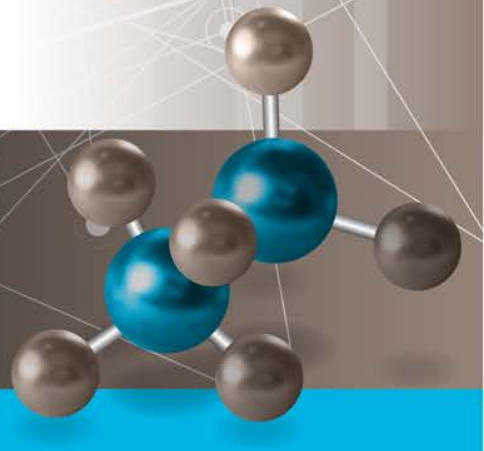
AECOM

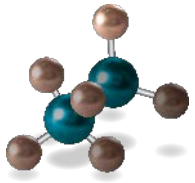
Nuclear Power Plant Decommissioning Waste Management Operations

33rd Summer Seminar of NUCE
Atomic Energy Society of Japan
August 25, 2017



Waste Management

- Plant Background
- Planning
- Characterization
- Primary System Decontamination & Hot Spot Reduction
- Spent Fuel Management
- Dismantlement & Demolition
- Waste Treatment & Disposal Options in the US
- Waste Disposition



AECOM

Financial Strength

- $18B in annual revenue
- Greater than $40B backlog
- Ability to provide appropriate guarantees and reach agreement on terms with client and stakeholders
- Board level initiative / reorganizing to grow decommissioning business

Acquisition & Integration

- Over 50 companies integrated since 1990
- Experience in nuclear power plant acquisitions
- Experience in transition and management of nuclear sites (largest in U.S. DOE complex)

D&D and Technical Expertise

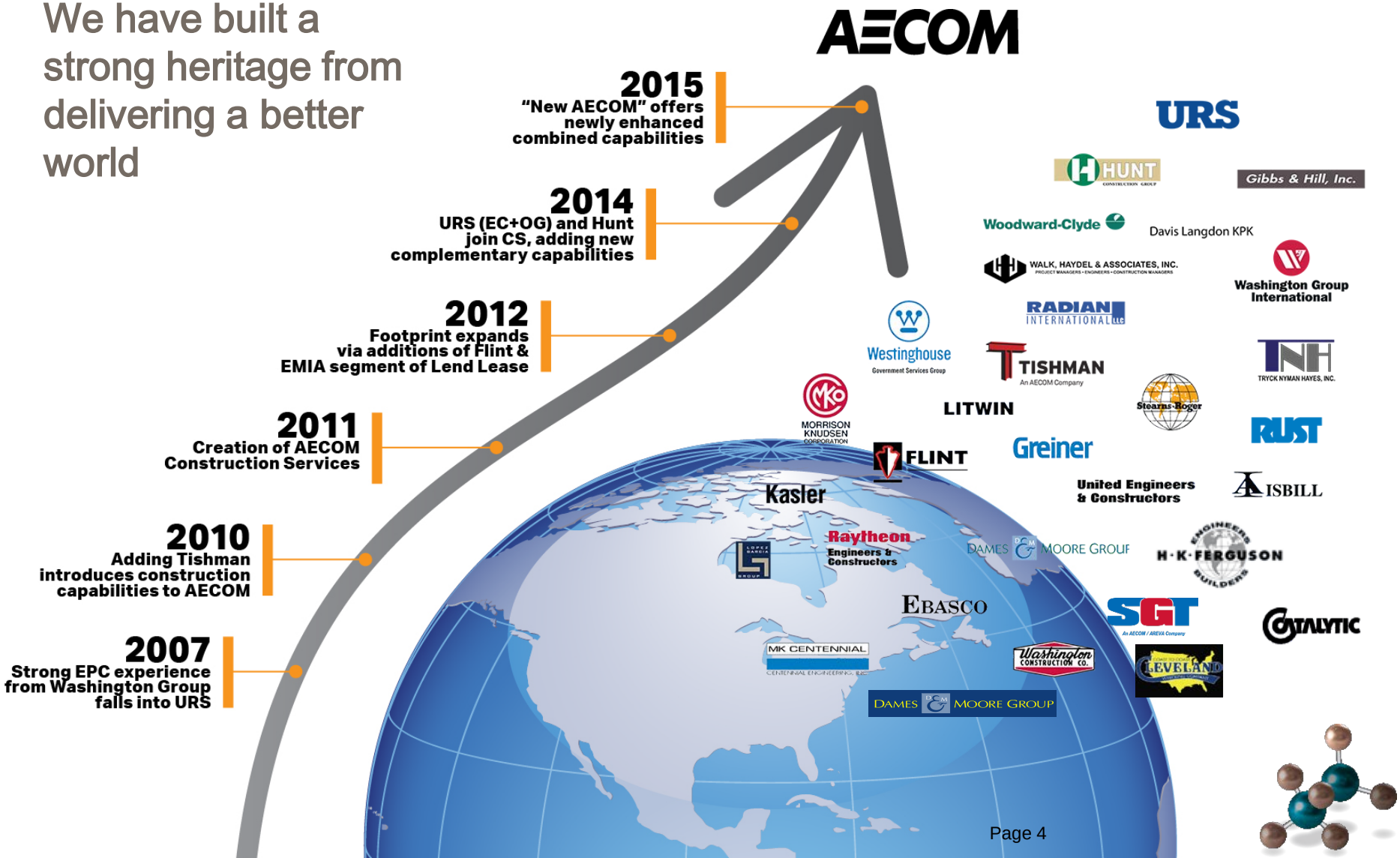
- 60 years of continuous involvement in the nuclear power industry
- 30+ years of nuclear decommissioning experience
- Over 1,650 facilities decommissioned (including 20+ production / test reactors)
- In-depth knowledge and experience with the NRC
- Local regulatory knowledge
- Expertise with plant decommissioning and used fuel stewardship
- Knowledge of plant policies, procedures and expectations

