation monitoring, and public education**.	No Action
12	**Strengthen regulatory oversight** of licensee safety performance (i.e., the Reactor Oversight Process) by focusing more attention on defense-in-depth requirements consistent with the recommended defense-in-depth framework.	No Action

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NMSS: Decommissioning Reactors and Complex Materials Facilities

Boby Abu-Eid
Senior Level Advisor for Waste Management and Environmental Protection

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Background

- ***Decommission*****:** remove a facility or site safely from service and reduce residual radioactivity to a level that permits:
  - (1) Release of the property for unrestricted use and termination of the license; or
  - (2) Release of the property under restricted conditions and termination of the license.
- NRC's "Decommissioning Program" ensures NRC-licensed sites are decommissioned in a safe, timely, and effective manner so that they can be returned to beneficial uses.

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Background (Cont'd)

- Radioactive materials during decommissioning are either on building surfaces, in soil, or could be stored in piles or in containers for ultimate packaging and disposition.

- The potential radiological hazard at decommissioning facilities, after defueling, is low;

- Low hazards may also be associated with generated decommissioning radioactive waste.

- Decontamination and treatment processes during decommissioning may cause industrial and minor hazards to workers.

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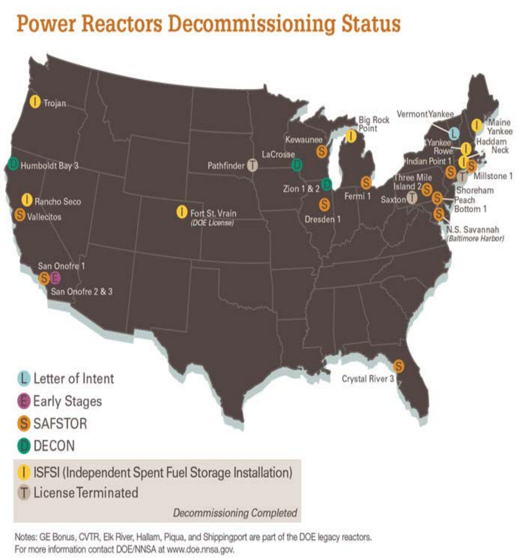
Regulatory Framework

- NRC regulates decommissioning of power reactors, research and test reactors, materials and fuel cycle facilities, and uranium recovery facilities.

- Radiological criteria for license termination in 10 CFR Part 20, Subpart E.

- Primary Guidance: Consolidated Decommissioning Guidance (NUREG-1757) & Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans (NUREG-1700, Rev. 1)



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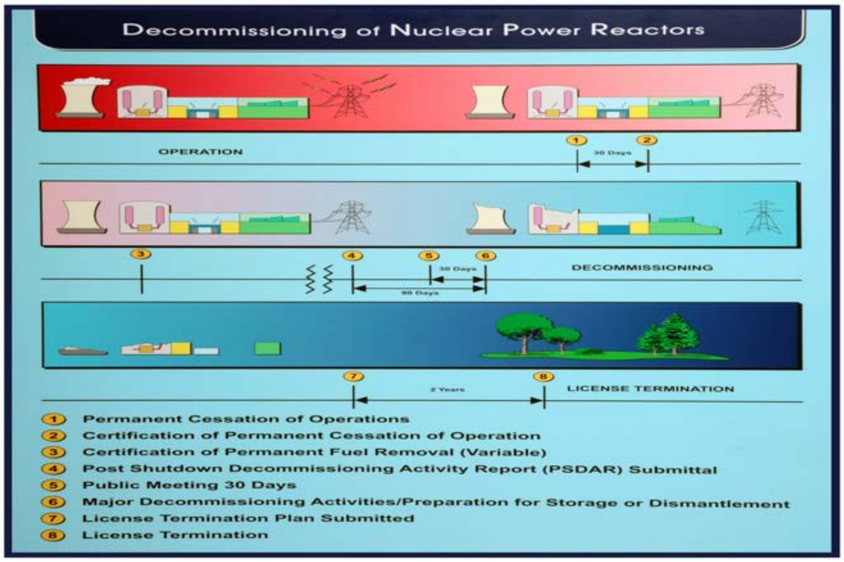
Regulatory Framework (Cont'd) Power Reactors Decommissioning



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Methodology

- The decommissioning process takes a risk-informed, performance-based approach.
- Staff reviewed various external events (e.g.; flood, seismic, severe climate conditions, etc.) to determine if a failure of safety barrier(s) at decommissioning facilities could cause significant release of radioactive materials to harm workers or the public.
- Staff reviewed overlap of decommissioning transition actions.

