U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

NRC Perspectives on DOE's Facility Layout and Operations

Mahendra Shah
United States Regulatory Commission

NRC/DOE Technical Exchange on Facility Layout and Operations
May 30, 2007

Outline

- Background
- Purpose
- Regulatory requirements
- Expectations for meeting
- Summary

Background

- Appendix 7 Meeting – March 28-29, 2007
  - Facility layout and operations for Canister Receipt and Closure Facility (CRCF) and Wet Handling Facility (WHF)
  - CRCF seismic analysis and design
  - Preclosure criticality

Regulatory Requirements

- 10 CFR 63.21 Content of application.
- 10 CFR 63.111 Performance objectives for the geologic repository operations area through permanent closure.
- 10 CFR 63.112 Requirements for preclosure safety analysis (PCSA) of the geologic repository operations area.

Staff Guidance

- NUREG-1804, Revision 2, Yucca Mountain Review Plan
- HLWRS-ISG-01 Review Methodology for Seismically Initiated Event Sequences
- HLWRS-ISG-02 Preclosure Safety Analysis – Level of Information and Reliability Estimation
- Draft HLWRS-ISG-04 Preclosure Safety Analysis – Human Reliability Analysis

Expectations for Meeting

- Discuss the following for CRCF and WHF
  - Facility layout and operations
  - Mechanical handling and material flow
  - Seismic analysis of CRCF

Expectations (continued)

- Clear description of the extent to which various seismic analyses are expected to be used to demonstrate compliance with 10 CFR Part 63
  - Lumped-mass multi-stick model
  - Finite-element analysis

Expectations (continued)

- Discussion of the methodology for seismic analyses including
  - Soil-structure interaction
  - Potential non-linear behavior at high seismic demand
  - System parameter assumptions (e.g., damping)
  - Uncertainties in parameters
  - Development of fragility curves

Status of DOE's PCSA

- Discuss preclosure safety analyses approach for CRCF and WHF, including
  - Identification of hazards, potential initiating events, and event sequences
  - Event sequences frequencies and categorization
  - Identification of structures, systems, and components (SSCs) important to safety (ITS)
  - Design bases and the design criteria (codes and standards)
  - Performance of SSCs ITS to comply with 10 CFR Part 63

Summary

- Regulatory requirements for the CRCF and WHF layouts and operations are in 10 CFR sections 63.21, 63.111, and 63.112

- For the CRCF and WHF, NRC expects DOE to discuss
  - Facility layout and operations for mechanical handling and material flow, to identify potential hazards, and event sequences
  - Seismic analysis of CRCF
  - Seismic analyses and performance demonstration
  - Preclosure safety analysis approach

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

NRC/DOE Technical Exchange On Layout and Operations

May 30, 2007
Las Vegas, NV

AGENDA

NRC/DOE TECHNICAL EXCHANGE ON LAYOUT & OPERATIONS

May 30, 2007
8:00 AM – 5:00 PM (PT)
11:00 AM – 8:00 PM (ET)

NRC Las Vegas Hearing Center
Building No. 1
3250 Pepper Lane
Las Vegas, Nevada 89120

And via videoconferencing to:

U. S. Nuclear Regulatory Commission
T-7A1
11545 Rockville Pike
Rockville, MD 20852

Center for Nuclear Waste Regulatory Analyses
Executive Room, Room A-237
6220 Culebra Road
San Antonio, TX 78238

INTERESTED PARTIES MAY PARTICIPATE VIA TELECON BY CALLING
1-800-638-8081, Passcode 8061# or 301-231-5539, Passcode 8061#

8:00 AM	**Introductions**	**NRC/DOE**
8:10 AM	**Opening Remarks**	**NRC/DOE (M. Williams)**
8:20 AM	**NRC Key Messages**	**NRC**
8:50 AM	**Introduction to Revised Program Approach**	**DOE (P. Harrington)**
9:10 AM	**Site Layout Waste Handling Overview**	**DOE/BSC (R. Slovic)**
10:15 AM	**Break**	**All**
10:30 AM	**Canister Receipt and Closure Facility (CRCF) and Wet Handling Facility (WHF) Layout and Operations**	**DOE/BSC (R. Slovic & M. Frank)**
11:30 AM	**Lunch**	**All**
1:00 PM	**Canister Receipt and Closure Facility (CRCF) and Wet Handling Facility (WHF) Layout and Operations (continued)**	**DOE/BSC (R. Slovic & M. Frank)**
2:00 PM	**Waste Handling Control Philosophy**	**DOE/BSC (S. Schmude & M. Frank)**
2:45 PM	**Break**	**All**
3:00 PM	**Seismic Design Considerations**	**DOE/BSC (M. Denlinger)**
4:00 PM	**Public Comments**	**All**
4:15 PM	**Break/Caucus**	**All**
4:45 PM	**Summary Discussion/Closing Remarks**	**NRC/DOE**
5:00 PM	**Adjourn**	**All**

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

Opening Remarks

Presented to:
NRC/DOE Technical Exchange on Layout and Operations

Presented by:
Mark H. Williams
Director, Regulatory Authority Office
Office of Civilian Radioactive Waste Management
Department of Energy

May 30, 2007
Las Vegas, Nevada

Opening Remarks

- **Discussions today will focus on the status of the design as we progress towards submittal of the LA**
- **LA will be submitted no later than June 2008**
- **Level of design in LA will contain sufficient information for NRC safety evaluation**

NRC / DOE Interactions

- **Scheduled**
  - **Emergency Planning, Appendix 7 Meeting, May 24 (completed)**
  - **Human Reliability Analysis, Appendix 7 Meeting, (telecon) June 5**
  - **Quarterly Management Meeting, June 14**
  - **Quality Assurance, Technical Exchange, June 26**
  - **Physical Protection, Material Control and Accountability, and Emergency Planning, Technical Exchange, June 28**
  - **Colloids and In-package chemistry, Appendix 7 Meeting, July 10**
  - **Postclosure subjects, Technical Exchange, September 27**

NRC / DOE Interactions

- **In Planning (dates TBD):**
  - **Near field environment, Appendix 7**
  - **Multiscale thermohydologic models, Appendix 7**
  - **Unsaturated Zone Testing, Appendix 7**
  - **Preclosure Safety Analysis:**
    - **Hazard identification, event sequences development and categorization**
    - **Identification of important-to-safety structures, systems, and components**
    - **Source term and consequences**
  - **Infiltration**
  - **Drift Degradation**

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

Introduction to Revised Program Approach

Presented to:
NRC/DOE Technical Exchange on Layout and Operations

Presented by:
Paul G. Harrington
Director, Office of the Chief Engineer
Office of Civilian Radioactive Waste Management
Department of Energy

May 30, 2007
Las Vegas, Nevada

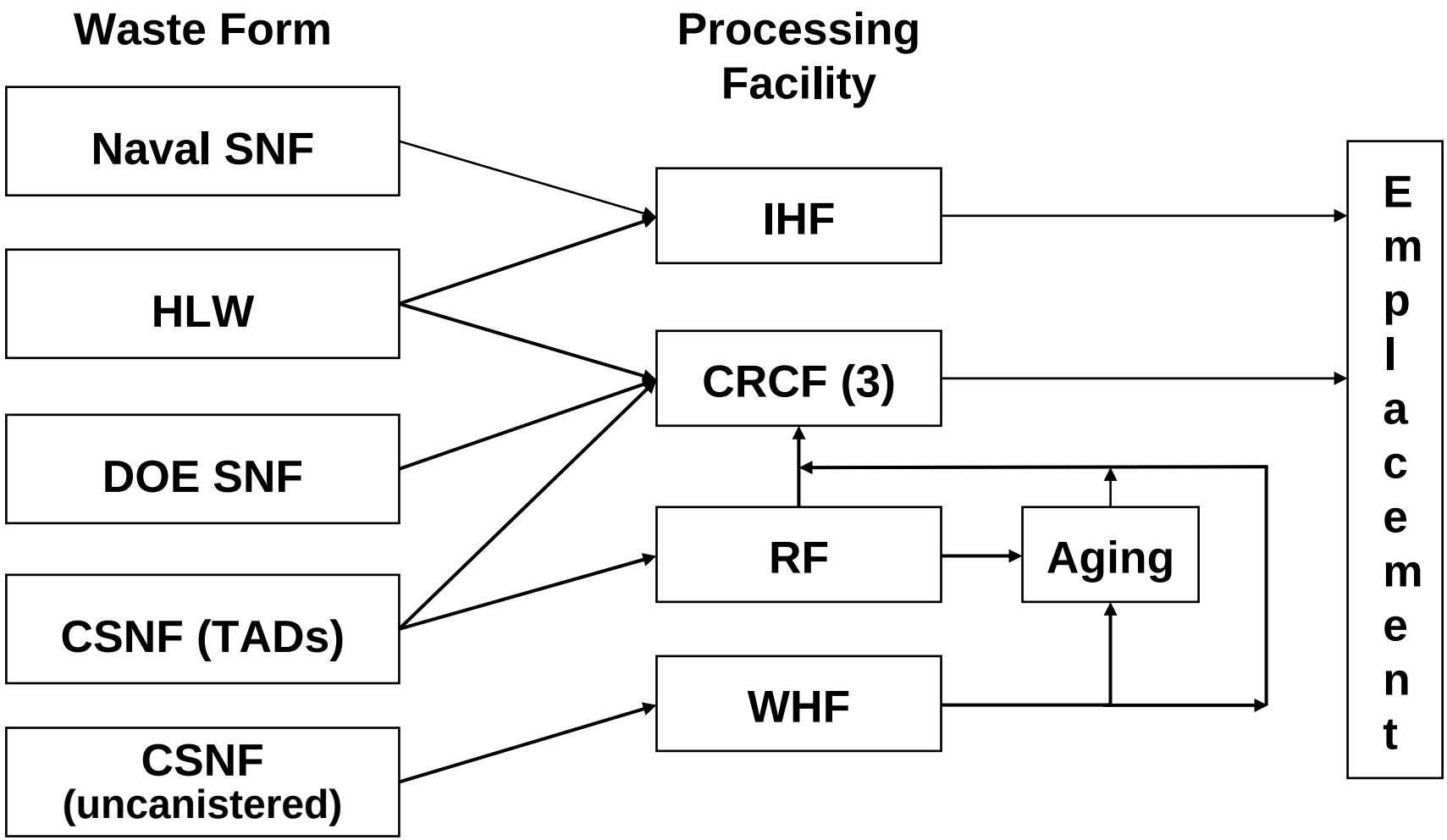
Introduction

- **Today's discussion will address:**
  - **The progress of design and the Preclosure Safety Analysis (PCSA) towards submittal of the License Application (LA)**
  - **Site and waste handling overview**
  - **The layout and operation of waste handling surface facilities and the interface between Engineering and PCSA**
  - **Waste handling control philosophy**
  - **Seismic design considerations**

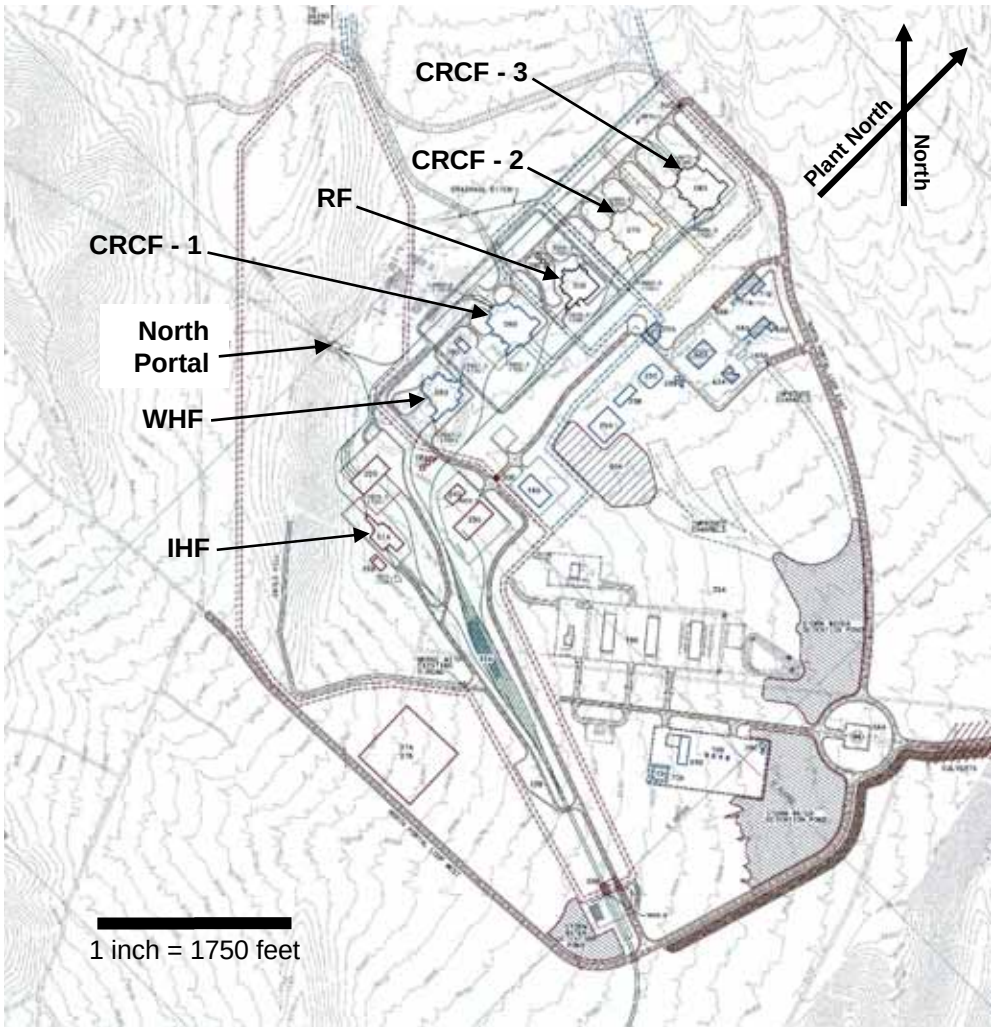
Design and PCSA Schedules

- **PCSA products are being developed to support the LA:**
  - **Design products will be completed November 2007**
  - **PCSA products (except seismic) will be completed November 2007**
  - **Seismic safety assessments will be completed February 2008**
- **Today's discussions reflect the integrated approach between Engineering and the PCSA group to achieve these schedules**
- **Important-to-Safety (ITS) vs. non-ITS**

Waste Form Processing Overview



Site Layout


CRCF - 3
CRCF - 2
RF
CRCF - 1
North Portal
WHF
IHF
Plant North
North
1 inch = 1750 feet

Presentations

- **Presentations:**
  - **Overview of site layout**
  - **Layout of the Canister Receipt and Closure Facility (CRCF) and Waste Handling Operations**
  - **Layout of Wet Handling Facility (WHF) and Waste Handling Operations**
  - **Waste Handling Control Philosophy**
  - **Seismic Design Considerations**