Management & Operational Capability to take over Site License

- Experience as a non-utility licensed operator of a nuclear facility for decommissioning purposes
- Proven ability to manage multiple D&D projects simultaneously
- Managed multi-billion D&D budgets in 2016
- Have incorporated 3 Yankees leadership experience in D&D and ISFSI-only operations

The Heritage & Evolution of Legacy Companies

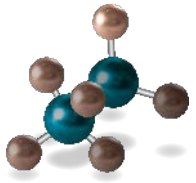
We have built a strong heritage from delivering a better world



Connecticut Yankee Plant Background

Connecticut Yankee (CY) PWR Plant Data

- Construction Permit Issued: May 26, 1964
- Operating License Issued: December 27, 1974
- Commercial Operation: January 1, 1968
- Ceased Operations: December 9, 1996
- Licensed Capacity: 1825 MWth / 560 MWe
- NSS Supplier: Westinghouse 4 Loop PWR
- AE/Constructor: Stone & Webster
- License: DPR-61 (Docket No. 50-213, 72-39)
- Site Size: 525 Acres (2.1×10^6 m^2)



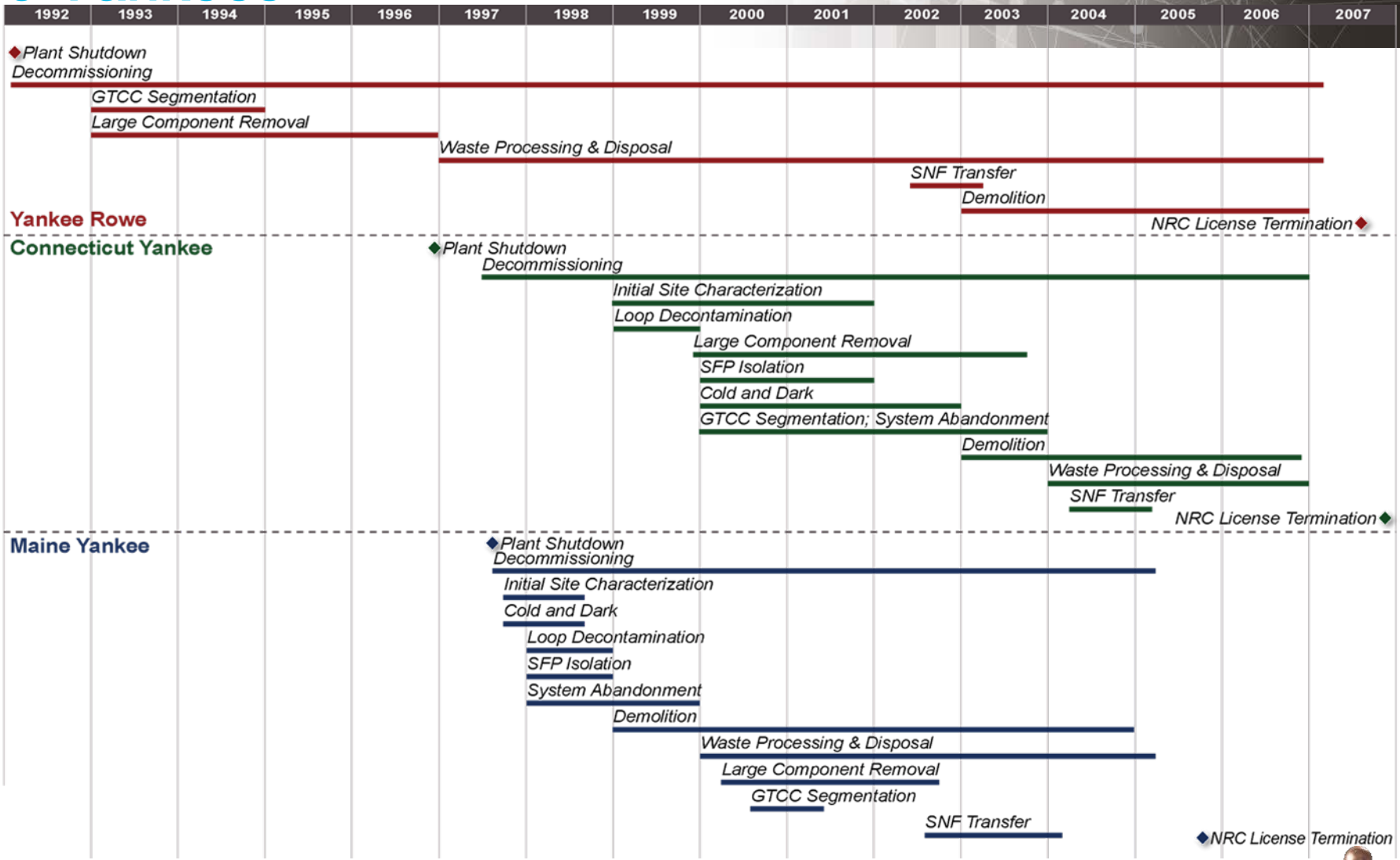
CY - Pre-Decommissioning Plant Photo

Connecticut Yankee Plant Site following Demolition Activities

Connecticut Yankee – Aerial View Today (with ISFSI on right)

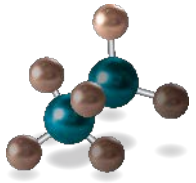
ISFSI: Independent Spent Fuel Storage Facility

Decommissioning Schedules
3 Yankees



CY – Regulatory Issues during Decommissioning

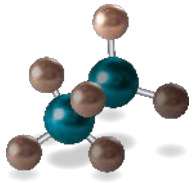
- Federal Regulations
  - New NRC regulations for Decommissioning
  - Generic Environmental Impact Statements for decommissioning projects
- License Termination
  - Creation of Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)
  - Memorandum of Understanding between NRC and EPA
- Regulatory Challenges
  - ISFSI encountered local opposition → Required litigation for resolution
  - Groundwater contamination was discovered → Required extensive radiological and non-radiological cleanup
  - State Release Criteria was stricter than the NRC limit of 0.25 mSv/year



CY – Other Key Takeaways

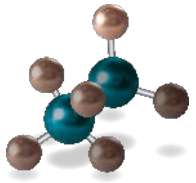
- Involve all stakeholders early and continuously
  - Agree on end state criteria → Drives the project strategy decisions
  - Obtain approval from stakeholders (NRC, EPA, and State) on the end state as early as possible

- NRC is not the only regulator
  - In the US, States have local jurisdiction of D&D sites
  - EPA regulations for chemical and industrial cleanup (RCRA/TSCA)
  - EPA and States have more stringent radiological release criteria



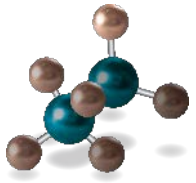
Connecticut Yankee
Waste Management Planning

