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SAND2013-7857P

Sandia National Laboratories

Design and engineering requirements for construction and operation

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URF Network Training Course on Engineering for Safe Geological Repository Construction and Operation

Peine, Germany

September, 2013

SAND2013-XXXX (Unclassified Unlimited Release)

Sandia National Laboratories

DBE TEC
DBE TECHNOLOGY GmbH

IAEA
International Atomic Energy Agency

U.S. DEPARTMENT OF ENERGY

NNSA
National Nuclear Security Administration

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Outline

- Development process overview
  - Objectives
  - Disposal concept development
  - Safety case
  - Licensing
  - Institutional
  - Steps in development
- Infrastructure requirements
  - Design process
  - Project management
  - System engineering
  - Quality assurance
  - etc.
- Technical Requirements for Construction & Operation
  - Design
  - Engineering
- Summary

Purpose: To review the overall process of repository program development to the point of readiness for construction and operation, and to provide a framework for subsequent discussions.

Overview: Introduction

- Repositories can be developed in many different ways
- Significant international experience exists, but with key differences
- Repository development is a technical/scientific/engineering challenge (relatively easy) combined with a sociopolitical challenge (relatively difficult)
- The U.S. spent fuel repository development program is "on hold" but many lessons were learned getting to that point

Overview: What is Success?

- Implementer perspective: All waste underground in a safe, sealed repository, by a given time, for a reasonable cost
- Stakeholder perspective: The decisions to develop, operate and close the repository were taken with their participation, with approval and/or consensus.
- These different perspectives meet at the issue of safety, i.e., assurance that the waste will be isolated from the accessible environment.

Every repository development program addresses both actual and perceived risk; and

Public acceptance and stakeholder participation, along with technical excellence, are prerequisites for success

Overview: Selection of Disposal Concept

Disposal Concepts will Typically Reflect:

- Waste inventory
  - Waste characteristics: volume, mass, chemistry, heat generation, radioactivity, etc.
- Siting Information
  - Repository site characteristics and their possible evolution, waste transportation, infrastructure needs, etc.
- Geologic Setting
- Regulatory Framework

Overview: Safety Assessment & Safety Case[1]

- Safety Case

  A safety case is a collection of arguments in support of the long-term safety of the repository. A safety case comprises the findings of safety assessment and a statement of confidence in these findings. It should acknowledge the existence of any unresolved issues and provide guidance for resolving these issues in future development stages.

- Safety Assessment

  Safety assessment is the evaluation of long-term performance, of compliance with acceptance guidelines[2] and of confidence in the safety indicated by the assessment results.

[1]NEA: "Confidence in the Long-term Safety of Deep Geological Repositories: Its Development and Communication" (http://www.oecd-nea.org/rwm/reports/1999/confidence.pdf)

[2]IAEA-TECDOC-1566 Factors Affecting Public and Political Acceptance for the Implementation of Geological Disposal. October, 2007.

Overview: Selected IAEA Safety Requirements (SSR-5) for Repository Program Development[1]

- Requirement 4: Understand and attempt to optimize safety for operations and postclosure, for the available disposal concepts
- Requirement 5: Safety should be ensured by passive means (minimize necessity of future actions)
- Requirement 6: Understand the disposal over sufficiently long time periods to have confidence that safety can be achieved
- Requirement 7: Employ multiple safety functions
  - Multiple physical barriers confidence
  - Defense in depth
  - No single points of failure
  - Both natural and engineered barriers

[1]IAEA Publication 1449: Disposal of Radioactive Waste—Specific Safety Standards. No. SSR-5

Overview: Select SSR-5 Requirements, continued

- Requirement 8: Containment of waste with engineered barriers
  - Use engineered barriers designed to retain integrity for a long enough period of time to enable shorter-lived radionuclides to decay and for the generation of heat to decrease substantially
- Requirement 9: Isolation of waste from accessible environment
  - Provide isolation for time periods commensurate with the hazard to the biosphere and people, and consider the natural evolution of the disposal system and events that disturb the facility
- Requirement 11: Use staged development and evaluate the safety of the disposal system with iterations

Overview: Select SSR-5 Requirements, continued

- Requirement 15: Site characterization
  - Characterize the site to sufficient detail to a specific understanding of the impact on safety of features, events and processes associated with the site and the facility. Understand the site's present condition, its probable natural evolution, possible natural events, and human actions affecting safety
- Requirement 16: Facility design for isolation
  - Design and site facility and its engineered barriers in compatible host formation to provide safety features after closure that complement the natural barriers (i.e., use both engineered and natural barriers in complementary ways to provide defense in depth).