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

Site Layout and Waste Handling Overview

Presented to:
NRC/DOE Technical Exchange on Layout and Operations

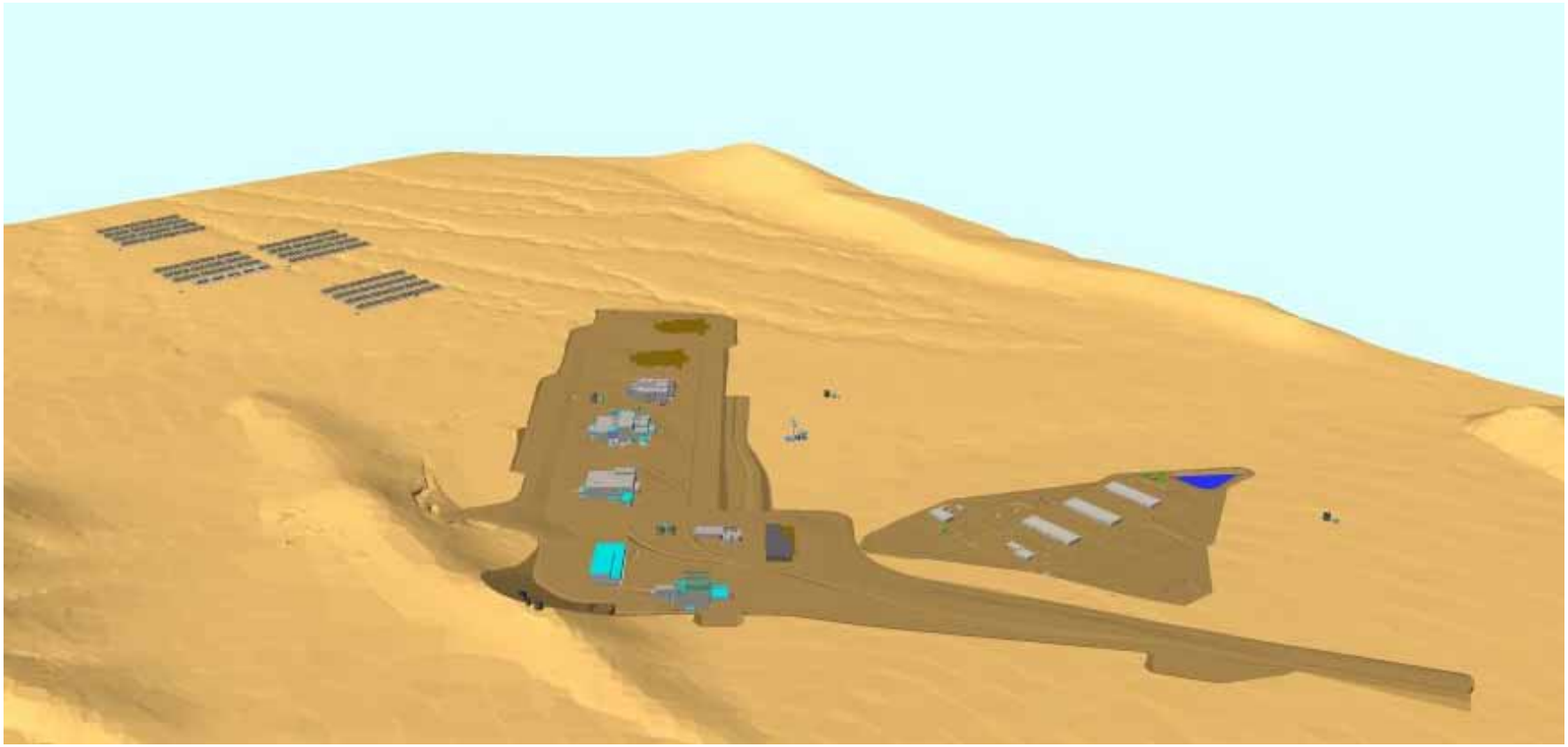
Presented by:
Robert C. Slovic
Senior Project Engineer
Bechtel SAIC Company, LLC

May 30, 2007
Las Vegas, Nevada

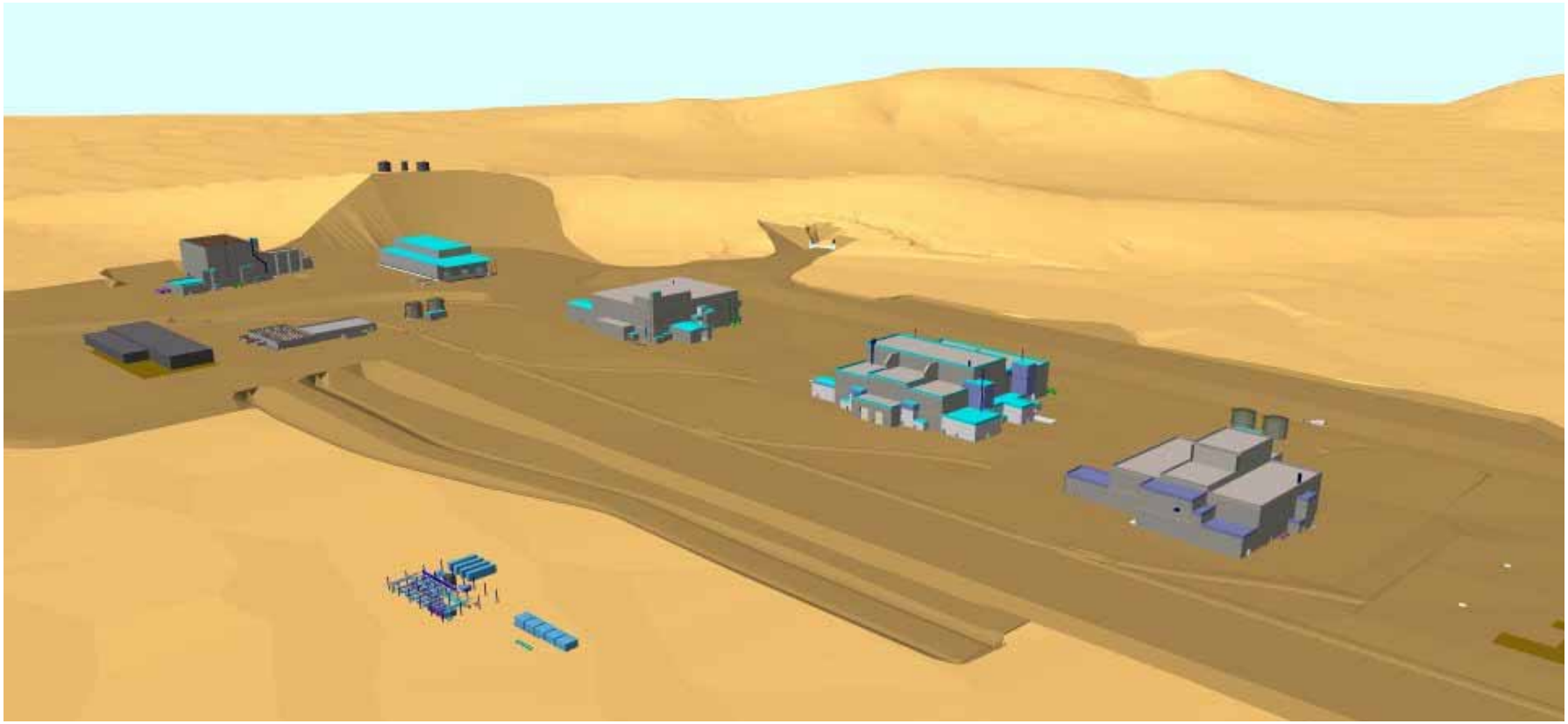
Acronyms

- **CDR** — **Conceptual Design Report**
- **CRCF** — **Canister Receipt and Closure Facility**
- **CSNF** — **Commercial Spent Nuclear Fuel**
- **GROA** — **Geologic Repository Operations Area**
- **HLW** — **High Level Waste**
- **IHF** — **Initial Handling Facility**
- **ITS** — **Important to Safety**
- **PCSA** — **Preclosure Safety Analysis**
- **PHA** — **Preliminary Hazards Analysis**
- **RF** — **Receipt Facility**
- **TAD** — **Transportation, Aging, and Disposal (Canister)**
- **TEV** — **Transport and Emplacement Vehicle**
- **WHF** — **Wet Handling Facility**

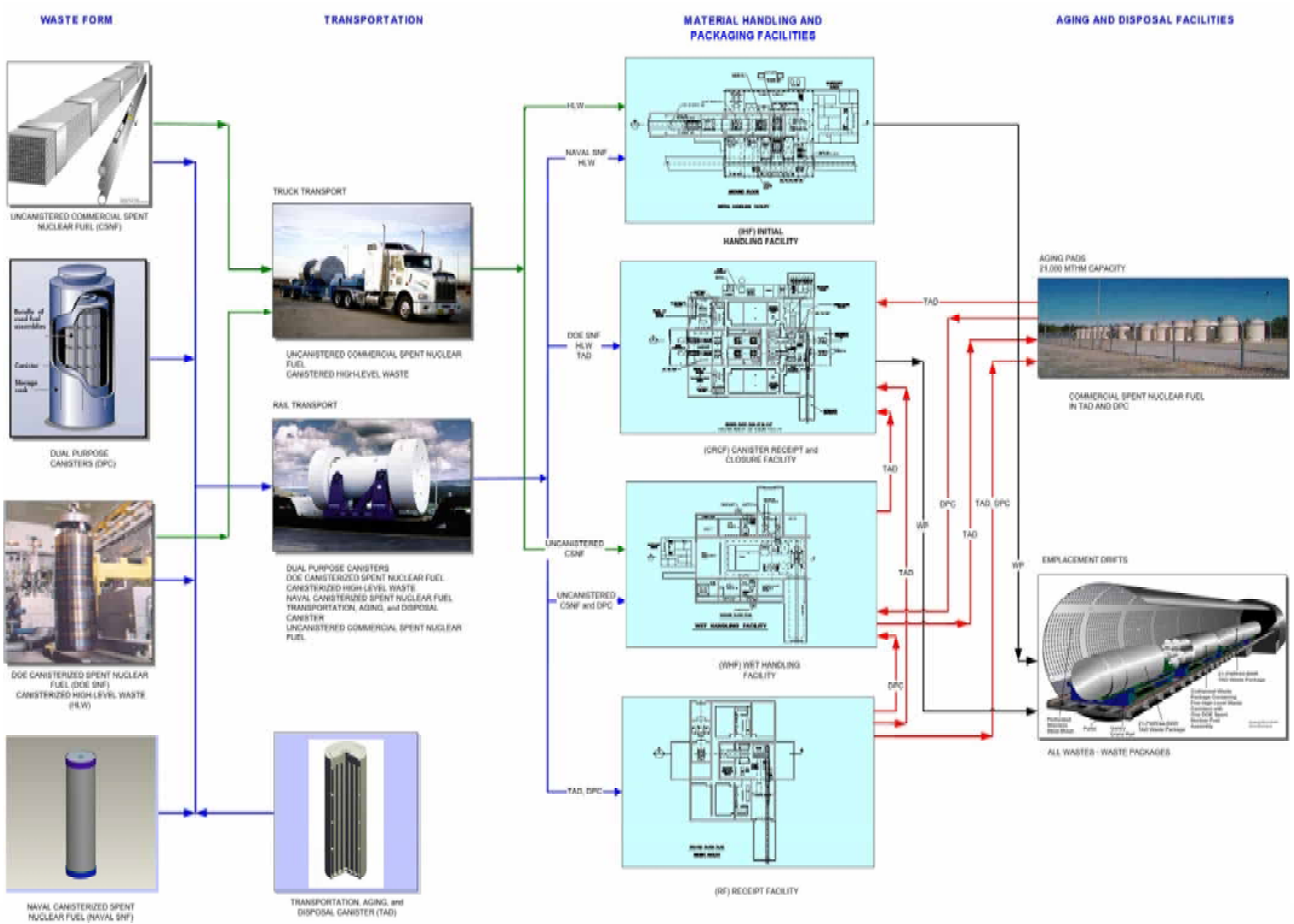
Surface Layout Overview



Surface Facilities



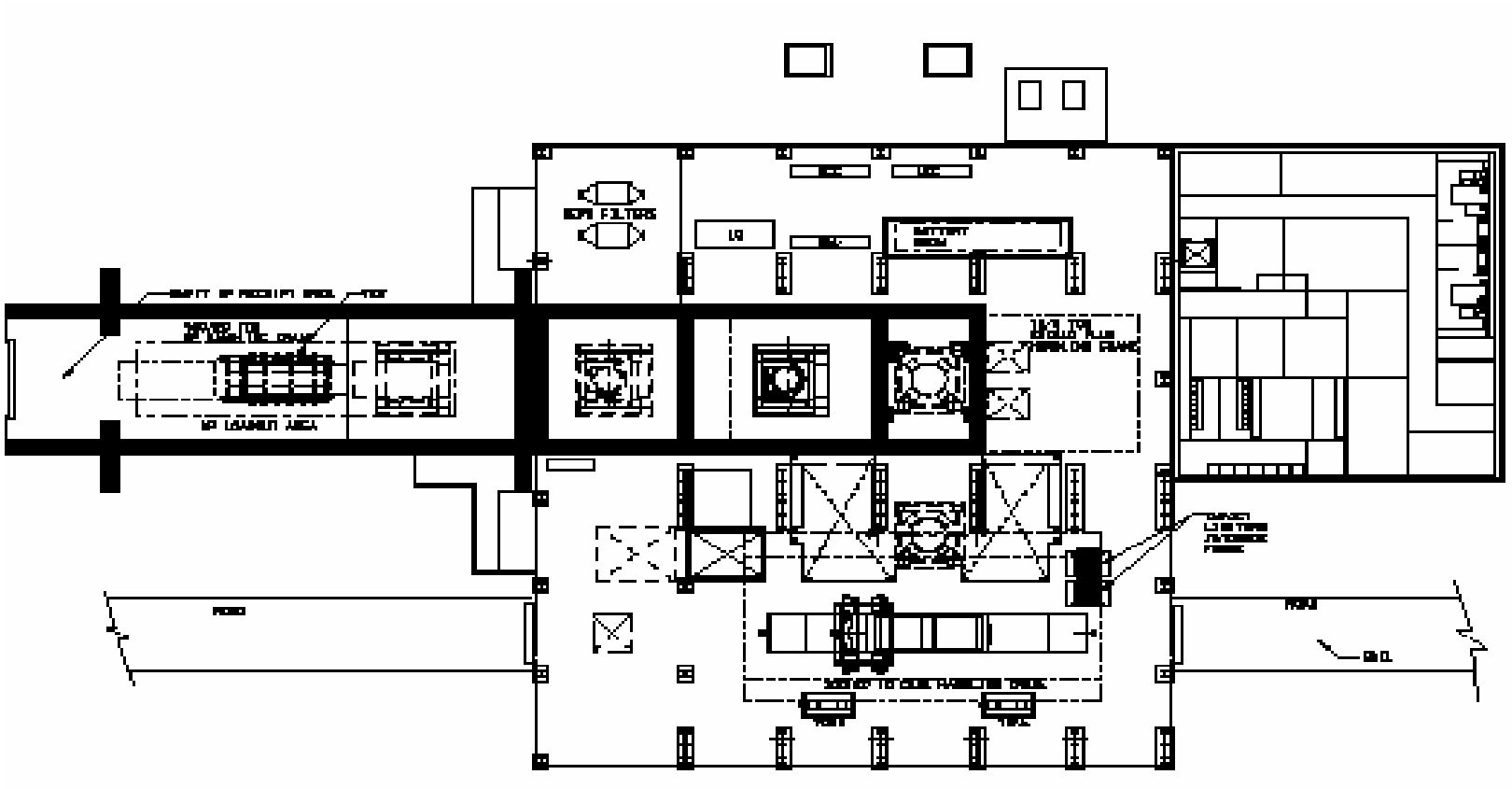
Concept of Operations



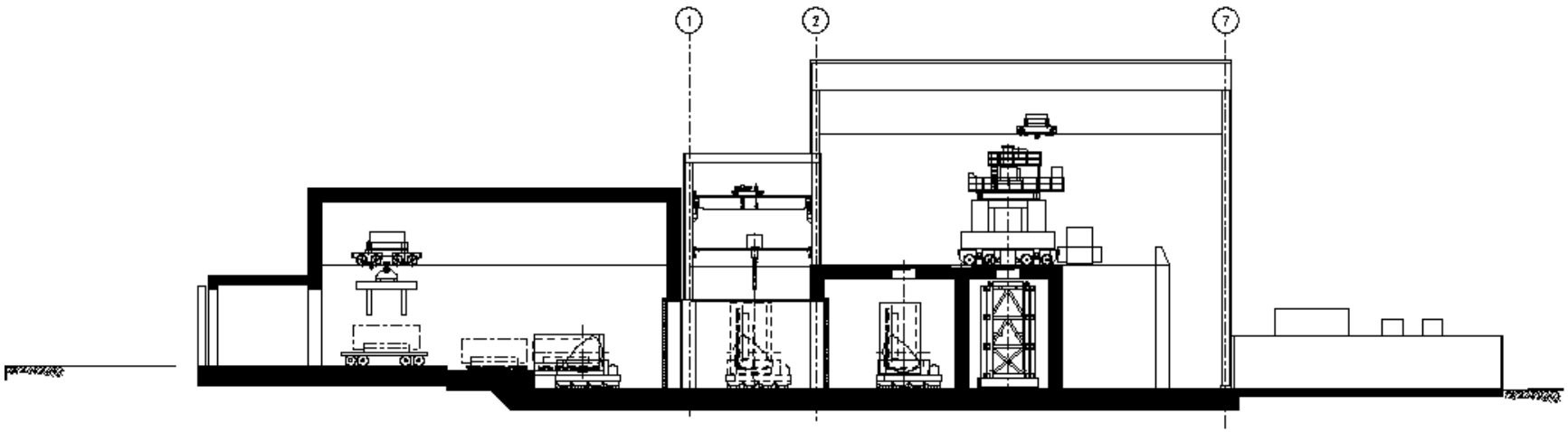
Waste Form Handling and Facility Features