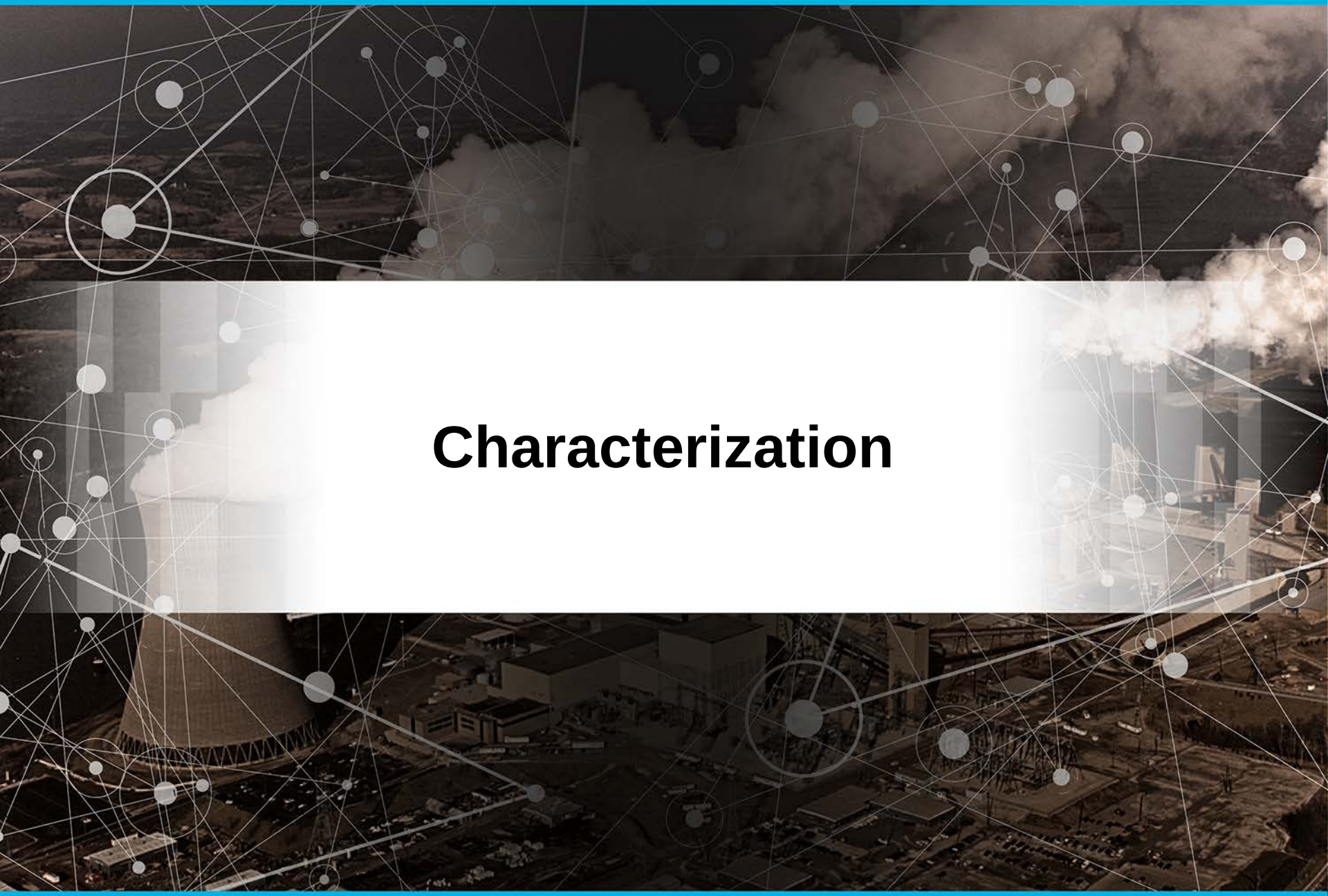
- Waste Management Planning is integrated into the Plant's overall Decommissioning Planning
- Key Components for Decommissioning & WM Planning
  - Detailed Facility and Systems Characterization
    - Before and after shutdown
  - Activation Analysis
- Characterization data drives the development of:
  - Waste Management Plans
  - Selection of Decontamination Method
    - For example, Primary System Full Scale Decontamination
  - Dismantlement and Demolition Methods



CY – Waste Management Planning

- Other Key Factors that impact Waste Management include:
  - Spent Fuel Management
  - Establishment of End State Conditions
    - Can you “abandon” certain structures and systems in place if they meet release criteria?
    - Can you rubblize and bury certain concrete products on site as fill?
  - Site-Specific Cost Estimate & Schedule
  - Cold & Dark Strategy
  - Flush & Drain Systems