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Conclusion

- No additional analysis or regulatory action is needed.
- NRC's existing regulatory framework and processes are appropriate for ensuring the adequate protection of public health and safety.
- Analysis of external events for sites going through extensive decontamination and remediation; as well as facilities having significant onsite waste storage should not cause dose impacts to members of the public exceeding EPA Protective Action Guidelines.
- Staff's review is in common agreement that it is not necessary to develop additional mitigation strategies during transitioning into decommissioning.

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Questions

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Fuel Cycle Facilities

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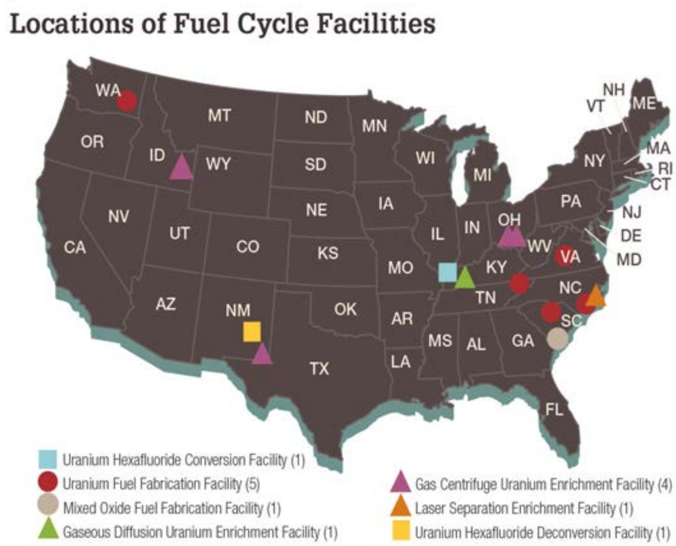
Fuel Cycle Facility Locations



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Regulatory Framework

- Code of Federal Regulation Parts 40, 70 and 76
- Integrated Safety Analyses (ISA) required for most facilities
  - Systematically assess hazards (including natural phenomena), likelihood and consequences
  - Identify Items Relied on for Safety (IROFS) needed to meet performance requirements
  - Implement management measures to ensure availability and reliability of IROFS
- ISAs form the foundation of licensees' safety program

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Methodology

- Information Notice 2011-08
  - Informed licensees of effects of the Tohoku-Taiheiyou-Oki earthquake
- Temporary Instruction (TI) 2600/015
  - Inspected and evaluated selected fuel facilities

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Methodology

- Objectives of TI 2600/15
  - Verify adequacy of licensees' mitigation strategies for licensing bases events
  - Evaluate adequacy of strategies for selected beyond licensing bases events
  - Collect information to determine if additional NRC regulatory actions are warranted

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Methodology

- Event Scenarios Considered
  - Seismic
  - Flooding
  - High Winds
  - Onsite Fires
  - Extended Loss of Power and Water

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Methodology

- Three Phases
  - Review of licensing bases for each facility
  - Inspections of licensee's prevention/mitigation strategies
  - Assessment of licensee's emergency response plan for beyond licensing basis events

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Methodology

- Inspection Results
  - Emergency mitigation strategies adequate for most facilities
  - Flooding, onsite fires , extended loss of power and water satisfactorily addressed
  - Potential generic issue with the bases for assumptions in licensees' safety analyses
- Path Forward: Staff will issue Generic Letter to collect information to verify compliance

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Methodology

- Applicability review of Near Term Task Force (NTTF) Recommendations
  - Reviewed the 12 recommendations to determine if additional actions were needed
  - Incorporates findings and lessons from TI 2600/015
  - Incorporates path forward to address TI issue
- No immediate actions identified