Waste Forms		Facilities			
		Initial Handling Facility (IHF)	Canister Receipt and Closure Facility (CRCF)	Wet Handling Facility (WHF)	Receipt Facility (RF)
HLW	Canister	X	X	-	-
NAVAL SNF	Canister	X		-	-
DOE SNF	Canister	-	X	-	-
CSNF	Uncanistered	-		X	-
CSNF	TAD	-	X	X	X
Features					
WP Loading & Closure		X	X		
ITS Seismic Structure		X	X	X	X
ITS Mechanical handling		X	X	X	X
ITS Confinement		-	X	X	X
ITS HEPA Exhaust		-	X	X	X
ITS Emergency Power		-	X	X	X
Rework / Repair Capability		Dry	Dry	Wet and Dry	Dry

Initial Handling Facility

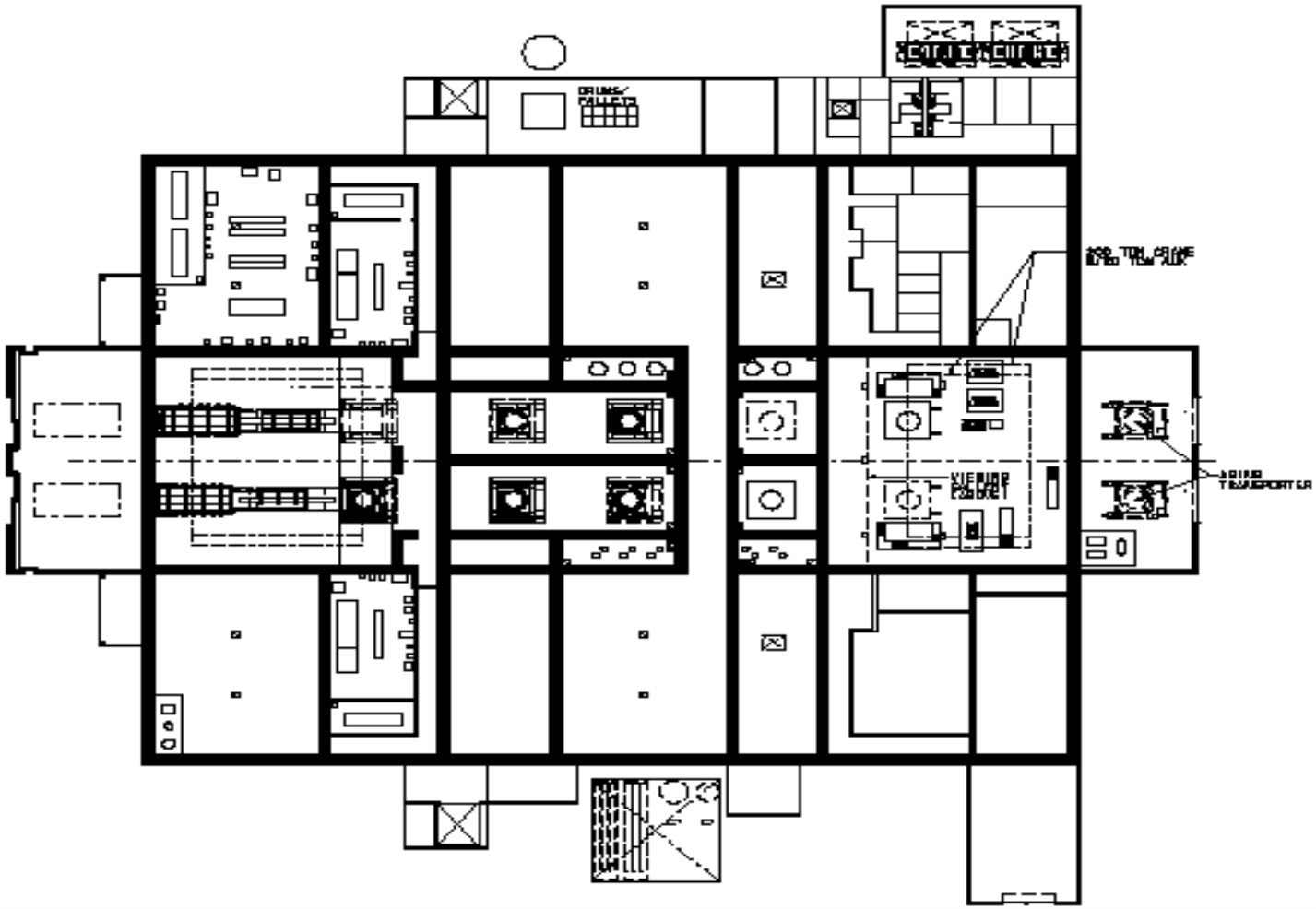


Initial Handling Facility

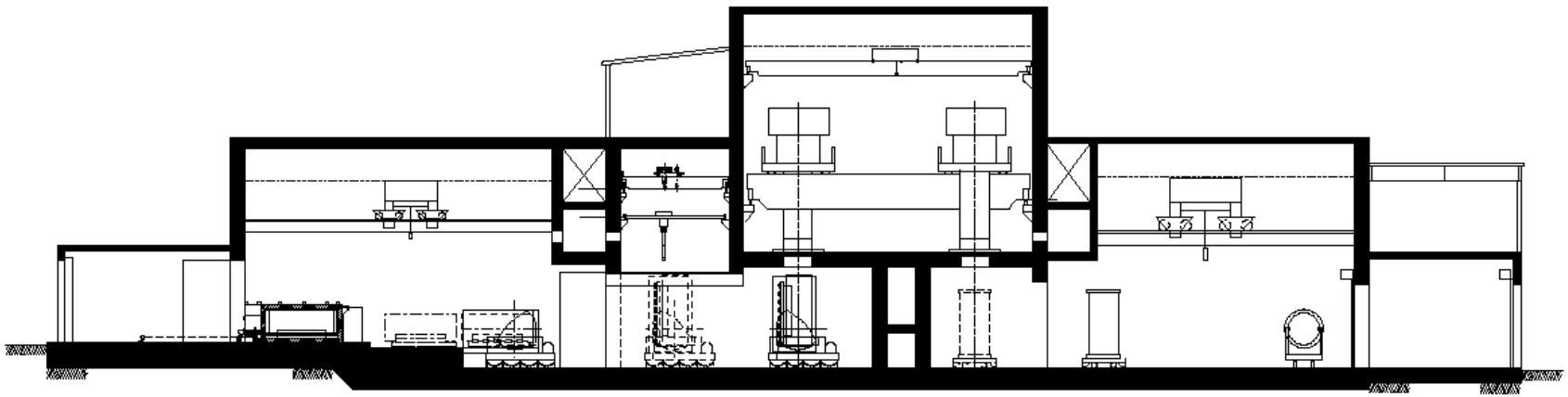


Wet Handling Facility

Canister Receipt and Closure Facility



Canister Receipt and Closure Facility

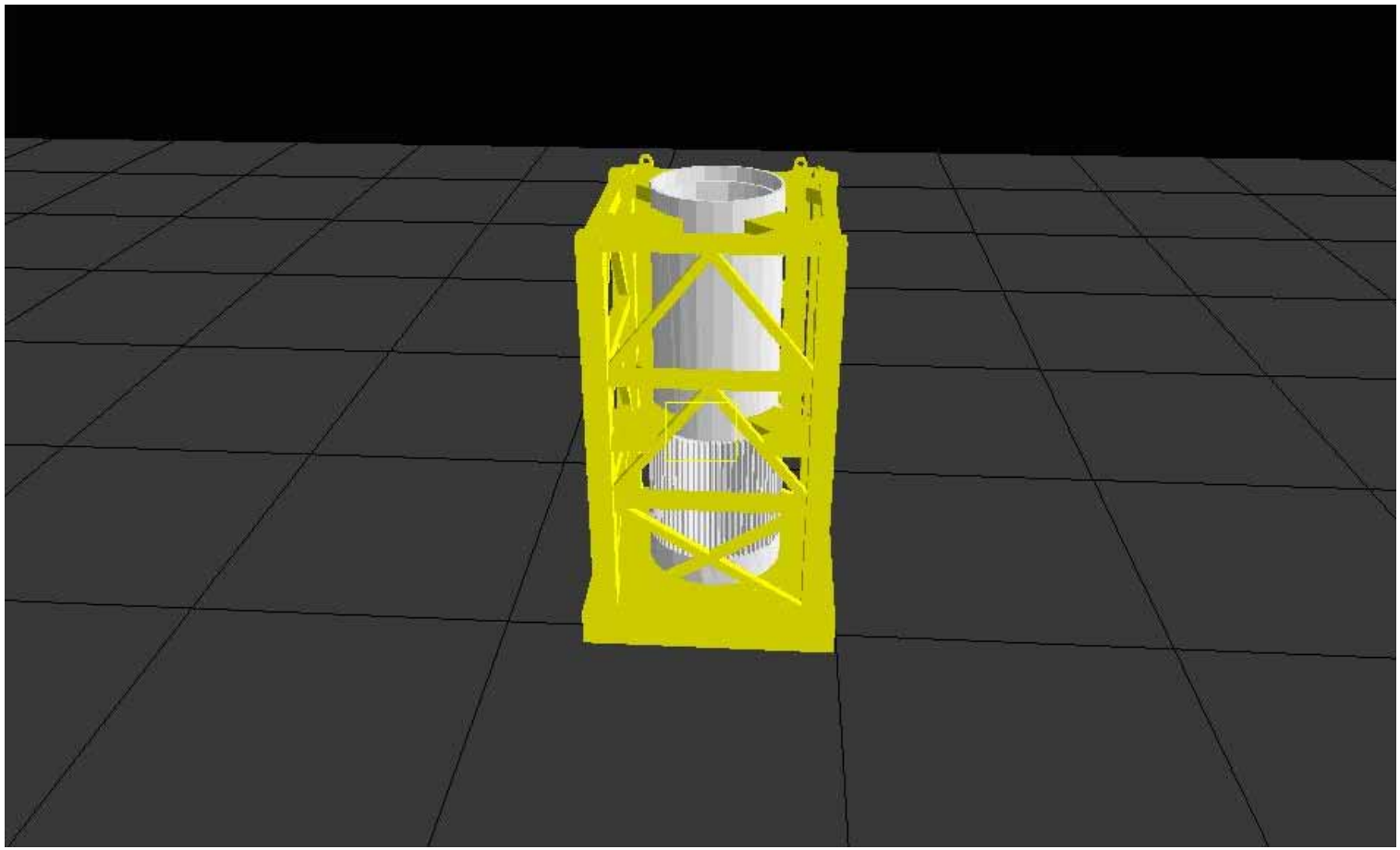


Receipt Facility

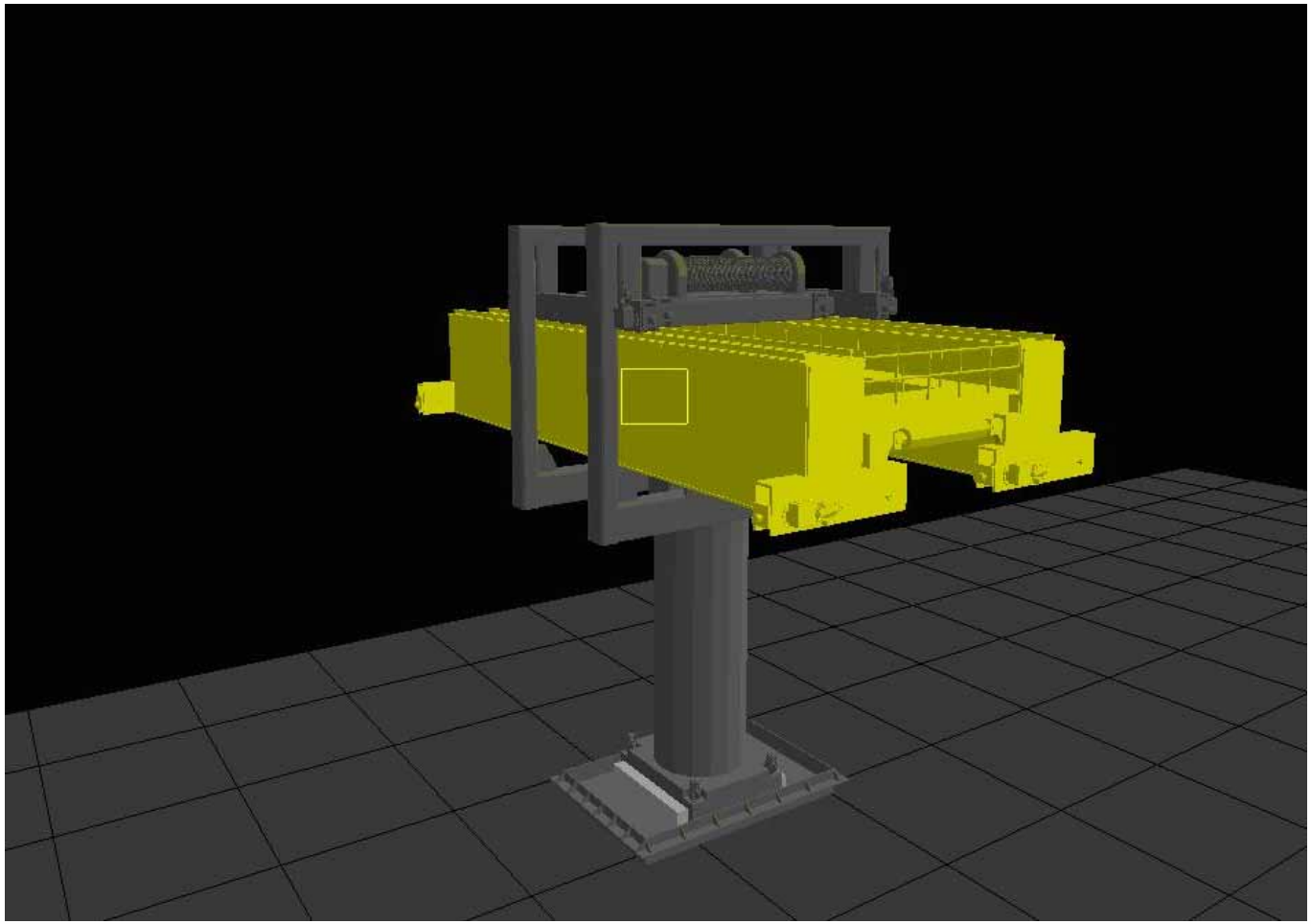
Commonality of Mechanical Handling Equipment

	Facilities			
	Initial Handling Facility (IHF)	Canister Receipt and Closure Facility (CRCF)	Wet Handling Facility (WHF)	Receipt Facility (RF)
Cask Handling Crane	X	X	X	X
Cask Transfer Trolley	X	X	X	X
Canister Transfer Machine	X	X	X	X
Waste PackageTransfer Trolley	X	X		
Transport and Emplacement Vehicle	X	X		
Site Transporter		X	X	X
Spent Fuel Transfer Machine			X	
TAD Closure Equipment			X	
DPC Cutting Equiupment			X	