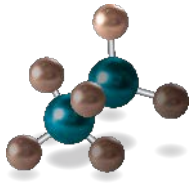


Characterization

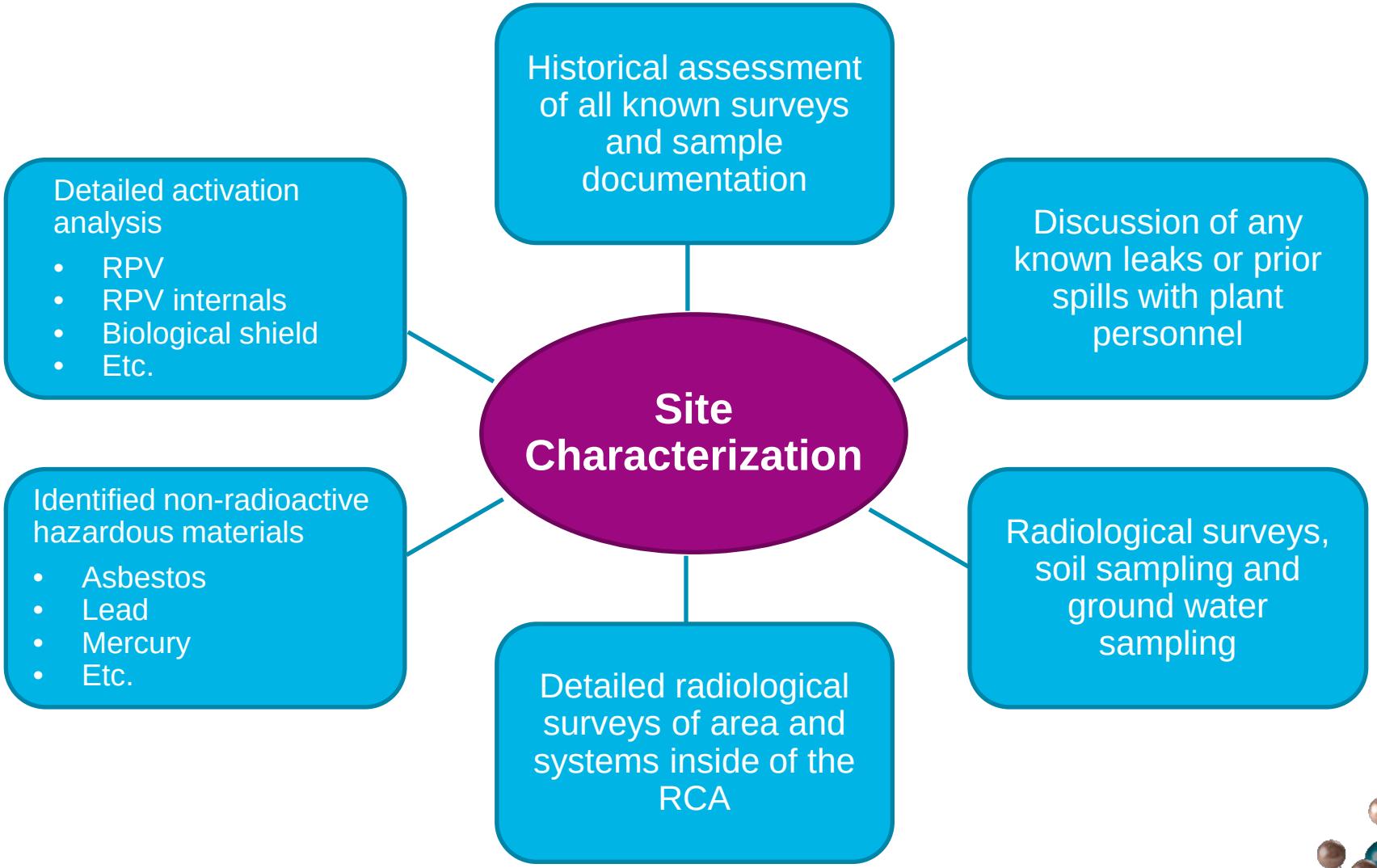
Site Characterization

- Primary Goal: Obtain enough understanding of the location and concentration of contaminants on the site to make project strategy decisions
  - Confirm the extent of known contaminates
  - Identify unknown contaminates at the Site → Characterization strategy should be developed to enable this

- Thorough characterization is critical for:
  - Defining the project scope
  - Bounding project costs and risks
  - Establishing a sound basis for planning
  - Validating compliance with the D&D Generic Environmental Impact Statement