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Conclusions

- Current regulatory approach and requirements for fuel cycle licensees provides reasonable assurance of adequate protection of public health and safety
- Generic Letter to collect information with regards to fuel facilities' safety assessments and the supporting documentation with respect to the treatment of natural phenomena hazards

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Questions

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Radioactive Material Users and Part 36 Irradiators

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Methodology

- **Regulatory Framework Review**
  - 10 CFR (Energy) and Statements of Consideration
  - NUREG 1556 - Consolidated Guidance about Material Licenses
  - ANSI / ISO standards
  - Sealed Source and Device Registration
- **Facility Screening / Review**
  - Location
  - Natural Events review (e.g., seismic / flooding)
- **Material Events Review**
  - Daily Report Review
  - Nuclear Materials Event Database
  - Other lessons learned

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Regulatory Framework Material Users

- Approximately 21,000 licensees in the US.
- 10 CFR (Parts 2, 19 - 21, 30 – 37, 40 , 51, 70, 71, 170, and 171)
- NUREG 1556, Consolidated Guidance About Materials Licenses – focus on operational and emergency procedures.
- Sealed Source and Device review.
- Material Events Review – Does the regulatory framework work? Do licensees maintain control of material?

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Regulatory Framework Part 36 Irradiators

- 10 CFR Part 36, Licenses and Radiation Safety Requirements for Irradiators
- NUREG-1556, volume 6, Program-Specific Guidance About 10 CFR Part 36 Irradiator Licenses
- ANSI N43.10, Safe Design and Use of Panoramic, Wet Source Storage Gamma Irradiators (Category IV) and Dry Source Storage Gamma Irradiators (Category II)
- ISO 2919, Radiological protection - Sealed radioactive sources - General requirements and classification
- American Concrete Institute standard, ACI 318-95 “Building Code Requirements for Structural Concrete”

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Natural Events

External Fire

Flood

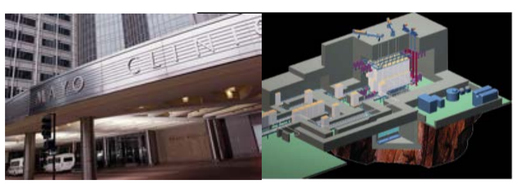
High winds

Seismic

Snow/Ice

Lightning

Drought



Loss of Power

Extreme Temperature

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Assessment – Materials Users

- The greatest concern is the loss of licensee control of radioactive material. The theft or the loss of a source could result in a health hazard.
- Sealed sources, storage containers, and facilities are very robust. The inherent nature of source storage is protective.
- Category 1 (e.g., irradiators) and Category 2 (e.g., well logging) sources must be reported to and tracked in the National Source Tracking System.
- The licensee must develop operating and emergency procedures and the operator must demonstrate an understanding of these procedures.

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Assessment – Part 36 Irradiators

- Panoramic irradiators are inherently robust and designed with multiple safety features to protect the health and safety of workers and members of the public.
- The concrete/steel reinforced radiation shield is designed to retain its integrity in the event of an earthquake by designing to local building codes or the American Concrete Institute Standard.
- A radiation shield constructed with steel plates and steel shot will retain its integrity in the event of the most severe earthquake.
- Emergency and abnormal event procedures address other natural phenomena, including tornado, hurricane, flooding, or other phenomena.

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Conclusion (1)

- Unsealed radioactive materials and sealed sources and devices used in industry, academia, and medicine are appropriately licensed and provide sufficient engineering controls to protect the health and safety of workers and members of the public.
- The safety evaluation conducted before authorizing a manufacturer or distributor to distribute the radioactive sources to a licensee assures the integrity of the device.
- Thousands of industrial sources have been routinely exposed to harsh environmental stressors under normal operation. Licensees have developed operational and emergency procedures to deal with unplanned accidents and emergencies.