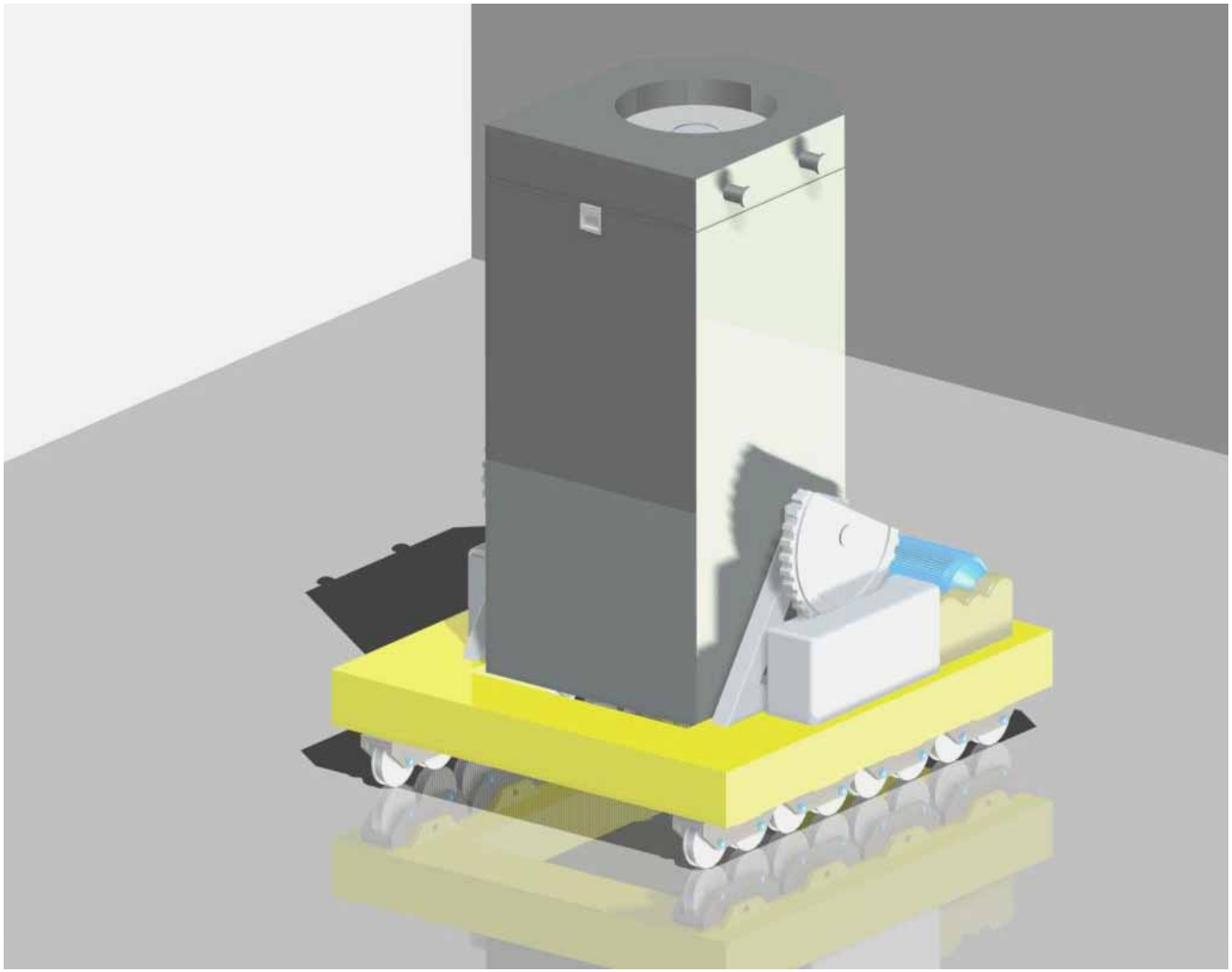
Cask Transfer Trolley



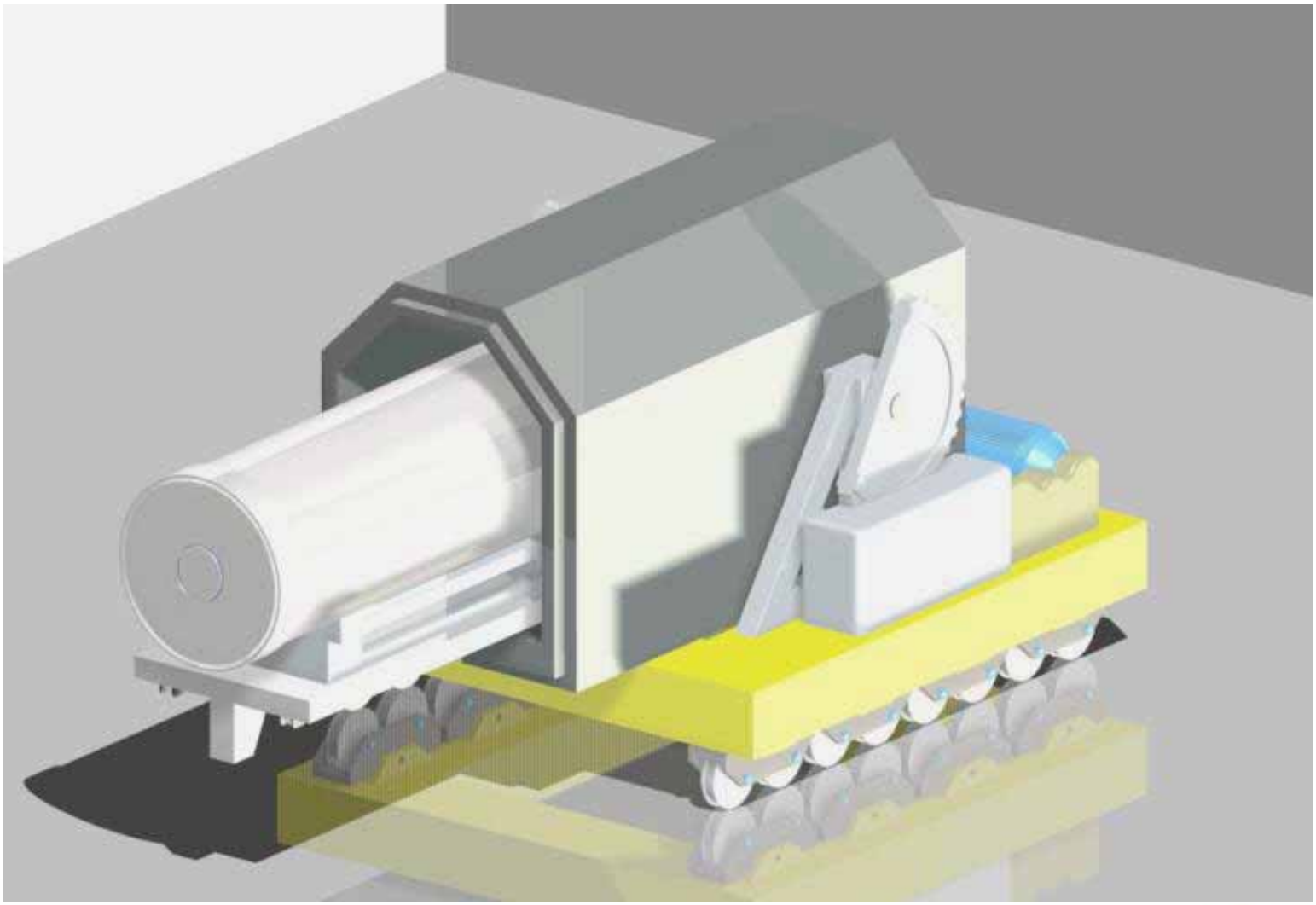
Canister Transfer Machine



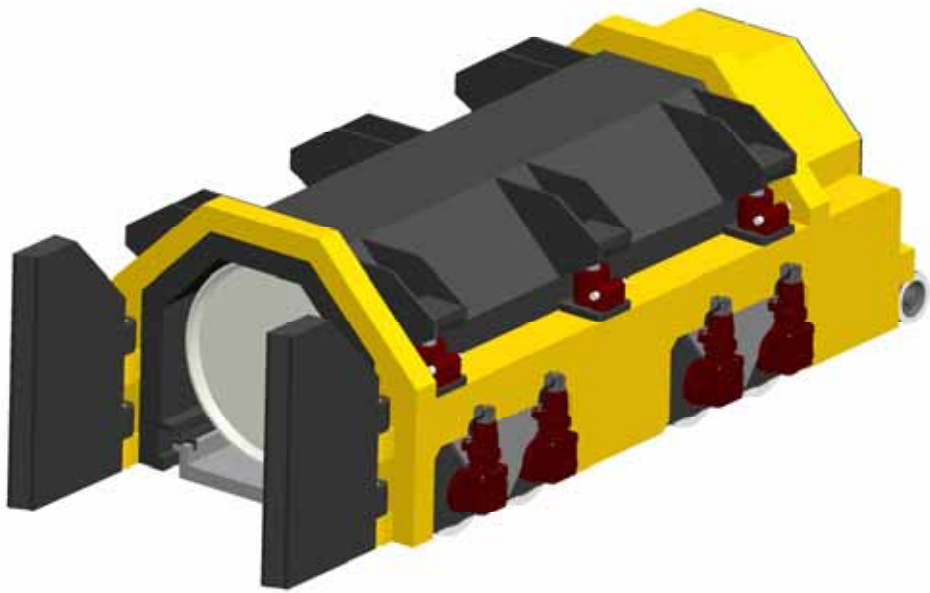
Waste Package Trolley - Vertical



Waste Package Trolley - Horizontal



Transport and Emplacement Vehicle



Mechanical Handling Equipment Principal Design Codes

- **Cask handling cranes, site transporters, spent fuel transfer machine, canister closure equipment and DPC cutting equipment are currently in use at commercial nuclear plants**
- **Will be designed to consensus codes and standards for the type of equipment:**
  - **For example, the cask handling cranes and spent fuel transfer machine will be designed to ASME NOG-1**

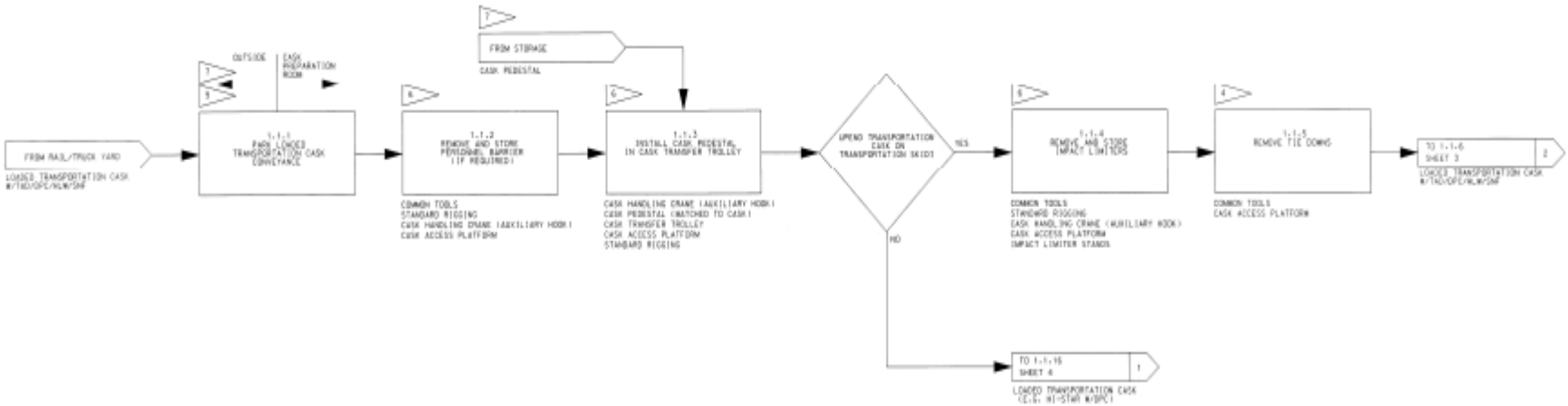
Mechanical Handling Equipment Principal Design Codes (cont.)

- **The cask transfer trolley and the waste package transfer trolley do not have a consensus design code and will be designed to the applicable portions of ASME NOG-1 and AISC *Manual of Steel Construction***
- **The canister transfer machine is essentially a crane and will be designed to ASME NOG-1**
- **The transport and emplacement vehicle does not have a consensus design code and will be designed to the applicable portions of ASME NOG-1 and AISC *Manual of Steel Construction***

Design Process for ITS Mechanical Handling Equipment

- The CDR (part of CD-1) identifies basic handling concepts and arrangements of nuclear facilities
- The PHA (part of CD-1) identifies functions of structures, systems and components that will be relied upon to prevent or mitigate event sequences
- A conceptual design for mechanical handling equipment is developed concurrent with an on-going PCSA assessment of the evolving design
- Block flow diagrams are developed to depict the mechanical handling process

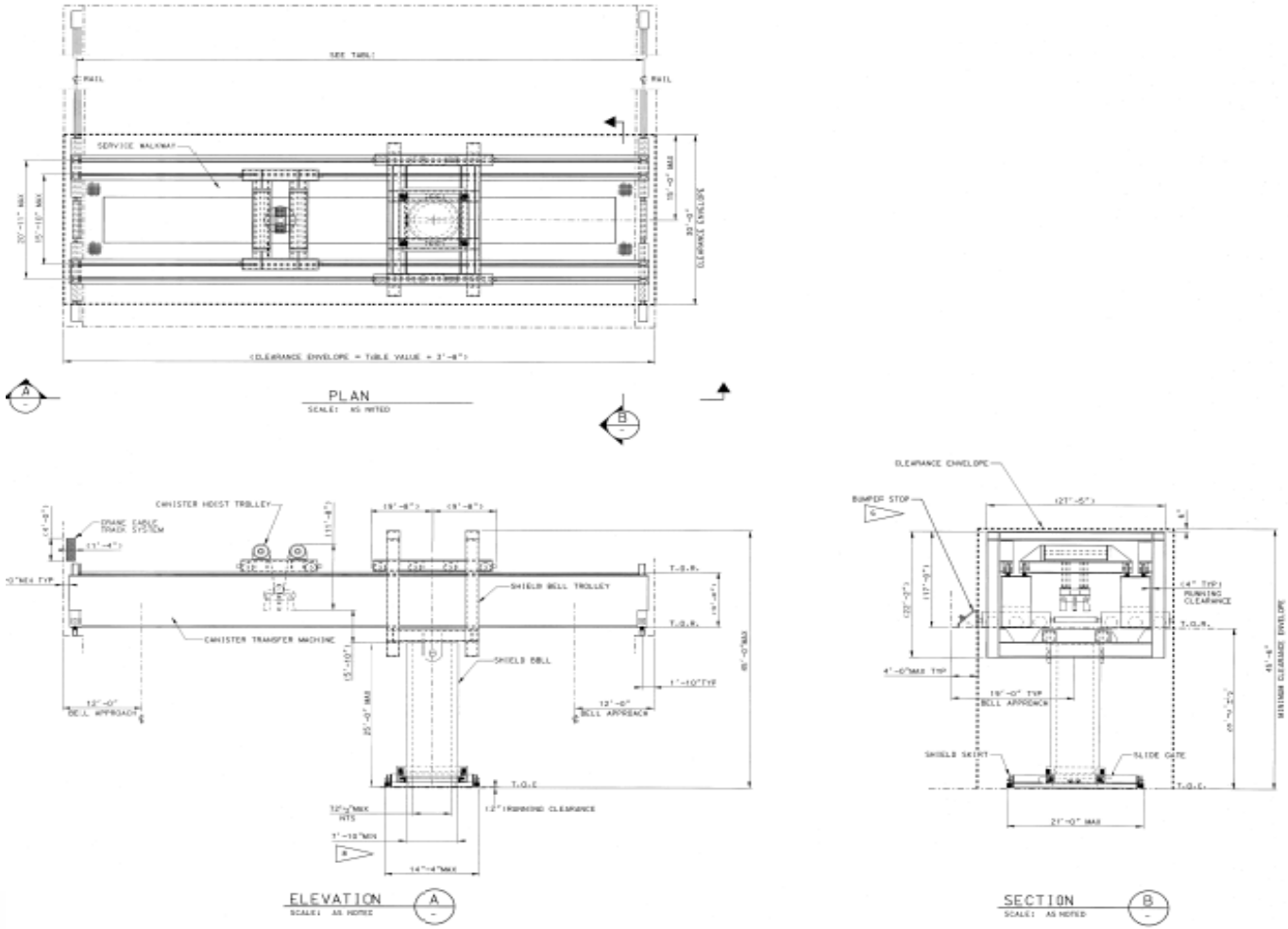
Portion of the CRCF Block Flow Diagram



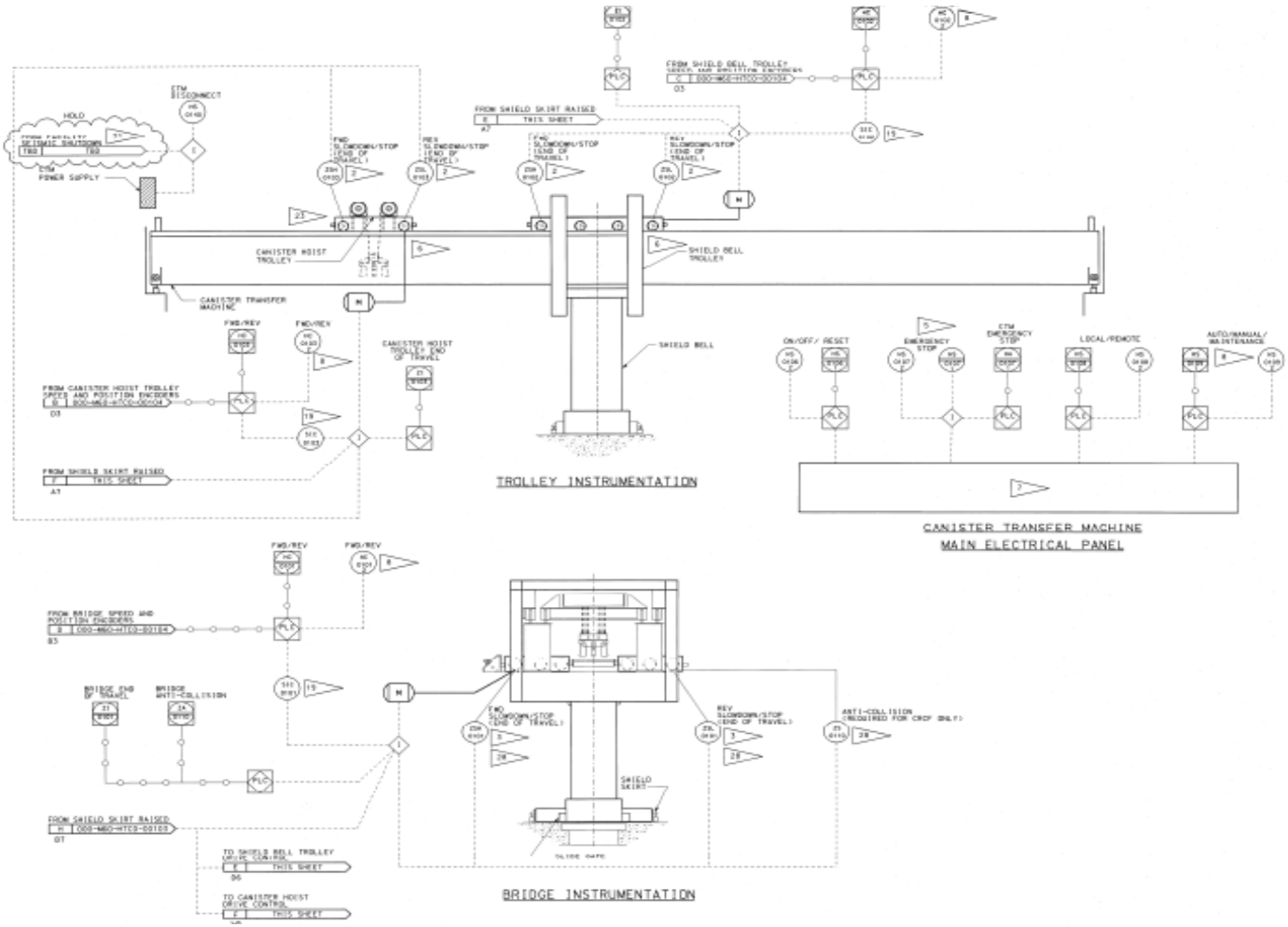
Design Process for ITS Mechanical Handling Equipment