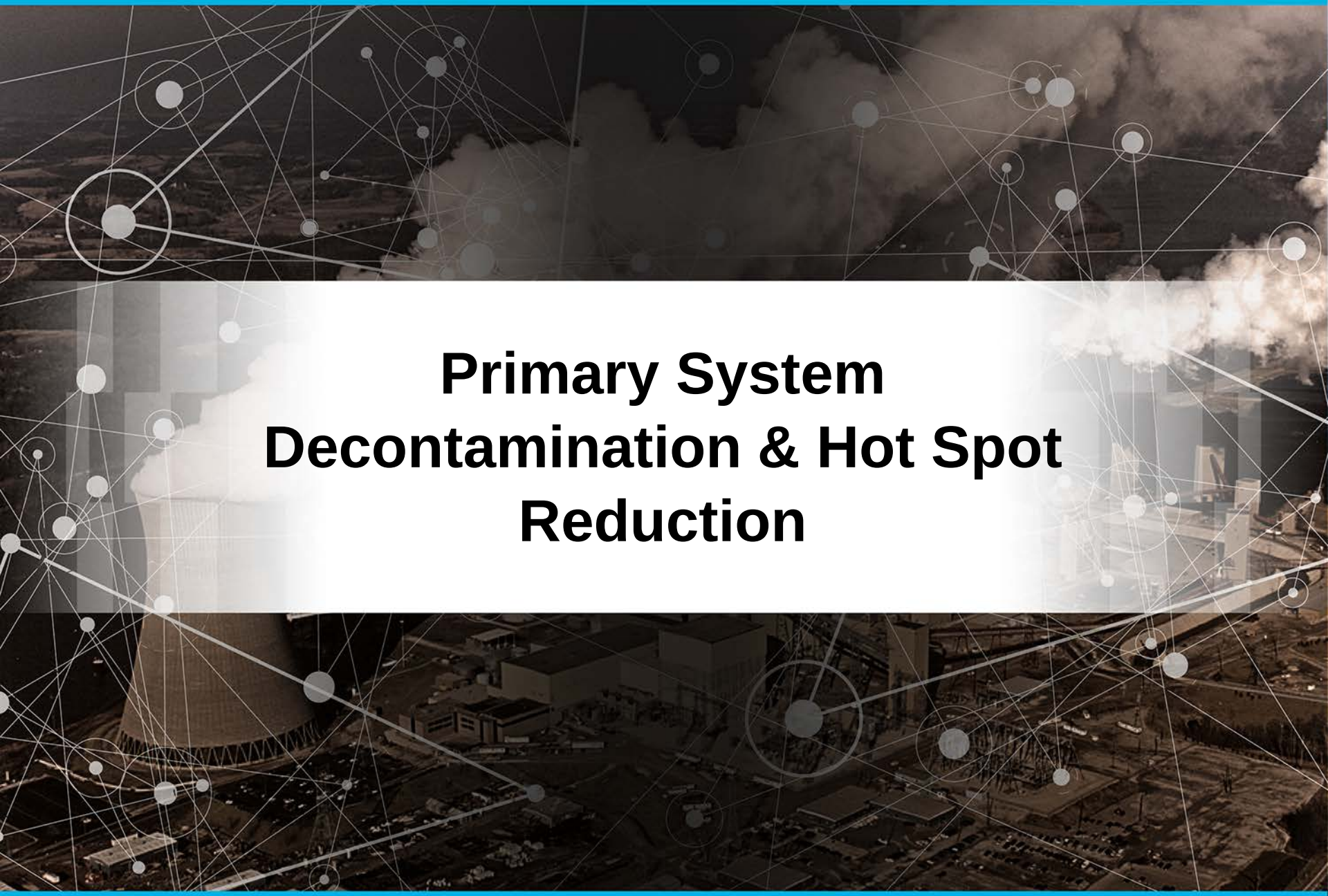
Site Characterization



Connecticut Yankee Characterization

- CY's characterization was not initially comprehensive
- The characterization was enhanced in 2003 before major dismantling
- Extensive Cs-137 and Sr-90 groundwater contamination from the tank farm was identified late in the process

Significant unplanned soil remediation efforts

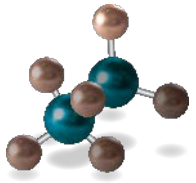


Primary System Decontamination & Hot Spot Reduction

Primary System Decontamination CY and Maine Yankee (MY)

Connecticut Yankee	Maine Yankee
Siemens CORD D UV	EPRI Decontamination for Decommissioning (DFD)
DF 15.9	DF 31.5
• Used installed plant equipment • Improper maintenance following permanent shutdown → Leaks → Decon halted → Reduced DF	Generated higher waste volumes compared to CORD D UV

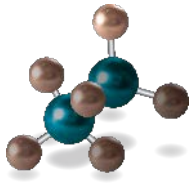
CORD D UV: Chemical Oxidation Reduction Decontamination, Decommissioning, Ultra Violet
EPRI: Electric Power Research Institute
DF: Decontamination Factor



CY Primary System Decon Lessons Learned

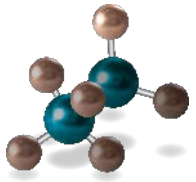
Purpose of Primary System Decontamination	Important Considerations
Reduce dose to plant personnel	• Has Co-60 already decayed since shutdown? • Are the cost savings of personnel dose greater than the cost of performing decontamination?
Reduce volume of higher-level solid waste	• Will decontamination reduce the waste classification of the Primary System? • Are the savings from reduced disposal cost greater than the cost of performing decontamination? • Will the decontamination process produce Level 1 waste (Class C or GTCC in US)?

- Data for deciding whether to perform Primary System Decontamination comes from the comprehensive Site Characterization.
  - If data support performing decontamination, start the process as soon as possible
- If using plant installed equipment, this equipment must be fully maintained until after completion of the decontamination process.