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Conclusion (2)

- Natural phenomena occur and potentially impact licensees every year. Databases and mapping tools have been successfully used to assist licensees and regulators before and after natural disasters.
- The likelihood of losing control of a radioactive source from a Part 36 irradiator due to a natural phenomena is very low.
- Upon completion of the NUREG-1556 series revision in FY16, no further study or regulatory action in response to the NTTF recommendations is warranted.

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Thank you !

Questions / Comments

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Back up slides

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Definitions

Category 1 sources and practices - personally extremely dangerous: This amount of radioactive material, if not safely managed or securely protected, would be likely to cause permanent injury to a person who handled it, or were otherwise in contact with it, for more than a few minutes. It would probably be fatal to be close to this amount of unshielded material for a period of a few minutes to an hour [A/D > 1000]

Category 2 sources and practices - personally very dangerous: This amount of radioactive material, if not safely managed or securely protected, could cause permanent injury to a person who handled it, or were otherwise in contact with it, for a short time (minutes to hours). It could possibly be fatal to be close to this amount of unshielded radioactive material for a period of hours to days. [1000 > A/D > 1]

IAEA-TECDOC-1344, Categorization of radioactive sources, 2003.

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Definitions

Category 3 sources and practices - personally dangerous: This amount of radioactive material, if not safely managed or securely protected, could cause permanent injury to a person who handled it, or were otherwise in contact with it, for some hours. It could possibly - although it is unlikely - be fatal to be close to this amount of unshielded radioactive material for a period of days to weeks. [10 > A/D > 1]

Category 4 sources and practices - unlikely to be dangerous: It is very unlikely that anyone would be permanently injured by this amount of radioactive material. However, this amount of unshielded radioactive material, if not safely managed or securely protected, could possibly - although it is unlikely - temporarily injure someone who handled it or were otherwise in contact with it, or who were close to it for a period of many weeks. [1 > A/D > 0.01]

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Description

- An irradiator is a facility that uses radioactive sealed sources for the irradiation of objects or materials and in which radiation dose rates exceeding 5 gray (500 rads) per hour exist at 1 meter from the sealed radioactive
- Part 36 irradiators are generally category 1 sources comprised of cobalt-60 with activities that range from 9 PBq (250 KCi) to 1 EBq (30 MCi).

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Sealed Source Tests

Test	§ 36.21 Performance Criteria for sealed sources	Nordion C-188 & C-442 Co-60 source
Temperature	-40ºC (20 min) +600º C (1 h) and Thermal shock to 20ºC 5	-40ºC (20 min) +800º C (1 h) and Thermal shock to 20ºC 6
Pressure	2 MPa (5 min) 3	70 MPa (5 min) 5
Impact	2 kg from 1 m or equivalent imparted energy 4	20 kg from 1 m or equivalent imparted energy 6
Vibration	25 Hz to 500 Hz at 49 m/s^2 (5 g); 3 times (10 min) 2	25 Hz to 80 Hz and 80 Hz to 2000 Hz at 196 m/s^2 (20 g); 3 times (30 min) 4
Puncture	50 gm from 1 m or equivalent imparted energy 4	1 kg from 1 m or equivalent imparted energy 6