- **Mechanical equipment envelope drawings are developed to bound the expected size of the equipment for utilization in the 3-D model development and to identify interface requirements**
- **Process and instrumentation diagrams are developed to identify the controls, instrumentation, and interlocks for the equipment**

Canister Transfer Machine Mechanical Equipment Envelope



Canister Transfer Machine Process and Instrument Diagram



Design Process for ITS Mechanical Handling Equipment

- **A mechanical handling design report is developed for the conceptual design to demonstrate that the equipment can be expected to perform the functions relied upon by the PCSA**
- **Fragility analyses and fault trees are developed for the conceptual design to demonstrate the expected reliability of the equipment meets the reliability used in the PCSA**
- **A performance specification is prepared to procure the equipment.**
- **The selected vendor prepares the detail design of the equipment, including analyses, to confirm the equipment is bounded by the parameters used in the PCSA**

Design and PCSA Status

- **A total of 1,318 products are being developed by Design and PCSA to support the 71 sections of the License Application**
- **More than 50 percent of the design and PCSA products have been completed**
- **Design and PCSA products (except as noted below) will be completed by November 2007**
- **PCSA's seismic safety assessments will be completed by February 2008**

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

Canister Receipt and Closure Facility and Wet Handling Facility Layout and Waste Handling Operations

Presented to:
NRC/DOE Technical Exchange on Layout and Operations

Presented by:
Robert C. Slovic
Senior Project Engineer
Michael V. Frank
Hazards, Event categorization & Reliability Supervisor
Bechtel SAIC Company, LLC

May 30, 2007
Las Vegas, Nevada

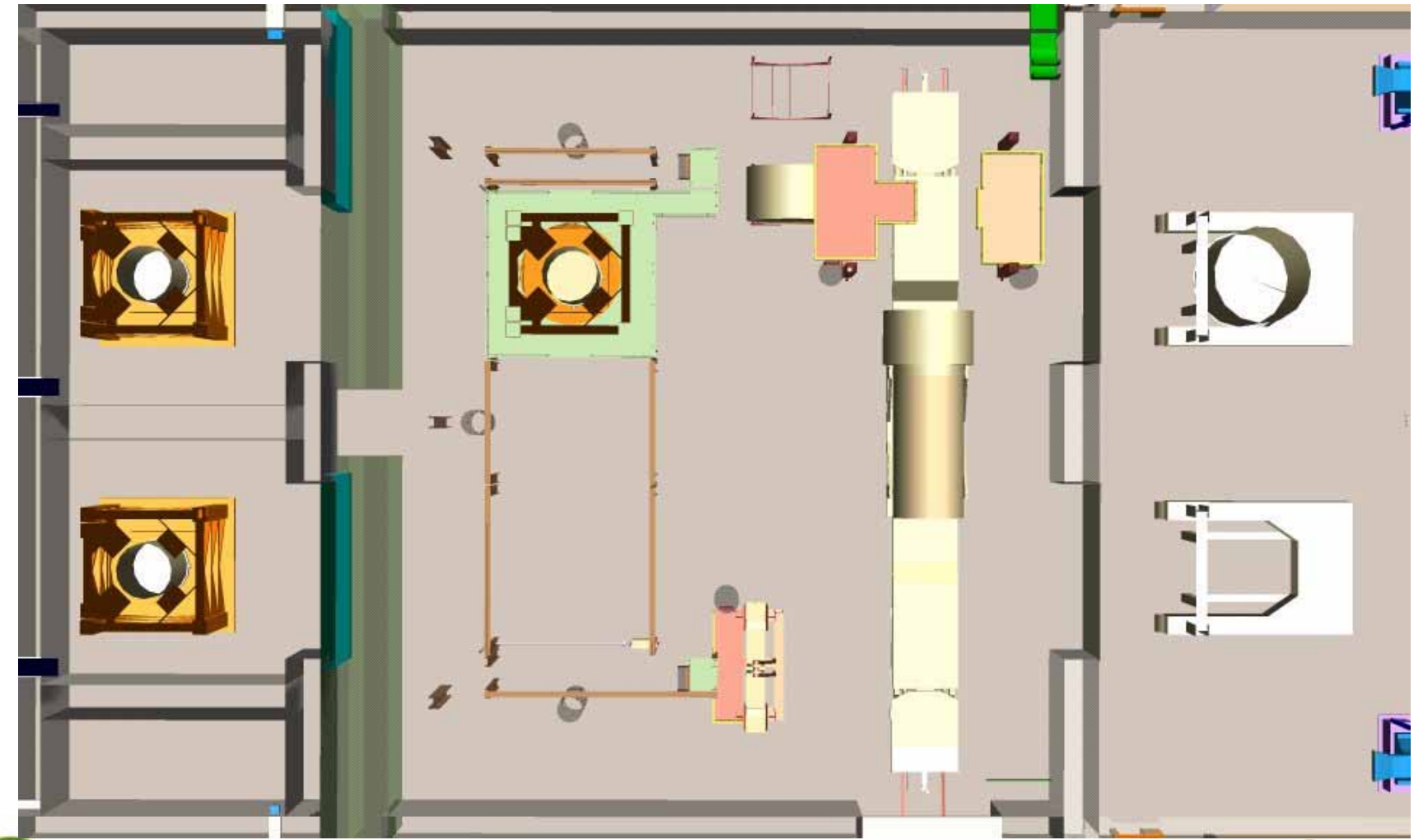
Acronyms

- **CRCF** **Canister Receipt and Closure Facility**
- **CSNF** **Commercial Spent Nuclear Fuel**
- **GROA** **Geologic Repository Operations Area**
- **IHF** **Initial Handling Facility**
- **ITS** **Important-to-Safety**
- **RF** **Receipt Facility**
- **TAD** **Transportation, Aging, and Disposal (Canister)**
- **WHF** **Wet Handling Facility**

Facility Layout and Waste Handling Operations

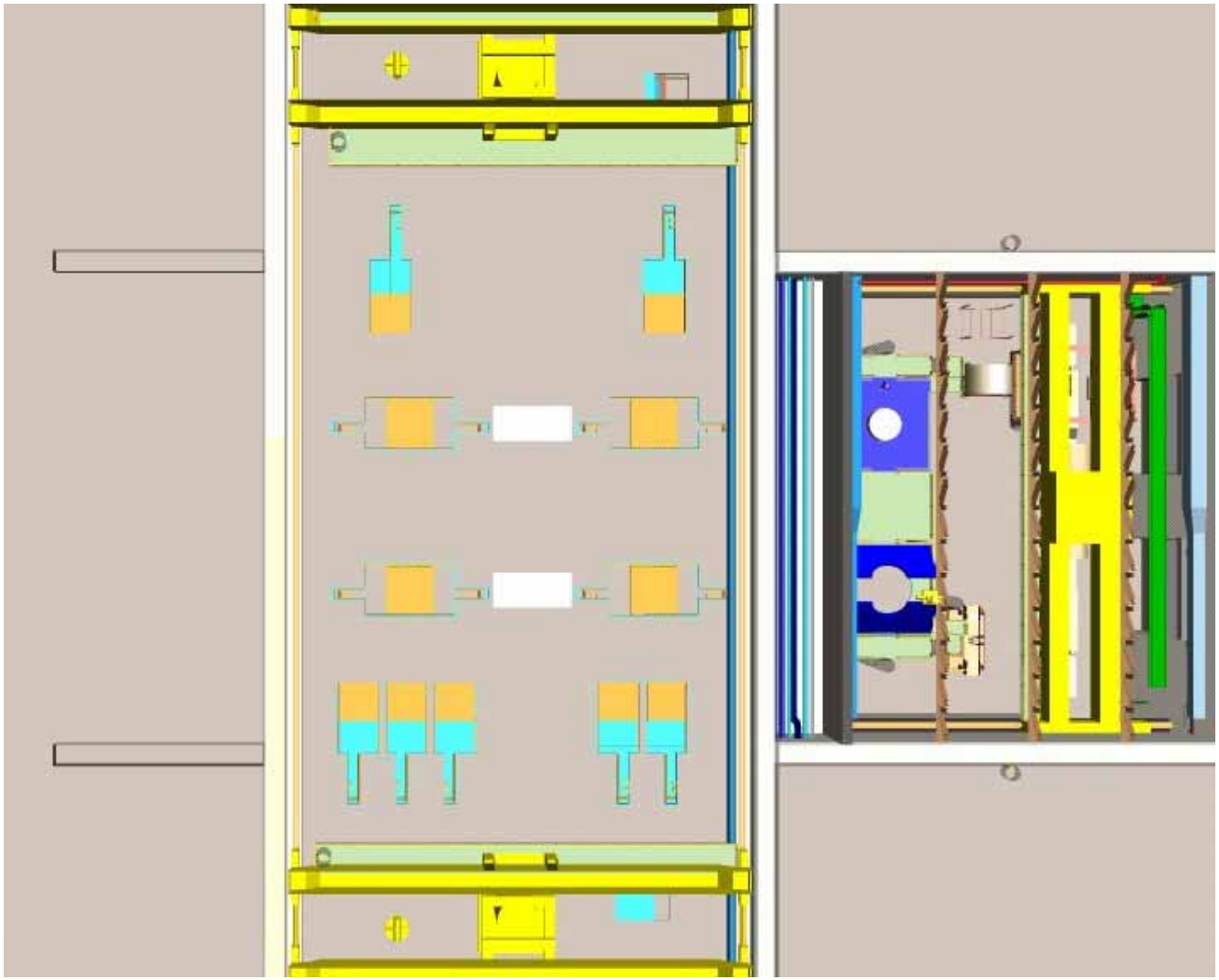
- **Similar Waste Handling in Facilities**
  - **Types of Operations**
  - **Equipment**
- **Design Minimizes Risk at Repository**
  - **Utilizes Transport, Aging and Disposal (TAD)**
  - **Fewer Handling Operations**
  - **Simplified Waste Movement**