Connecticut Yankee – Hot Spot Reduction during D&D / WM Ops

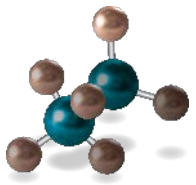
- In addition to the initial primary system full scale decontamination, CY utilized a **gamma camera** to survey different plant areas and determine hot spots in those areas that would impact worker personnel dose
- These hot spots were identified and removed independent of other operations



Spent Fuel Management

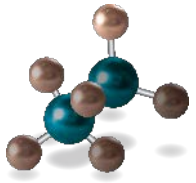
Spent Fuel Management

- US Department of Energy (DOE) was assigned responsibility to site, build, and operate a deep geological repository for the disposal of High Level Waste and spent nuclear fuel
  - There are no spent fuel reprocessing facilities in the US
- Repository Funding: Fee from electric utilities on nuclear-generated electricity
- DOE executed standard contracts with the nuclear utilities for the disposition of their spent fuel
  - DOE was expected to start accepting fuel in 1998
- DOE was unable to open the facility → Breached contract for spent fuel disposition
  - Many utilities have sued or settled with the US Government to pay for spent fuel management
  - 25% of US spent fuel inventory is at dry storage facilities (ISFSI)



ISFSI Spent Fuel Management @ 3 Yankees

- Centralized common corporate management for all 3 ISFSI facilities
  - Yankee Rowe
  - Connecticut Yankee
  - Maine Yankee
- Each site has limited management personnel and security staffing
- Common services are performed by common resources
  - Licensing
  - Engineering
  - Project support
  - Financial services, etc.
- Sites implement a “firehouse” approach: security staff also performs monitoring and maintenance of the facilities on a rotating basis