Overview: Select SSR-5 Requirements, continued

- Requirement 12: Use safety case and safety assessment
  - Prepare and update at each step in repository development a sufficiently detailed and comprehensive safety case and supporting safety assessment
- Requirement 13: Safety case and safety assessment scope
  - Address all relevant safety aspects for both operational and postclosure phases (see FEP screening presentation)
- Requirement 14: Safety case and safety assessment documentation
  - Document the safety case and safety assessment with detail and quality to allow independent review, and to support decision making

Overview: Licensing

- Repository licensing is a complex process that lasts throughout the repository program
  - It begins at the initiation of repository development
  - Licensing can be for construction, waste acceptance, closure, termination, or combinations depending on the regulation
  - Construction licensing will typically expect a safety case for the full emplacement inventory (needs to be known at the outset of design)
- The operator/implementer prepares and submits a license application to the regulatory authorities, demonstrating that the repository would be safe and comply with regulatory requirements
- Primary elements of a license application are the safety assessment and the safety case, design information, and supporting detail

Overview: Institutional Issues

- Public attitudes about nuclear energy and nuclear waste place institutions responsible for the repository program, at best, under great scrutiny, and at worst, great distrust or suspicion
- Trust is asymmetric
  - Trust-decreasing events have greater negative impact on public perception (personal or institutional) than trust-increasing events
  - Trust is easily and quickly lost, even by a single event, but once lost is typically difficult to regain—if it can be regained at all
- As noted earlier, repository development is a technical challenge combined with a sociopolitical challenge that stands on trust

Thus there are extraordinary demands placed on the institution and the people in it to perform with integrity and transparency over long time frames

Overview: Repository Development Process Map

- (Prerequisites: legal, institutional, financial, regulatory)

Site selection process/disposal concept development

Site characterization/conceptual design

Application/preliminary design

Licensing

Authorization to construct/final design

Procurement

Construction

Authorization to operate (receive/possess)

Operation

Authorization to close

Closure/monitoring

- Duration: >100 yrs!

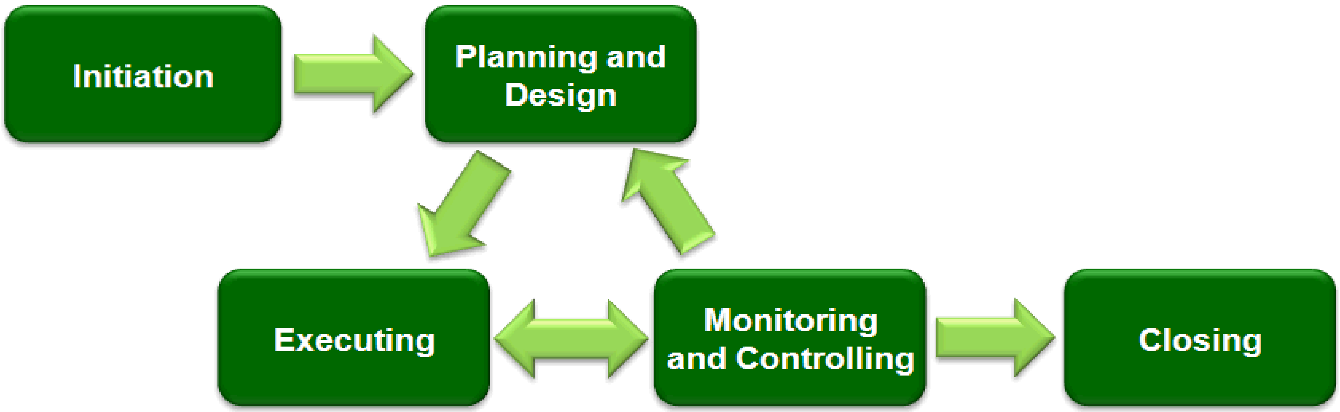
Design Process (e.g., DOE Order 413.3)

Phased "critical" decisions

- CD-0 Approve Mission Needs
- CD-1 Approve Alternative Selection and Cost Range (conceptual design)
- CD-2 Approve Performance Baseline (preliminary/final design)
- CD-3 Approve Start of Construction (procurement and readiness Review)
- CD-4 Approve Start of Operations or Project Completion
- Project Execution Plan

Design and Engineering Requirements
Project Management

- Traditional approach: phases (cone of uncertainty)
- Planning/reporting
- Project control (cost/schedule model)
- Earned value status reporting



Design and Engineering Requirements

System Engineering

Program Components:

- Architecture
- Function analysis
- Work breakdown structure
- Requirements management
- Basis of design
- Interface management
- Configuration management
- Technology readiness
- Risk/opportunity management

Design and Engineering Requirements
Quality Assurance Program (ASME NQA-1-2008)

ASME (American Society of Mechanical Engineers) 2008. *Quality Assurance Requirements for Nuclear Facility Applications*. NQA-1-2008.