1 g = 9.8 m/s^2

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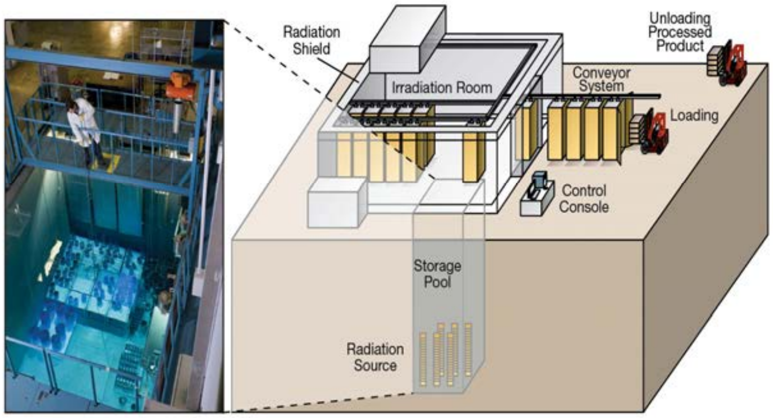
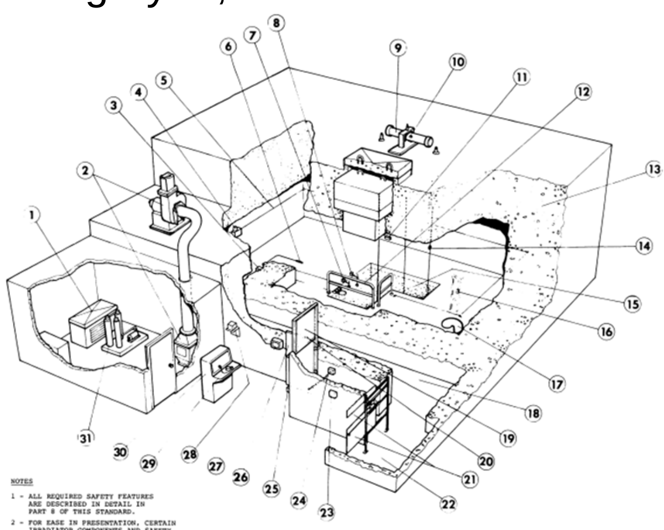
Description

Commercial Irradiator



Category IV, Part 36 Irradiator



NOTES

1 - ALL REQUIRED SAFETY FEATURES ARE DESCRIBED IN DETAIL IN PART 8 OF THIS STANDARD.

2 - FOR EASE IN PRESENTATION, CERTAIN IRRADIATOR COMPONENTS AND SAFETY FEATURES HAVE BEEN OMITTED FROM THIS ILLUSTRATION e.g. PRODUCT PASS MECHANISM AND RADIATION SOURCE.

Figure 2. *Safety features (typical) for Category IV irradiators.*

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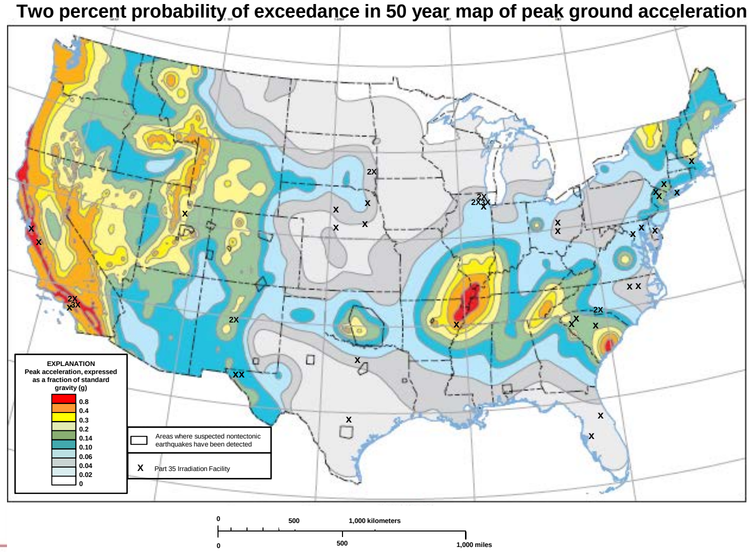
Part 36 Irradiator Locations