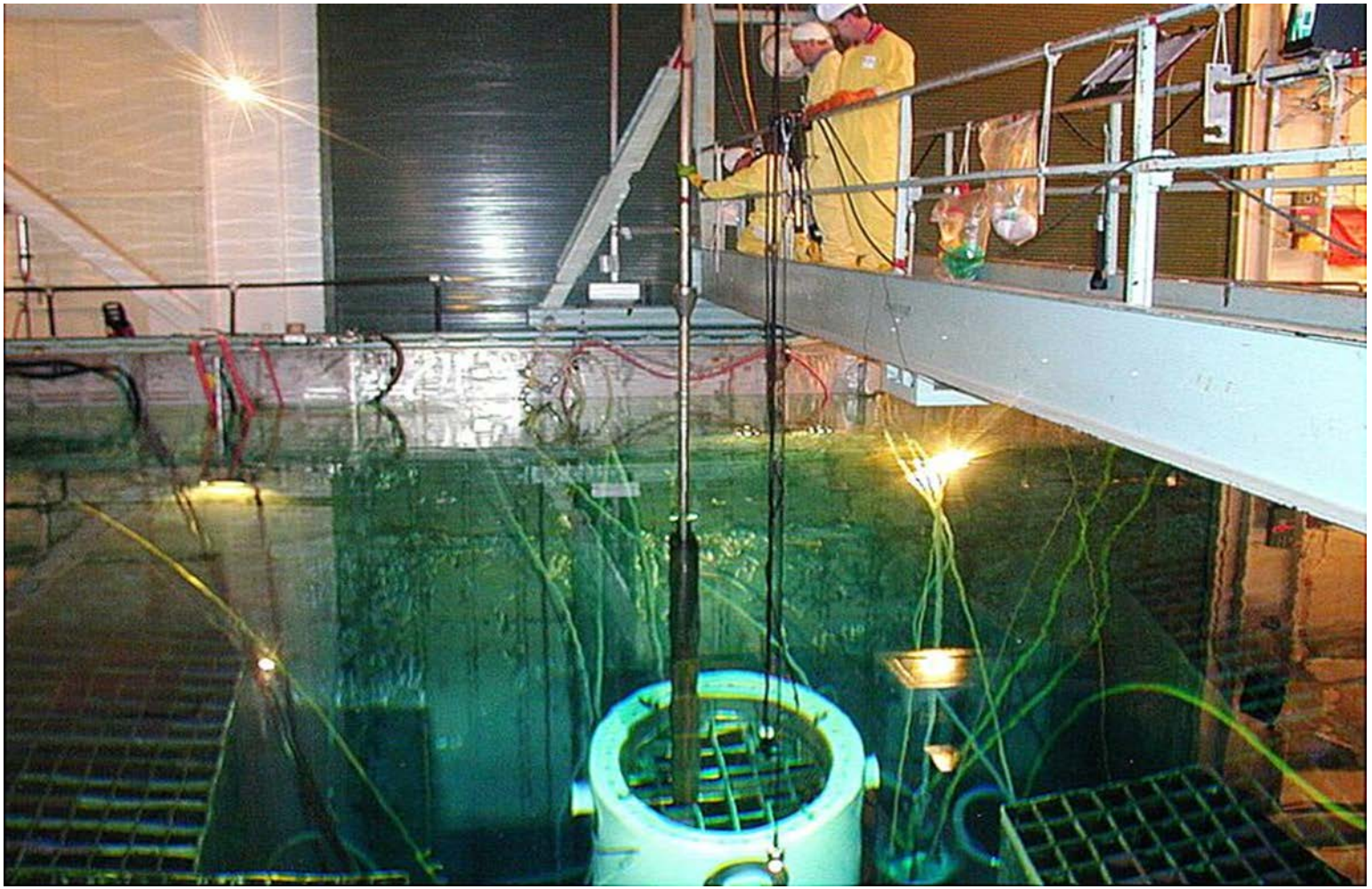


Connecticut Yankee Spent Fuel and GTCC Waste

- **Canister Type:** NAC Multi-Purpose Container (MPC)
- **USNRC Docket/Certificate of Compliance:** 72-1025
- **Number of Fuel Assemblies:** 1,019 (1,825 MWth Westinghouse fuel)
- **Number of Fuel Assemblies per Canister:** 24 - 26
- **Number of Canisters of Spent Fuel:** 40
- **Number of Canisters of HLW:** 3
  - GTCC (Level 1 in Japan) RPV internals segmented via ultra-high pressure abrasive water jetting
  - Cut and loaded into 64 fuel assembly sized canisters
- All spent fuel is currently stored on the ISFSI pad at CY

Vertical Concrete Cask (VCC)

Spent Nuclear Fuel Loading



– Dependent on fuel utilization, fuel assemblies may require cooling in the spent fuel pool for 5 to 7 years prior to being able to load into dry storage canisters

Connecticut Yankee ISFSI Facility

- Involve stakeholders early in ISFSI siting and spent fuel management operations
- Moving fuel from wet to dry operations has significant impact on decommissioning schedule

Dismantlement & Demolition

Connecticut Yankee – Sequence of Dismantling Operations

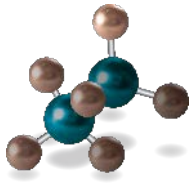
– Reactor Pressure Vessel (RPV) and Large Components
  - RPV Internals
  - 4 x Steam Generators and Pressurizer
  - Reactor Coolant Pumps & Motors
  - Primary Loop & Surgical Removal of Contaminated Systems
  - Reactor Pressure Vessel

– Facility Demolition
  - Primary Auxiliary Building / Control Building / Service Building
  - Turbine Building
  - Containment Building
  - Spent Fuel Building

– Soil and Groundwater Remediation Cleanup

Three parallel critical paths

- Fuel transfer to ISFSI and SFPI D&D
- Containment Building D&D
- Tank Farm / PAB remediation and groundwater restoration / monitoring



Connecticut Yankee – Large Component Removal Photos

2

3

1

Photos Clockwise from left:

1. RCP (Reactor Coolant Pump) Removal
2. Pressurizer Removal
3. S/G Lower Assembly Removal
   - At CY, the steam domes were removed and dispositioned as non-rad waste
4. RPV Removal & Packaging

4

Connecticut Yankee – March 2005