NQA-1 "Criteria:"

1. Organization
2. Quality Assurance Program
3. Design Control
4. Procurement Document Control
5. Instructions, Procedures and Drawings
6. Document Control
7. Control of Purchased Material, Equipment and Services
8. Identification and Control of Materials Parts and Services
9. Control of Special Processes
10. Inspection
11. Test Control
12. Control of Measuring and Test Equipment

Design and Engineering Requirements
Quality Assurance Program (ASME NQA-1-2008)

More NQA-1 "Criteria:"

13. Handling, Storage and Shipping
14. Inspection, Test and Operating Status
15. Nonconforming Items
16. Corrective Action
17. Quality Assurance Records
18. Audits

Part 3 (Supplemental)

- Data qualification
- Scientific investigation
- Software development and use

Graded QA

Design and Engineering Requirements
Roles and Responsibilities

- R2A2 (roles, responsibilities, authority, accountability)
- Define implementing and regulating institutions (think multi-national)[1]
- Financing (waste producers?)
  - Example: U.S. Nuclear Waste Fund ($0.001/kW-hr at retail)
- Contractural relationship with waste generators
  - Example: U.S. "Standard Contract" 1980's (contract law)
- Establish regulations (acknowledge/use international input)

[1]IAEA-TECDOC-1413 *Developing multinational radioactive waste repositories: Infrastructural framework and scenarios of cooperation*. October, 2004.

Design and Engineering Requirements
Roles and Responsibilities, continued

- **Government Responsibilities**
  - Establishes objectives, timeline, decision points, allocates responsibilities (including independent functions), and financing
- **Regulatory Body Responsibilities**
  - Establishes regulatory requirements (i.e., the safety objectives, compliance metrics, etc.) and procedures for demonstrating compliance and other licensing conditions
- **Operator/Implementer Responsibilities**
  - Responsible for the disposal facility safety
  - Implements site selection, characterization, facility design, etc.
  - Assembles the safety assessments and safety case, license application
  - Works in accordance with national strategy, in compliance with regulatory requirements and within the legal regulatory framework
  - Maintains management systems for quality assurance, quality control, information management, workforce training, etc.