Two percent probability of exceedance in 50 year map of peak ground acceleration



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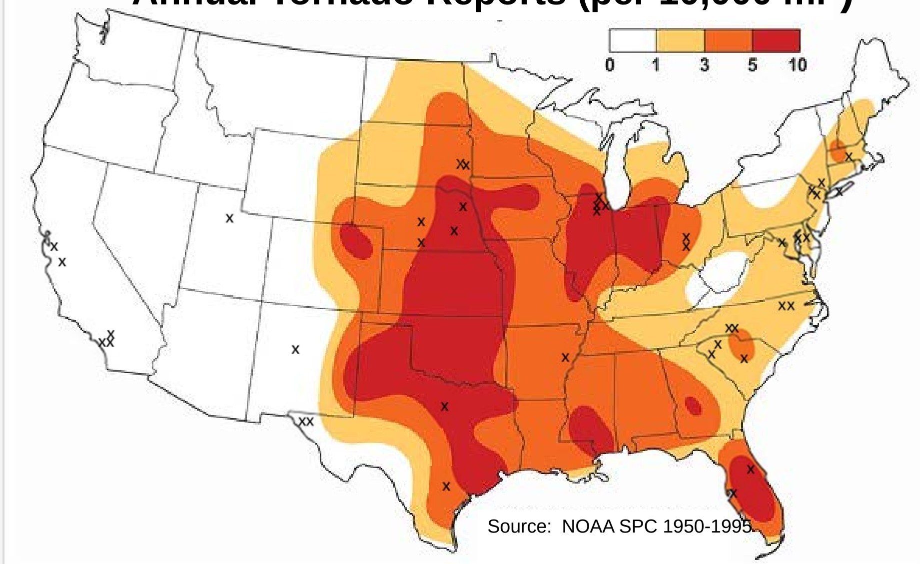
Part 36 Irradiators

Annual Tornado Reports (per 10,000 mi^2)



Source: NOAA SPC 1950-1995

NMSS:
Low Level Waste Disposal Facilities

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Senior Level Advisor for Waste Management and Environmental Protection

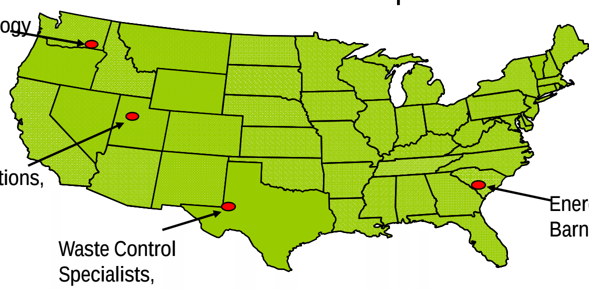
Background

- Low-Level Waste (LLW) is not high-level radioactive waste, spent nuclear fuel, or byproduct material.
- LLW includes items contaminated with radioactive material or items become radioactive through exposure to neutron radiation.
- LLW typically consists of contaminated protective shoe-covers and clothing, wiping rags, filters, reactor water treatment residues, equipment and tools, luminous dials, medical tubes, and swabs.
- LLW may also include large components such as reactor vessels and contaminated steam generators
- May include large volumes of specific waste streams such as depleted uranium.

Background (Cont'd)

Pictured: Barnwell SC LLW Disposal Facility (Energy Solutions)

Commercial LLW Disposal Sites



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Regulatory Framework

- Part 61 - Licensing requirements for land disposal of radioactive waste
  - Site-Specific Analysis Rulemaking (Unique Waste Streams)
  - Potential Revision of 10 CFR Part 61
  - Currently, LLW regulations/technical guidance being developed to address three tiers of performance periods.
  - Defense-in-depth, analysis of FEPs, and safety case concepts are being incorporated.

- 10 CFR 20.2002:
  - A general provision that allows for other disposal methods, different from those already defined in Part 61
  - Doses must be maintained as low as is reasonably achievable (ALARA) and within the dose limits of Part 20.

- Part 62 - Criteria and procedures for emergency access to non-Federal and regional low-level waste disposal facilities

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Methodology

- Staff reviewed LLW NRC regulations & guidance, as well as Agreement State compatible regulations, addressing potential accidents or external events scenarios and impacts.
- Based on Fukushima lessons learned, staff conducted technical evaluations of LLW facilities for potential impacts of external events/accidents:
  - fire, flooding, severe erosion, containment breakdown, earthquakes.
- The current assessment and reviews focused on severe external events to determine if a failure of safety barrier(s) at LLW disposal facilities could cause significant release of radioactive materials to harm workers or the public under emergency situation.