CRCF Waste Input Area

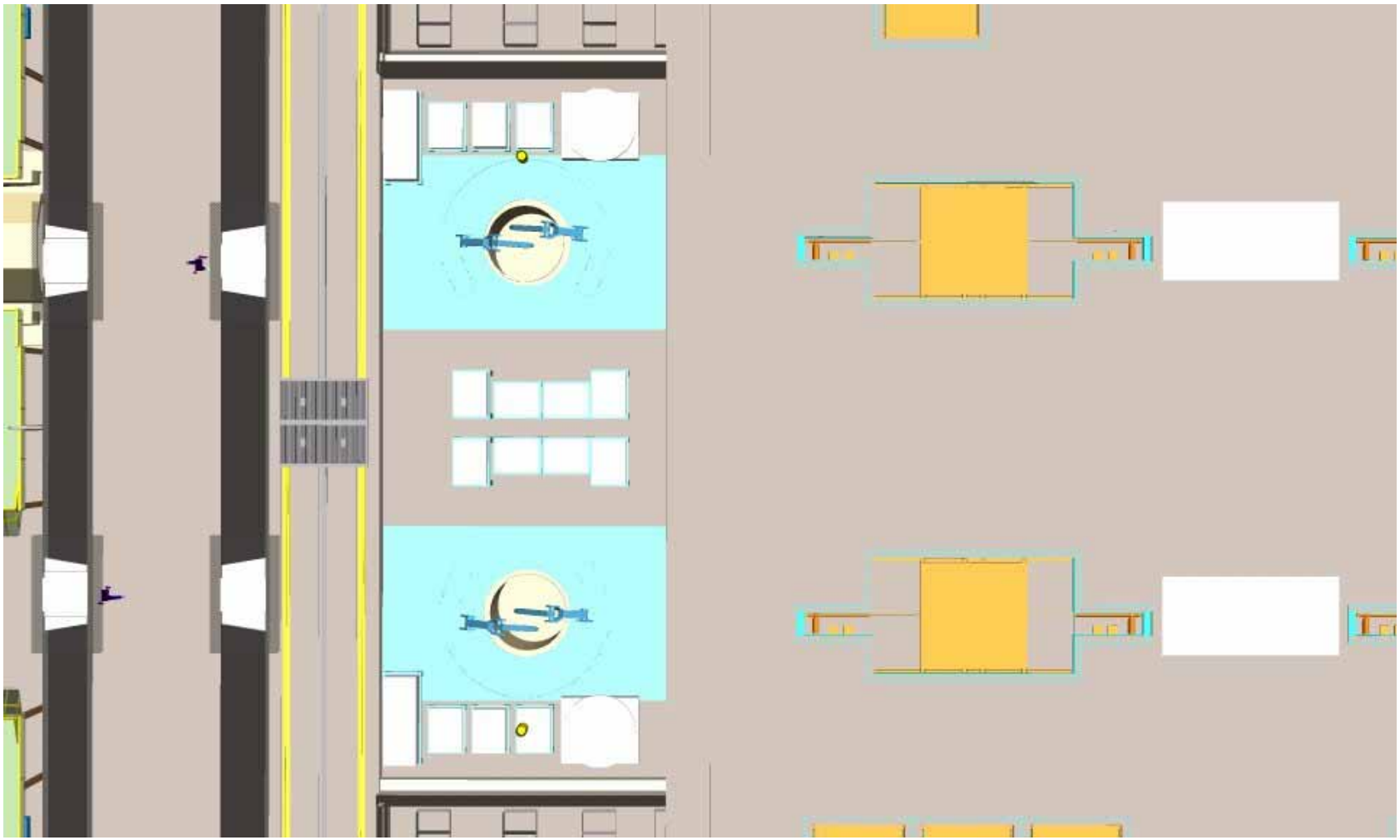


CRCF Waste Handling Section

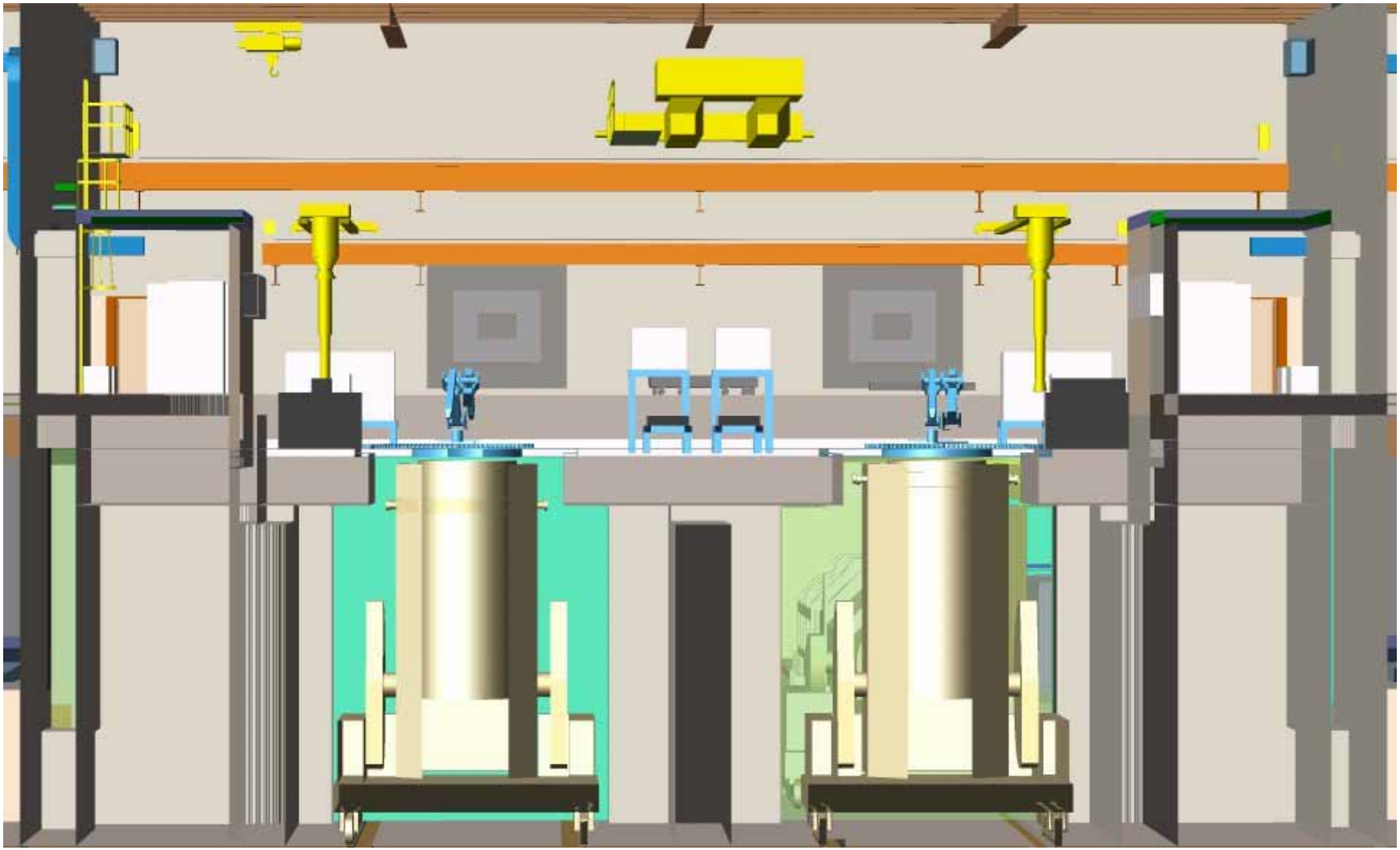
CRCF Canister Transfer Area



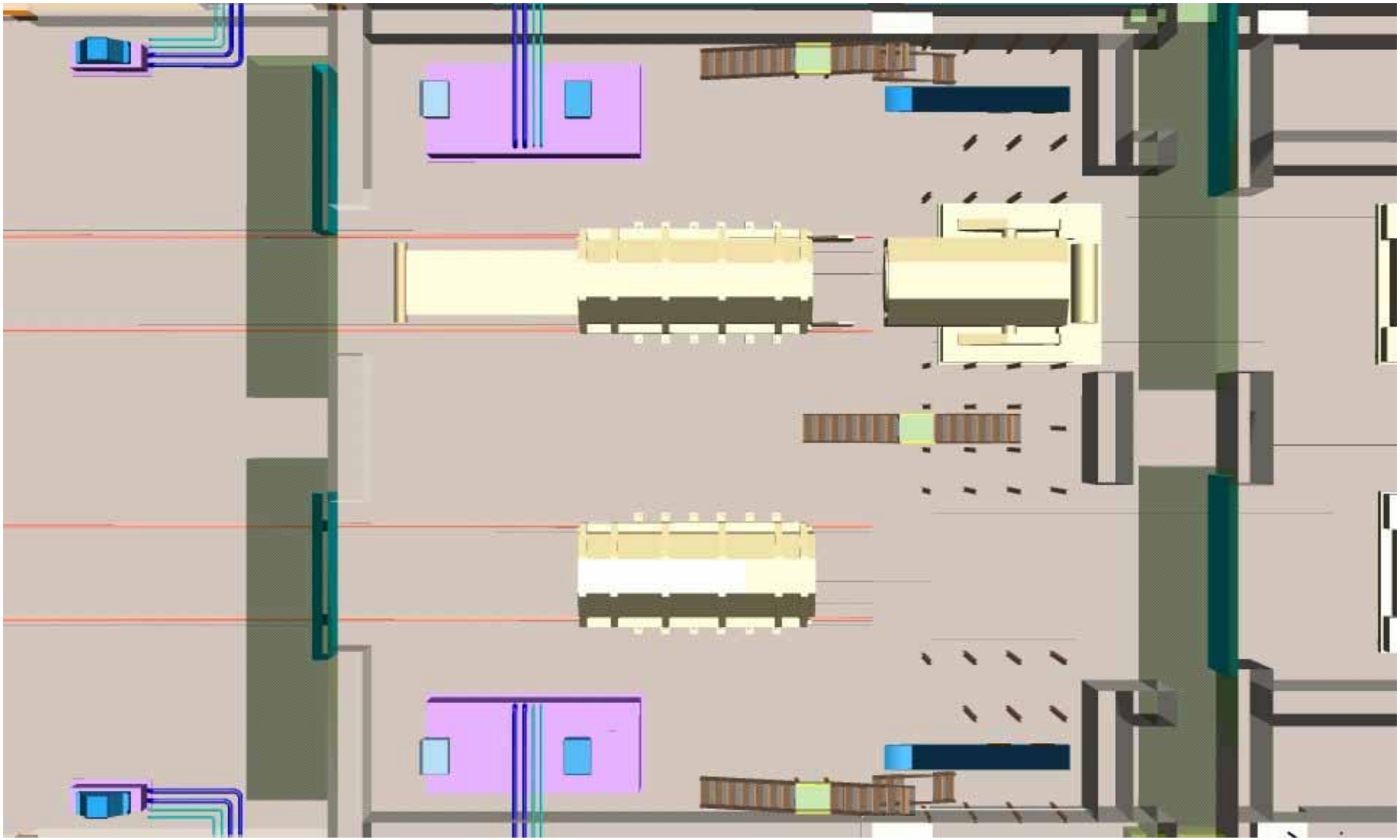
CRCF Waste Package Closure Area



CRCF Waste Package Closure Area



CRCF Waste Package Loadout Area



WHF Waste Handling and Pool Area

WHF Waste Handling and Pool Area

WHF Pool Area

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

Waste Handling Control Philosophy

Presented to:
NRC/DOE Technical Exchange on Layout and Operations

Presented by:
Steven T. Schmude
Instrumentation and Controls Engineering Group Supervisor
Michael V. Frank
Hazards, Event categorization & Reliability Supervisor
Bechtel SAIC Company, LLC

May 30, 2007
Las Vegas, Nevada

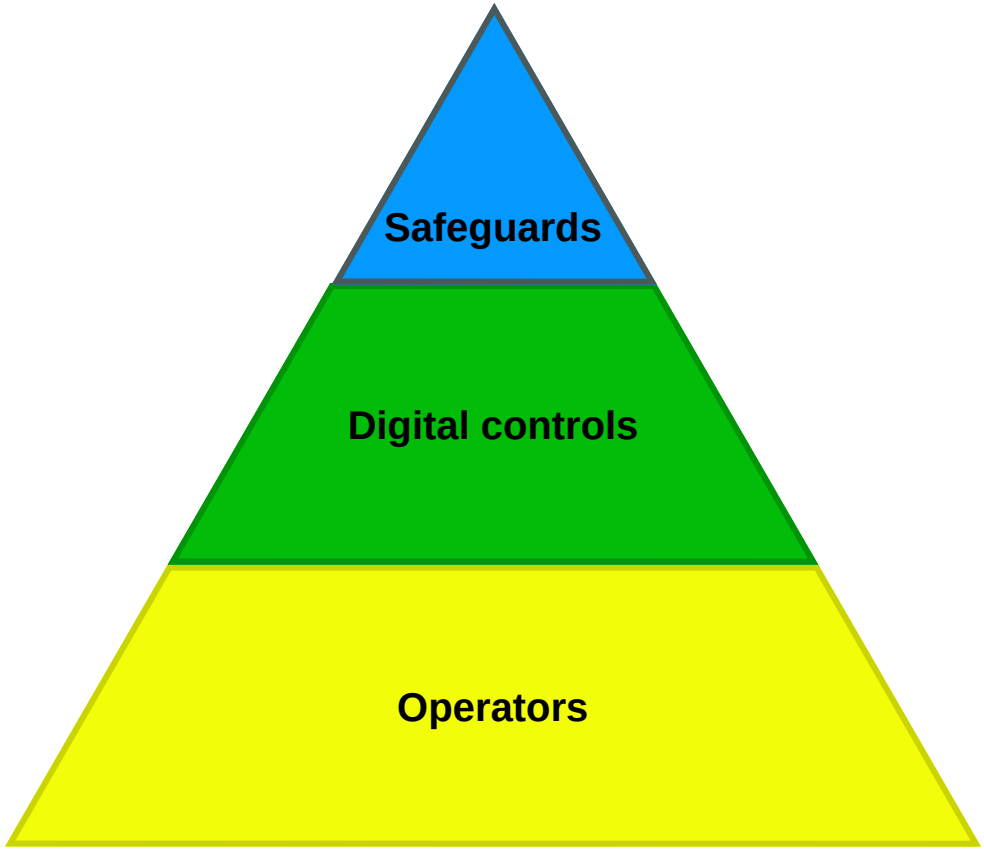
Acronyms

- **CTM** — **Canister Transfer Machine**
- **DCMIS** — **Digital Control and Management Information System**
- **DPC** — **Dual Purpose Canister**
- **HMI** — **Human Machine Interface**
- **ITS** — **Important to Safety**
- **PLC** — **Programmable Logic Controller**
- **TAD** — **Transportation, Aging, and Disposal**
- **TEV** — **Transport and Emplacement Vehicle**

Introduction

- **Safe waste handling control philosophy**
- **Safeguard Hierarchy**
- **Waste handling control objectives**
- **Waste handling control elements**
  - **ITS examples**
- **Control and monitoring locations**
- **Summary**

Safe Waste Handling Control Philosophy



Safeguard Hierarchy

- **Inherent mechanical design**
  (e.g., speed limitation on crane motors; TEV gear ratio, lift heights)
- **Structural**
  (e.g., shield walls)
- **Mechanical**
  (e.g., TEV operations)
- **Electrical, electro-mechanical, electronic**
  (e.g., shield doors and slide gates)
- **Procedural controls with alarms**
  (e.g., vacate waste package load out area before transfer operations)

Waste Handling Control Objectives

- **Objectives:**
  - **Minimize consequences of operator errors**
  - **Minimize possibility of operator errors**
  - **Maximize safety of waste handling operations**

Waste Handling Control Elements

- **Major elements of control system strategy**
  - **Digital control systems**
    - **DCMIS**
    - **Packaged Mechanical Handling Equipment Control Systems**
  - **ITS functions**
  - **Communications system**

Waste Handling Control Elements

- **DCMIS**
  - **Non-ITS**
  - **Industry standard Distributed Control System**
  - **Provides operator HMI consoles**
    - **Consistent platform for operator interface**
  - **Provides non-ITS control and monitoring of equipment operations**
  - **Interfaces with packaged mechanical handling equipment control systems for non-ITS supervisory control and monitoring**

Waste Handling Control Elements

- **Packaged mechanical handling equipment control systems**
  - **Provide non-ITS control of waste handling equipment operations**
    - **PLCs**
    - **Embedded controllers**
    - **Hardwired**
  - **Operator interface is provided through the DCMIS**

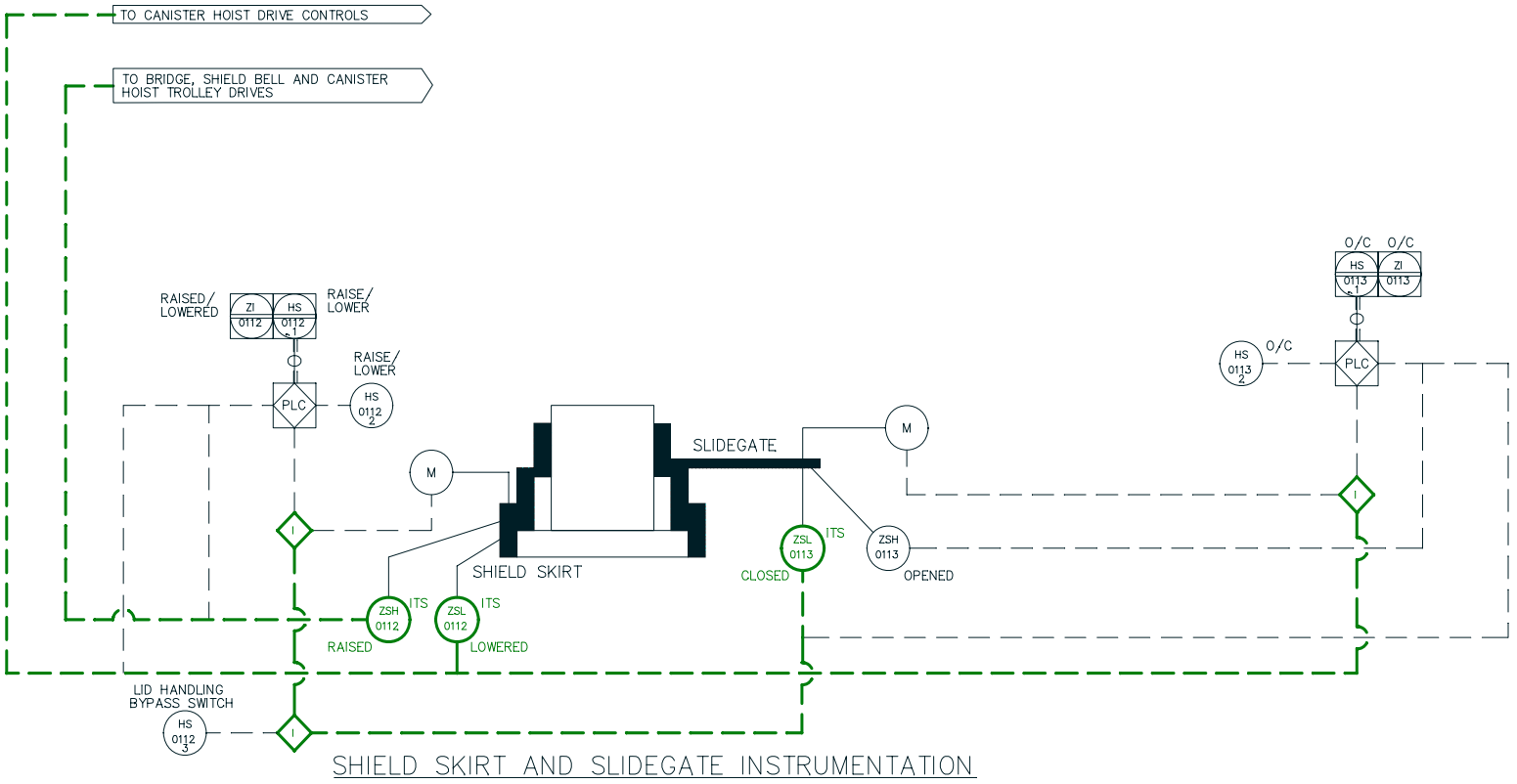
Waste Handling Control Elements

- **ITS Functions**
  - **Can be structural, mechanical, electrical, electro-mechanical, or electronic**
  - **Electrical/electronic controls do not rely on DCMIS or PLC software**
  - **ITS permissives/interlocks are hardwired**
    - **Operator commands and digital control systems cannot override ITS functions**