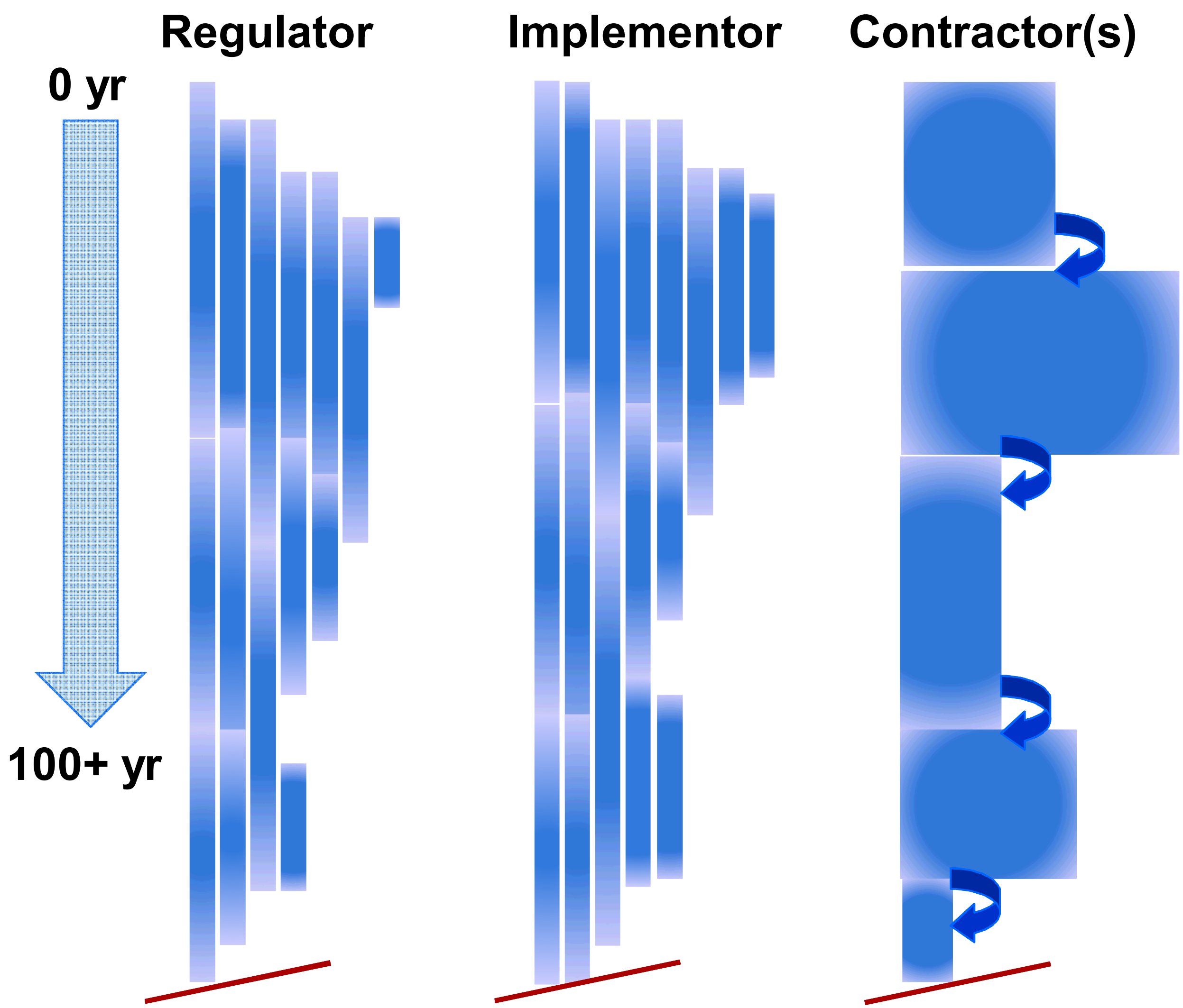
Staffing and Culture

- "Right size" organization (phased, commensurate with importance)
- Quality assurance/nuclear safety culture
- Technical/managerial excellence
- Employee relations (e.g., DPO) and succession (>100 yr = ≥ 4 generations)
- Manage duration/longevity (e.g., contractors)

Longevity/Duration Planning

Phased actions:
Hiring
Retention
Succession
Transition
Completion

Objectives:
Project execution
Safety
Excellence
Stakeholder acceptance



Technical Requirements for Repository Construction

- **Design Requirements, System Level**
  - Disposal mission
  - Regulatory (e.g., license application content, performance objectives)
  - Waste acceptance (type, source, rate, packaging, etc.)
  - Facility and worker safety
  - Retrievability
  - Site boundaries
  - Host formation
  - Disposal concept

Technical Requirements for Repository Construction & Operation, continued

- **Surface Facility Design Requirements, Subsystem Level, Functional and Performance**
  - Thermal/radiological limits
    - Fuel temperature
    - Exposure to air/moisture
  - Shielding requirements
  - Receiving subsystem
  - Handling (e.g., wet, dry)
  - Lifting/hoisting
  - Dewatering
  - Transport
  - Storage/aging
  - Packaging (incl. closure methods and treatments)
  - Ground motion, faulting, and other hazard requirements
  - Inspections
  - Balance-of-plant (roads, utilities, structures, backups, etc.)

Technical Requirements for Repository Construction & Operation, continued

- **Subsurface Facility Design Requirements, Subsystem Level, Functional and Performance**
  - Geologic setting (layers, zones, faults, fractures, etc.)
  - Dimensions and layout
  - Thermal requirements
  - Support features (ground support, invert, etc.)
  - Operational lifetime (monitoring, ventilation)
  - Emplacement/deposition subsystems
  - Engineered barriers (buffer, backfill, shields, etc.)
  - Drainage and pumping
  - Ventilation
  - Plugs, seals and other closure features

BSC (Bechtel-SAIC Co.) 2008. *Basis of Design for the TAD Canister-Based Repository Design Concept*. 000-3DR-MGRO-00300-000-003.

Technical Requirements for Repository Construction & Operation, continued

- **Engineering Requirements**
  - Geological constraints
  - Geologic unit penetrations
  - Temperature limits
  - Host medium exposure to air, etc.
  - Engineered materials
  - Engineered barriers
  - Material composition and treatment
  - Testing specifications
  - Introduced materials control
    - Water (quantity and/or composition)
    - Organics (e.g., diesel exhaust, lubricating oil)
    - Dissimilar metals, etc.
  - Reliability
  - Preclosure safety approach

Technical Requirements for Repository Construction & Operation, continued

- **Engineering Requirements, continued**
  - Limits on engineered barrier "early failure" conditions
  - Performance monitoring and confirmation
    - Program support
    - Non-interference
  - Natural hazard monitoring
    - Seismic
    - Faulting
    - Slope stability
  - Groundwater monitoring
  - Applicable standards
  - Analysis/calculation controls
    - Documentation/drawings
    - Checking/approval
  - Certification/training
  - Conformance verification

Summary

- Scope
  - Many technical disciplines, multiple institutions
- Stakeholders
  - Public interest groups
  - Social and religious organizations
  - Trade groups and unions
  - Industry
  - Nuclear waste generators
  - Implementing organization
  - Regulatory agencies
  - Other external reviewers
  - Financial support
  - Government
  - International organizations
  - Foreign governments
- Personnel
  - Thousands involved over ≥4 generations
- Duration
  - ≥100 years
- Cost
  - €200,000 to €1M per MTHM
  - Engineered vs. natural barriers
  - Waste package size
  - Economy of scale

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