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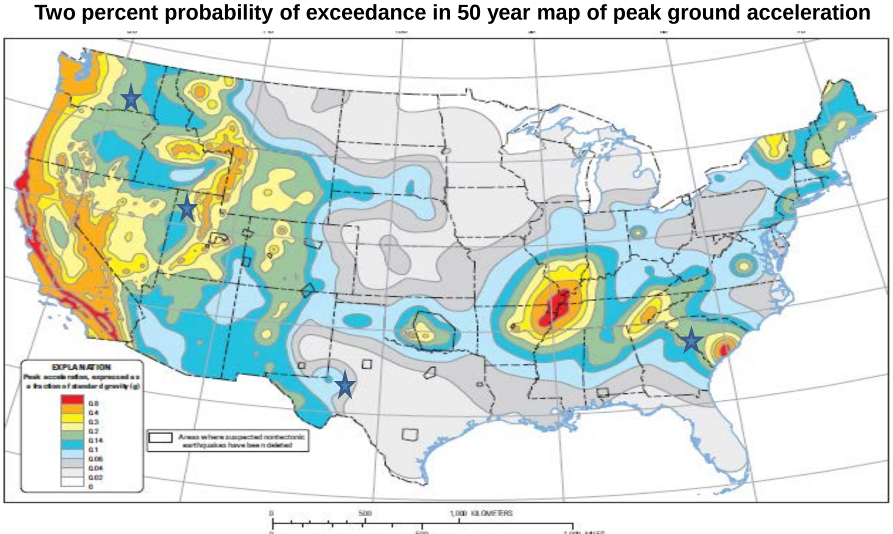
Methodology

LLW Sites Locations & Seismic Hazard Evaluation

Two percent probability of exceedance in 50 year map of peak ground acceleration



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Conclusion

- No additional analysis or regulatory action is needed.
- NRC's existing regulatory framework and Agreement State regulations are appropriate for ensuring adequate protection of public health and safety.
- Ongoing development of 10 CFR Part 61 regulations & guidance provide further assurance of defense-in-depth, FEPs analysis, and overall safety case analysis.
- Staff's analysis provides assurance that potential dose impacts to members of the public from external events would not exceed the dose limits to member of the public or inadvertent intruder into the disposal facility.
- Considering highly conservative severe external events scenarios, the dose to members of the public should not exceed EPA Protective Action Guidelines criteria under emergency situations.

NMSS: Uranium Recovery Facilities and Uranium Mill Tailings

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Background

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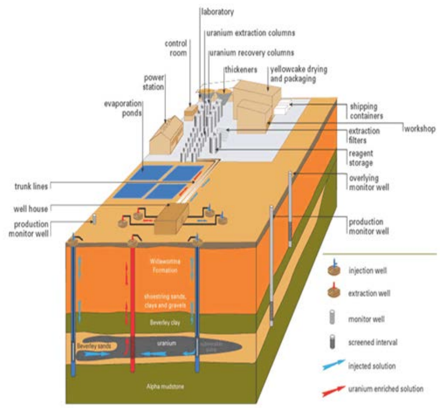
- Uranium Recovery Facilities
  - In Situ Recovery (Subsurface)
  - Conventional Uranium Milling (Near Surface)

- Uranium Mill Tailing
  - The mill tailings generated during conventional milling process considered byproduct material (Near Surface)



Regulatory Framework

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- 10 CFR Part 40, "Domestic Licensing of Source Material.“
- 10 CFR Part 40 Appendix A: “Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material From Ores Processed Primarily for Their Source Material Content.”
- 10 CFR Part 20, "Standards for Protection Against Radiation"

- NUREG-0706, Final Generic Environmental Impact Statement on Uranium Milling.
- NUREG/CR-6733, A Baseline Risk-Informed, Performance Based Approach for In Situ Leach Uranium Extraction.
- NUREG-1569, SRP for In Situ Leach Uranium Extraction License Applications.

Methodology

Staff evaluated NRC oversight program at uranium recovery facilities including:

- Review/approval of safety and environmental monitoring reports, operational data at uranium recovery facility, and evaluation of overall safety in accordance with NRC regulations and license conditions.
- Inspections and site visits; and observation and verification of actions.
- Review of operational procedures.