Waste Handling Control Elements

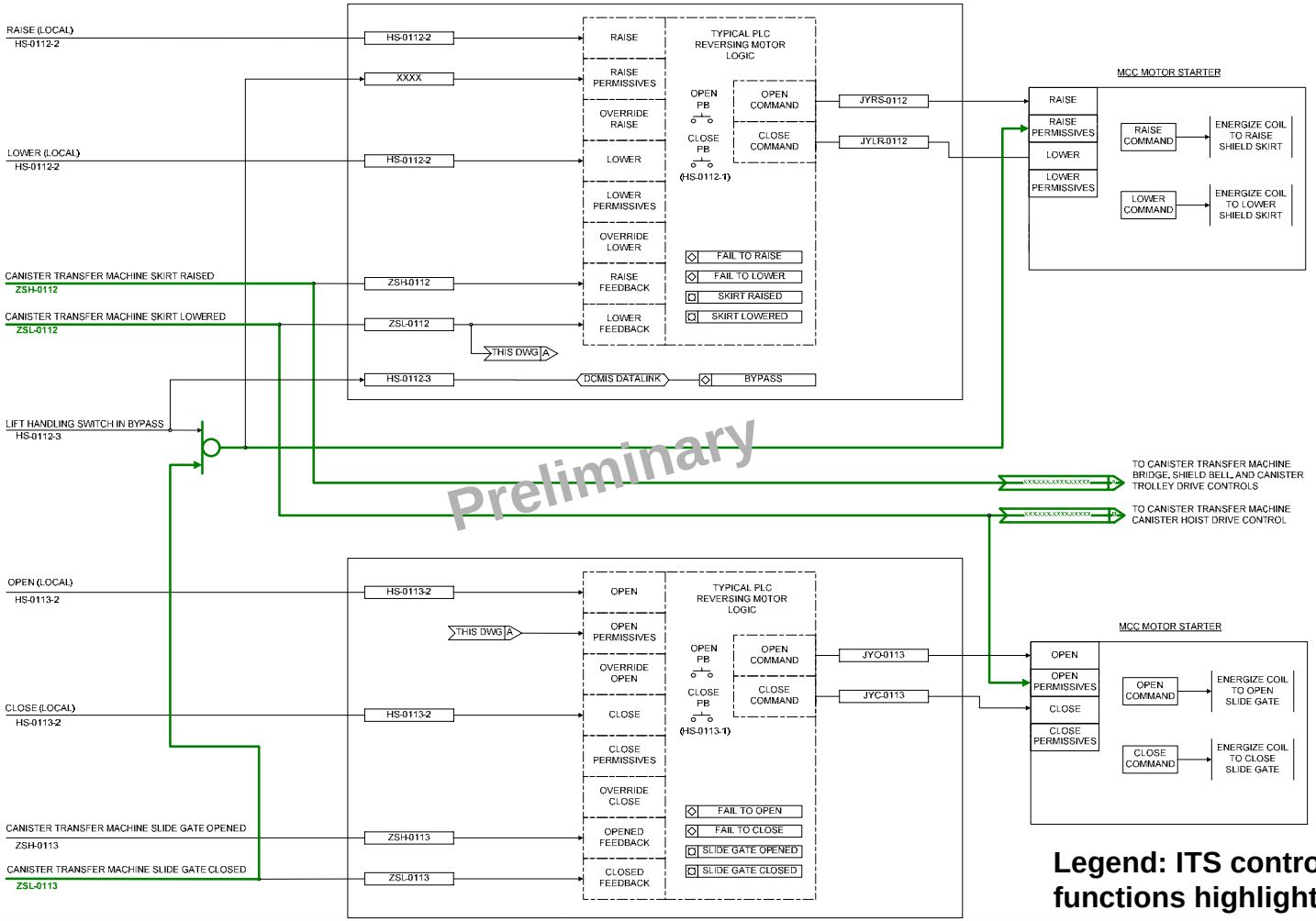
- **ITS Functions (continued)**
  - **Example ITS functions**
    - **Shielding**
      - » **Building shield; TEV doors; slide gates**
    - **Lifting and transfer operations**
      - » **Slide gate can open only when CTM shield bell in correct position and skirt down**
      - » **Canister lift height limits; prevent simultaneous horizontal and vertical motion; CTM can move only when skirt is up and slide gate is closed**
      - » **Positive yoke and grapple latching; lift motors disabled unless positive latch/unlatch signal; grapple motors disabled during lift**

P&ID for CTM Shield Skirt and Slide Gate



Legend: ITS control functions highlighted in bold / green and identified as "ITS"

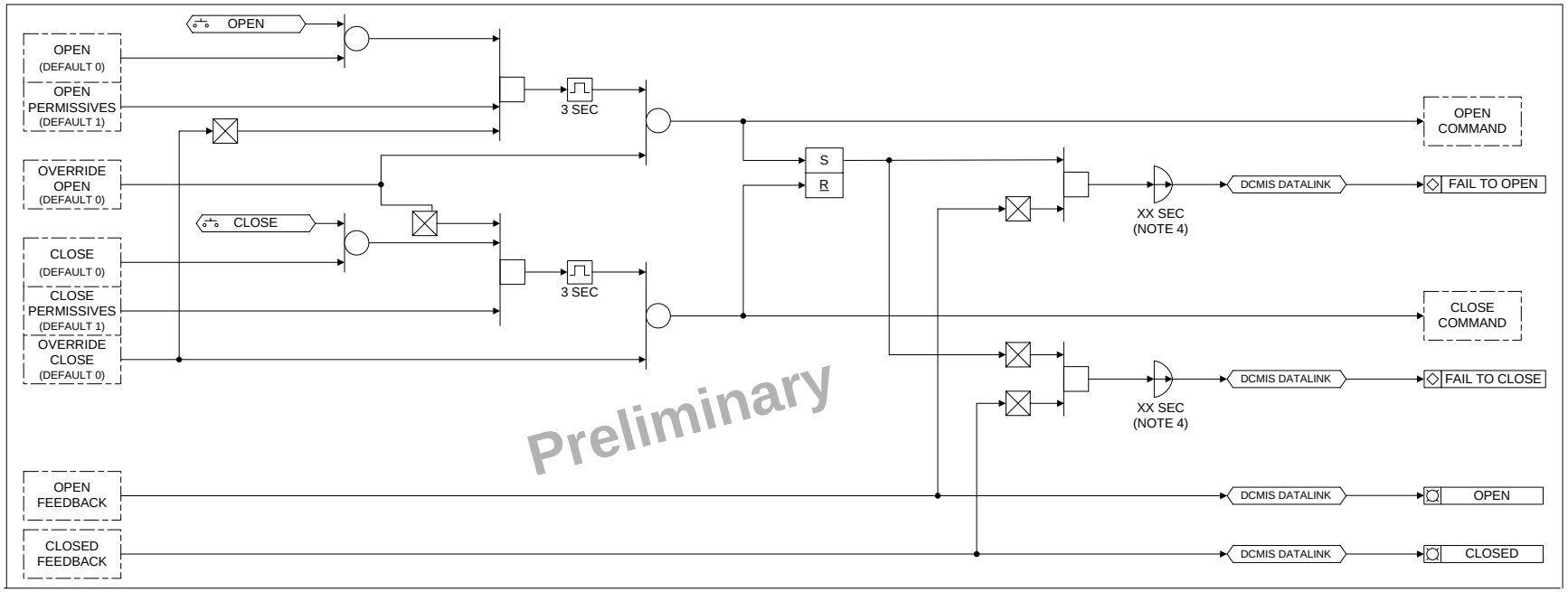
Sample Logic for CTM Shield Skirt and Slide Gate Controls



Legend: ITS control functions highlighted in bold / green

Sample of Typical PLC Logic

Typical PLC Reversing Motor Logic



Waste Handling Control Elements

- **Communications System**
  - **Non-ITS**
  - **Provides video interface with DCMIS for process monitoring**
  - **Provides wireless data and video transmission with TEV**

Control and Monitoring Locations

- **Remote**
  - **Central Control Center**
    - **Located in the Central Control Center Facility**
- **Local-Remote**
  - **Nuclear Facility Operations Rooms**
    - **Located in each nuclear waste handling facility**
- **Local**
  - **At Selected Equipment**

Control and Monitoring Locations

- **Central Control Center**
  - **Contains HMI consoles**
  - **Remote monitoring of nuclear facility waste handling operations**
  - **Remote stop capability of waste handling operations within a nuclear facility**
  - **Remote supervisory control and monitoring of TEV**

Control and Monitoring Locations

- **Nuclear Facility Operations Rooms**
  - **Contains HMI consoles**
  - **Provides local-remote control, supervisory control, and monitoring of facility waste handling operations**
- **Local**
  - **Operator interfaces provided as part of packaged mechanical handling equipment control system**
    - **Spent fuel transfer machine**
    - **DPC cutting**
    - **TAD closure**

Summary

- **Waste handling control philosophy:**
  - **Minimize consequences of operator errors**
    - **Many ITS functions are inherently designed in**
    - **ITS permissives/interlocks are hardwired**
    - **Operator actions cannot override ITS functions**
  - **Minimize possibility of operator errors**
    - **Common operator interface platform**
    - **Video integrated with control**
  - **Maximize safety of waste handling operations**
    - **Operations controlled as close to the process as practical**
    - **Centralized location provides overall monitoring**

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

www.ocrwm.doe.gov

Seismic Design Considerations

Presented to:
NRC/DOE Technical Exchange on Layout and Operations

Presented by:
Michael A. Denlinger
Civil / Structural Engineering Group Supervisor
Bechtel SAIC Company, LLC

May 30, 2007
Las Vegas, Nevada

Seismic Analysis Approach

- **Two Tier Analysis Approach**
- **Tier-1 Analysis**
  - **Lumped Mass Multiple Stick Model**
- **Tier-2 Analysis**
  - **Finite Element Model with Soil Structure Interaction (SSI) Analysis**

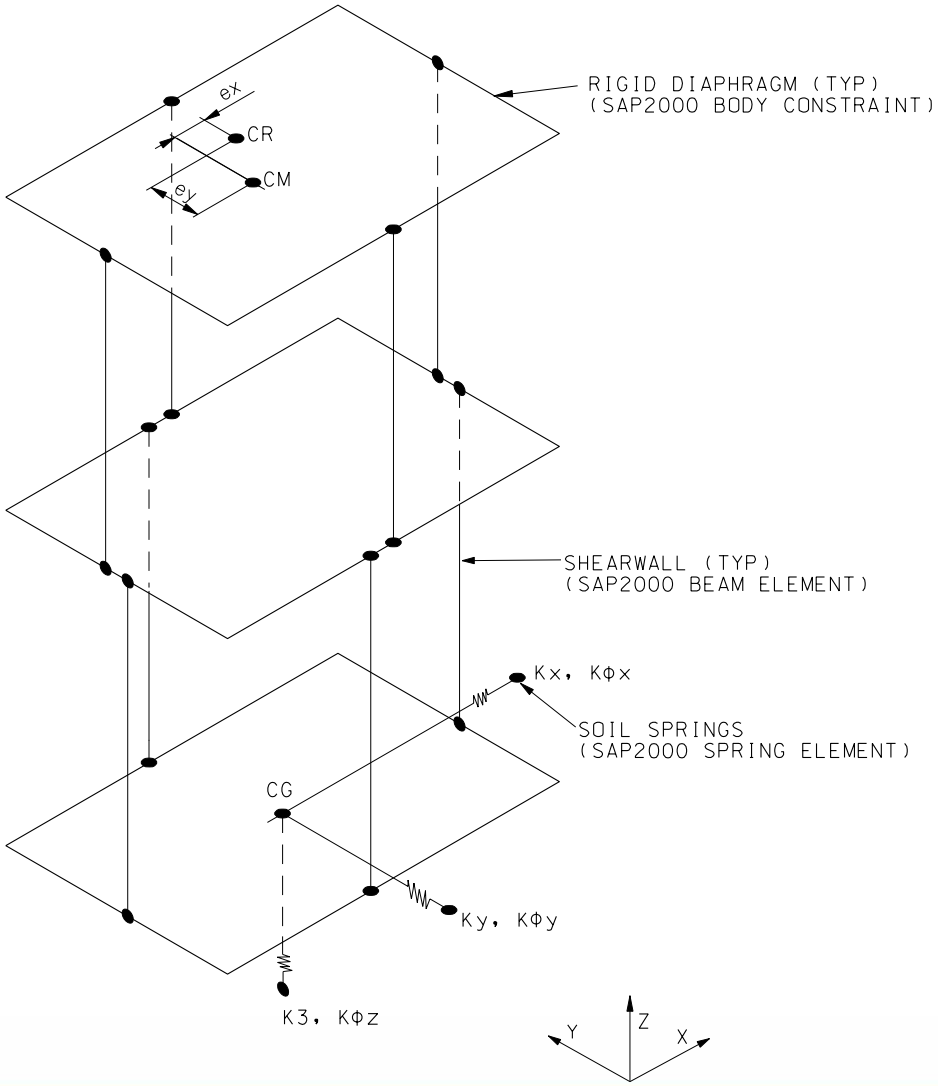
Seismic Analysis Approach

- **Tier-1 Analysis**
  - Determine response of structures for seismic loads
  - Determine seismic forces and design structural members
  - Demonstrate Compliance with Nuclear Safety Design Bases in License Application
  - Development of In-Structure Response Spectra (ISRS) for component qualification
  - Demonstrate safety of ITS facilities
- **Tier-2 Analysis**
  - Basis of Detailed Design Calculations
  - Confirm Tier-1 Analysis Results
  - Available May 2008

Tier-1 Model

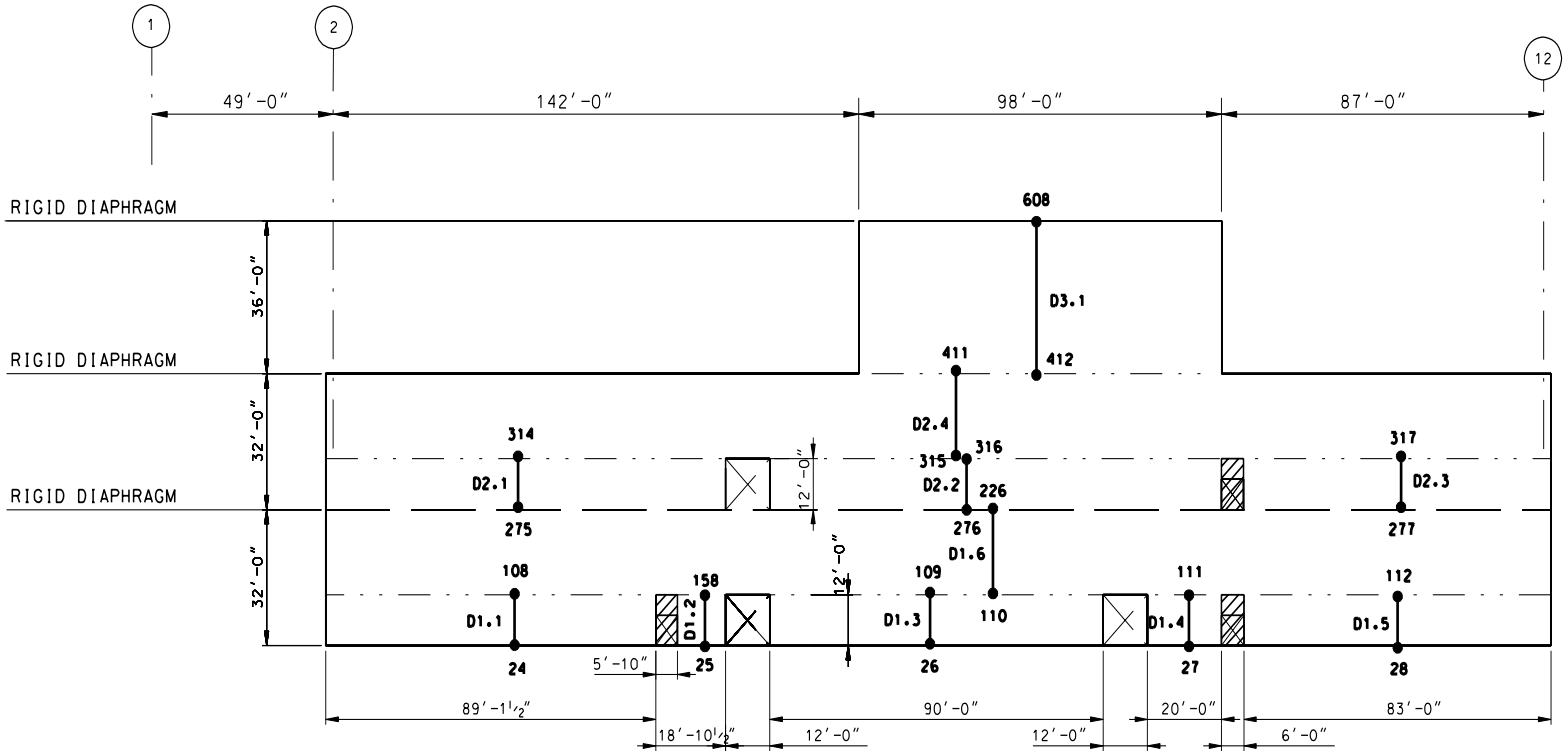
- **Lumped Mass Multiple Stick Model**
- **Foundation Impedance Functions Based on Elastic Half Space Theory**
- **Floors considered as Rigid Diaphragms**
- **Mass and Center of Mass computed at each Diaphragm**
- **Shear Walls modeled with Beam Elements**

Tier – 1
Lumped Mass Multiple Stick Model Schematic



CR:Center of Rigidity
CM:Center of Mass
CG:Center of Gravity

Tier-1 Typical Shear Wall Stick Element Representation



TYPICAL WALL ELEVATION

Tier–1 Soil Springs

- **Six Sets of Soil Springs**
  - **35 feet & 110 feet of Alluvium Overlaying Tuff**
  - **Lower Bound, Median & Upper Bound Shear Wave Velocities**
  - **Equations from BC-TOP-4A (ASCE 4-98)**

ASCE 4-98: AMERICAN SOCIETY of CIVIL ENGINEERS, STANDARD 4-98

BC-TOP-4A: BECHTEL TOPICAL REPORT 4A, SEISMIC ANALYSES OF STRUCTURES AND EQUIPMENT FOR NUCLEAR POWER PLANTS

Tier–1 Soil Damping

- **Equivalent Damping Coefficients Computed using BC-TOP-4A (ASCE 4-98)**
- **Geometric (Radiation) Damping**
- **Damping computed for six soil cases**
- **Damping limited to 20% in Response Spectrum Analysis**

TIER-1 Soil Damping

	% CRITICAL DAMPING (1)	TIER-1 SOIL DAMPING
TRANSLATION X (kip-sec/ft)	85%	20%
TRANSLATION Z (kip-sec/ft)	85%	20%
VERTICAL Y (kip-sec/ft)	140%	20%
ROCKING X ft-kip-sec/rad	70%	20%
ROCKING Z ft-kip-sec/rad	90%	20%
TORSION ft-kip-sec/rad	35%	20%

(1) CRITICAL DAMPING $Ccr = 2 * \sqrt{K * m}$

Tier-1 Structural Damping

- **ASCE / SEI 43-05**
  - **Response Level 1 In-Structure Response Spectra**
  - **Response Level 2 Design Basis**
  - **Response Level 3 Beyond Design Basis**

ASCE / SEI 43-05: American Society of Civil Engineers, Standard 43-05

Tier-1 Analysis - CRCF Frequencies

	FIXED BASE	35' UPPER BOUND	110' LOWER BOUND	
MODE	FREQUENCY CYC/SEC	FREQUENCY CYC/SEC	FREQUENCY CYC/SEC	
1	11.0	8.2	3.7	(SSI MODE X DIRECTION)
2	11.3	8.2	3.8	(SSI MODE Y DIRECTION)
3	20.2	11.4	4.4	(SSI MODE VERTICAL)
4	23.5	17.3	12.9	
5	27.4	19.2	13.0	
6	27.7	22.8	21.5	
7	34.3	26.2	24.4	
8	37.2	30.0	29.0	
9	53.7	35.0	34.4	
10	57.0	37.3	37.0	
11	76.1	39.5	37.3	
12	103.1	53.8	42.2	

Greater than 85% Mass Participation in First Three (SSI) Modes

Tier-1 Response Spectrum Analysis

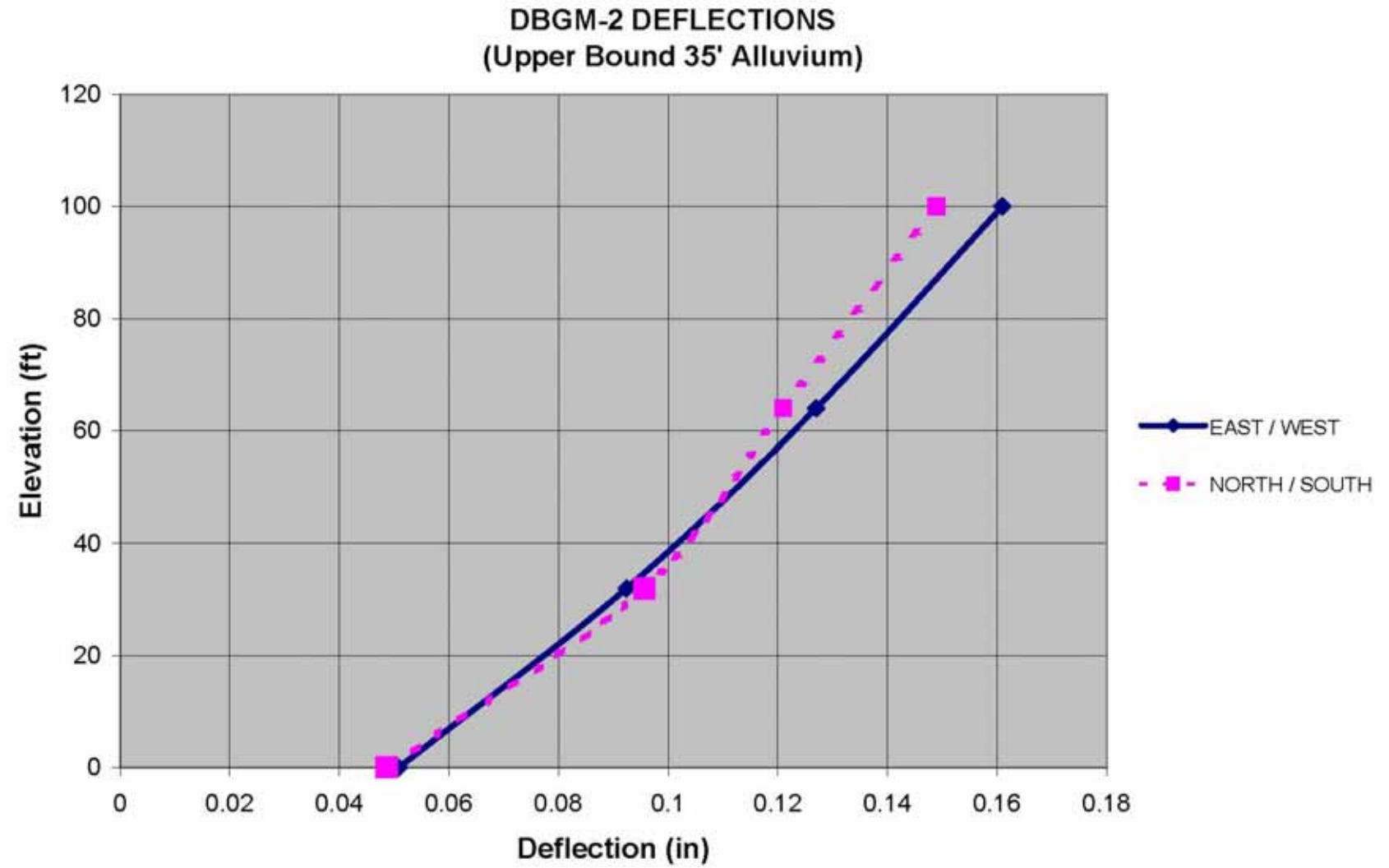
- **20% Damping for SSI Modes**
- **7% (DBGM-2) and 10% (BDBGM) for Structural Modes**
- **Modal Combinations 10% Method**
- **N/S, E/W, and Vertical Spectra**
  - **Spatial Combinations SRSS**

DBGM-2: DESIGN BASIS GROUND MOTION-2, $5x10^{-4}$ MEAN ANNUAL PROBABILITY OF EXCEEDANCE

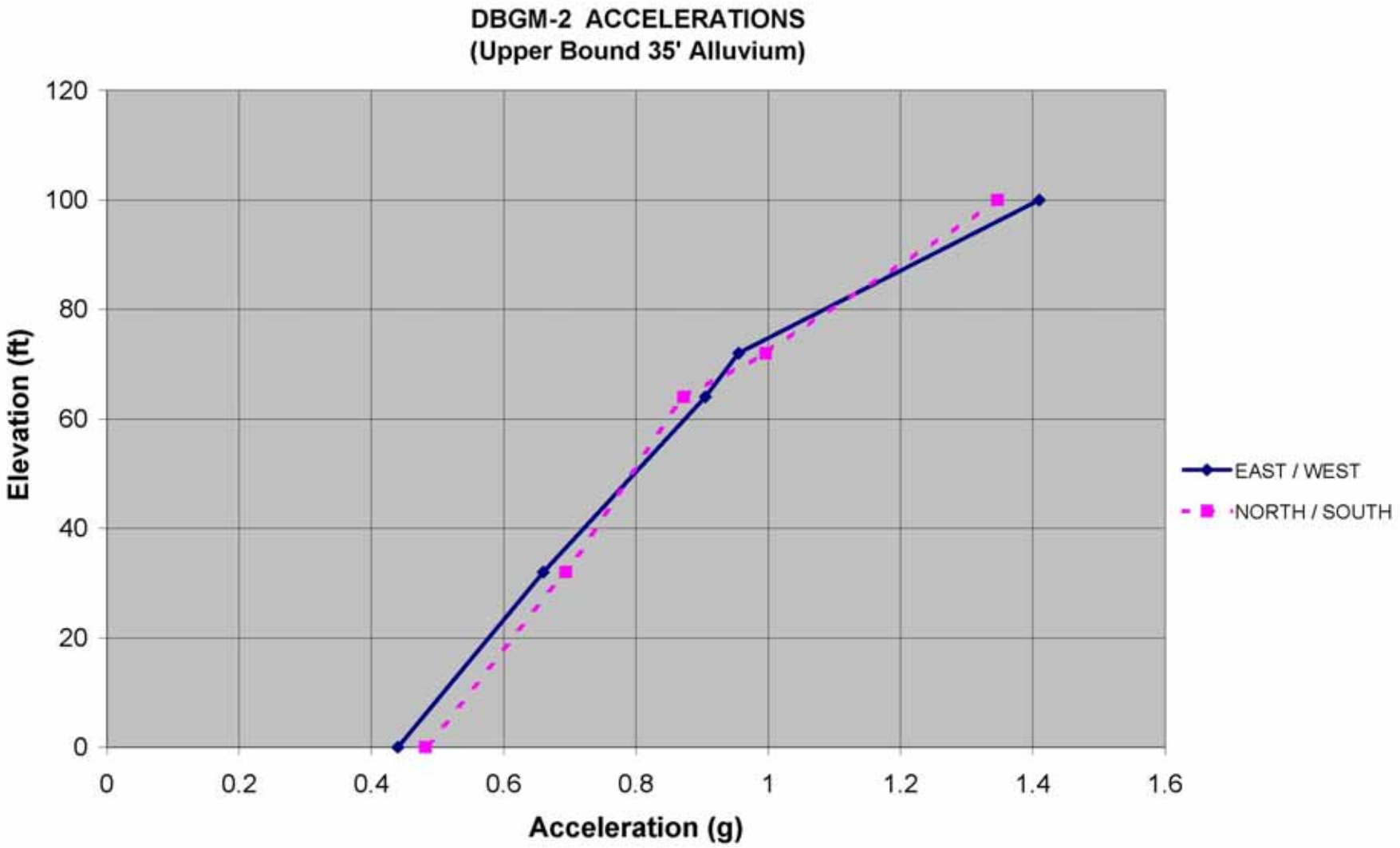
BDBGM: BEYOND DESIGN BASIS GROUND MOTION, $1x10^{-4}$ MEAN ANNUAL PROBABILITY OF EXCEEDANCE

SRSS: SQUARE ROOT OF THE SUM OF THE SQUARES

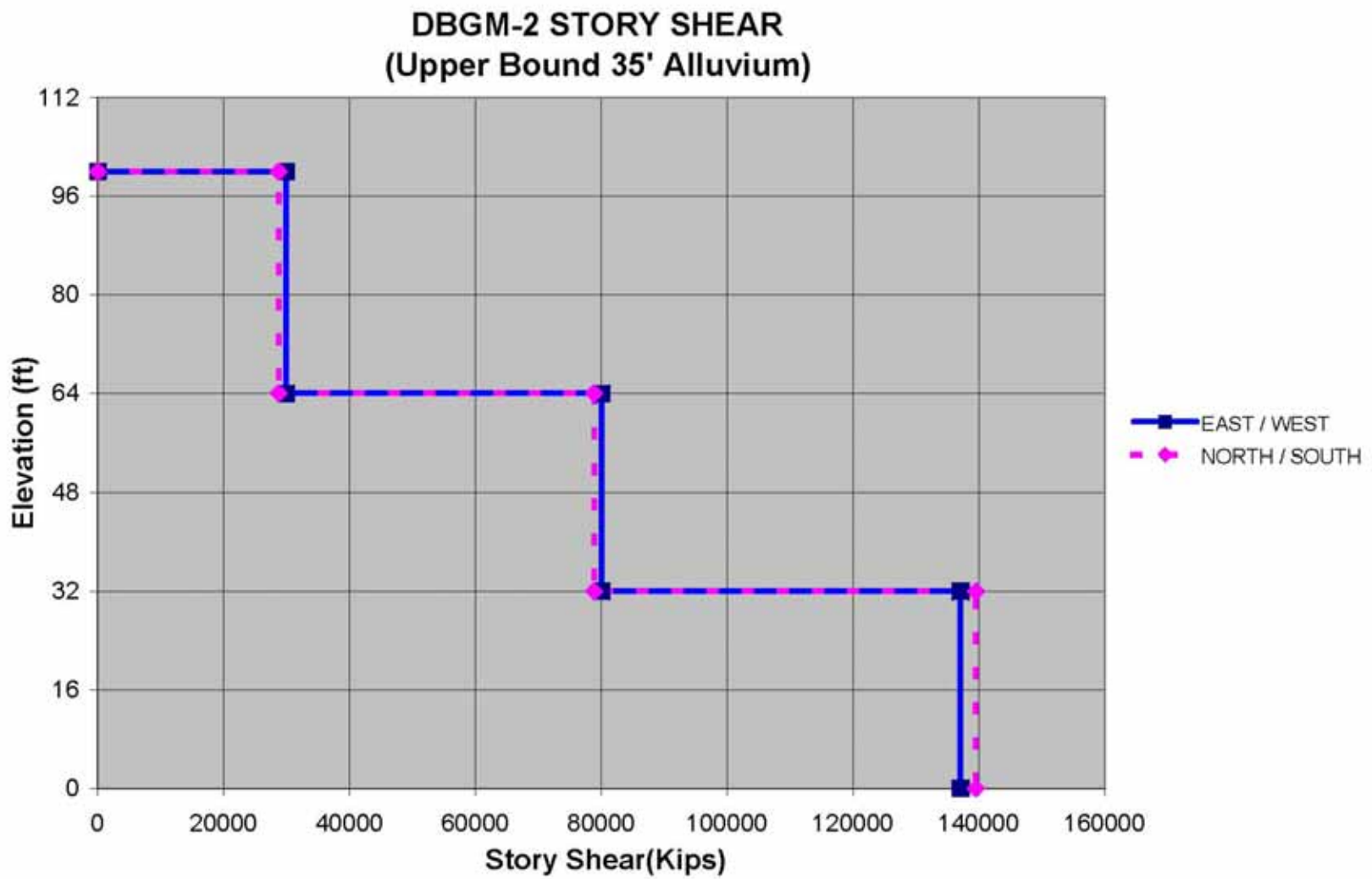
Tier-1 CRCF Response Spectrum Analysis



Tier-1 CRCF Response Spectrum Analysis



Tier-1 CRCF Response Spectrum Analysis



Tier-1 In-Structure Response Spectra

- Based on Tier-1 Lumped Mass Multiple Stick Model
- Soil Springs with corresponding damping coefficients
- Time History Analyses for each soil case
  - Upper Bound, Median, and Lower Bound (35 feet & 110 feet Alluvium)
- Generate In-Structure Response Spectra at selected points for each Time History Analysis Case
- Envelope ISRS from six Time History Analysis cases
- Broaden and Smoothen ISRS using Regulatory Guide 1.122
- Currently In Process

Summary

- **Two tiered approach used for seismic analysis**
- **License Application based on Tier-1 analysis results**
- **Tier-1 analysis methodology consistent with NUREG-0800 and ASCE 4-98**
- **Tier-1 analysis demonstrates safety of facilities**
- **Tier-2 complete May 2008**