Japan Lessons Learned

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Methodology (Cont'd)

- Staff evaluated the Uranium Recovery Licensing process and site suitability features:
  - Flooding, faulting, folding, seismic activities, volcanism, meteorology, climate/climatology, and surface water as well the hydrological system.
- The current assessment reviewed external severe events based on Fukushima lessons learned to:
  - determine if a failure of safety systems or barrier(s) at uranium recovery facilities could cause significant release of radioactive materials to harm workers or the public.
- Staff evaluated emergency response plans (e.g.; including NRC/State Inspections and/or IMPEP reviews) to ensure appropriate external events, emergency procedures, and emergency response plans are in place.

Japan Lessons Learned

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Conclusion

- No additional analysis or regulatory action is needed.
- The NRC's existing regulatory framework and oversight processes are appropriate for ensuring adequate protection of public health and safety.

Japan Lessons Learned

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Assessment of the Lessons Learned from the Fukushima Dai-ichi Accident for NRC-Licensed Research and Test Reactors

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Japan Lessons Learned

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Research and Test Reactor Post-Accident Assessments

Assessment of Research and Test Reactors

- Staff reviewed the 12 Near-Term Task Force (NTTF) recommendations, external events, and other information related to Fukushima lessons learned for applicability to Research and Test Reactors (RTRs)
- Considered potential consequences resulting from a beyond design basis external event (BDBEE) – assessment considered conditions beyond those required for licensing
- Staff assessment included a review of:
  - RTR designs and licensing information
  - licensing requirements and guidance
  - specific Fukushima accident information
- Assessed the 31 RTRs in two groups:
  - Less than 2 MW_t [Megawatts-thermal]
  - Greater than or equal to 2 MW_t

Japan Lessons Learned

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Research and Test Reactor Post-Accident Assessments

Assessment of RTRs (continued)

- Assessed facility resilience to the loss of active decay heat removal capability, electrical power and loss of coolant as a result of the BDBEE
- Considered the potential for fuel cladding failure and radiological release
- Determine need for additional assessment

Japan Lessons Learned

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Research and Test Reactor Post-Accident Assessments

RTR Assessment Conclusions

- Less than 2 MW_t Research Reactors (26)
  - No additional assessments or actions are needed
  - The risk of a significant release of radioactive material as a result of a BDBEE, is very low
  - Conditions driving the low risk include:
    - low thermal power ratings - all 1.1 MW_t or less
    - a low fission product inventory
    - a low decay heat generation
    - the capability for air cooling of fuel - adequate to prevent overheating and failure of the fuel cladding
    - Insensitive to the loss of coolant, electrical power, and active decay heat removal systems

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Research and Test Reactor Post-Accident Assessments

RTR Assessment Conclusions (continued)

- 2 MW_t Research Reactors (2)
  - Considering the postulated radiological consequences based on actual power history, each of these two reactors present the decay heat equivalent of a reactor of less than a 1.1 MW_t
  - No additional assessments or actions needed

Research and Test Reactor Post-Accident Assessments

RTR Assessment Conclusions (continued)

- Research Reactors greater than 2 MW_t (2)
  - Air cooling of the reactor core may not be adequate to prevent fuel cladding failure if reactor coolant is lost
  - Adequate decay heat can be removed through natural convection (passive) flow of reactor coolant if the reactor pool retains its integrity or sufficient make up is available following a BDBEE
  - With adequate reactor coolant, they are not reliant on electrical power or active decay heat removal systems to prevent fuel cladding failure
  - Additional assessment needed to determine the resilience of the reactor coolant system integrity to a beyond design basis seismic event

Research and Test Reactor Post-Accident Assessments

RTR Assessment Conclusions (continued)

- Test Reactor greater than 2 MW_t (1)
  - The test reactor can initially remove adequate decay heat to prevent fuel cladding failure via natural convection cooling supplemented by a passive coolant makeup system
  - Following the loss or depletion of make up coolant sources decay heat removal may become inadequate if coolant inventory make up, or electrical power and active decay heat removal systems are not restored
  - Additional assessment needed to determine the resilience of the reactor coolant, electrical power, and active decay heat removal systems to a beyond design basis seismic event

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Questions & Comments

Japan Lessons Learned

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