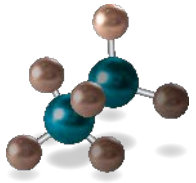
Connecticut Yankee — August 2005

Connecticut Yankee — January 2006: 85% complete

Connecticut Yankee — August 2006

CY — Significant Dismantling Challenges

- Soil & Groundwater Remediation
  - Continuous pump and treat system used to lower groundwater table to allow soil excavation/removal
  - Large amounts of soil excavated up to 40 feet (12.3 m) deep to bedrock
- Soil Remediation required prior to removal of adjacent structures
  - Required temporary structure support
  - Strategic planning for soil haul routes
  - Multiple shift operations
  - Alternative packaging containers
- Due to the contamination levels under the Tank Farm, soil remediation had to be performed under a containment tent

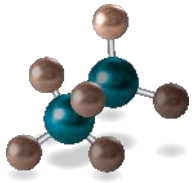


CY — Soil Excavation and Remediation

Photos show extensive soil excavation and remediation of below grade contaminated areas under the Primary Auxiliary Building (down to bedrock)

CY – Additional Dismantling Challenges

- Containment structure demolition had to begin prior to work completion in the Spent Fuel Building (structures were 15 cm apart)
  - Devised innovative method to remove the containment structure from bottom to top
  - Allowed work to continue safely in the Spent Fuel Building
  - Allowed for safe rubblization of structure for packaging and off-site shipment
  - Method was devised based on experience gained from MY Containment demolition
    - This methodology required significantly less time compared to MY
    - MY used explosive demolition, which requires extensive planning time
- Heavy equipment was used to access and remove contaminated systems
  - Maximized the safer use of yellow iron and equipment for removal instead of manual labor and small tools
- Temporary waste storage areas had to be established to stage outbound waste shipments
- Containment tents were assembled to allow outdoor processing



Connecticut Yankee – Containment Structure Demo

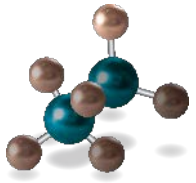
CY – Containment Structure Demolition

CY – Containment Structure Demolition

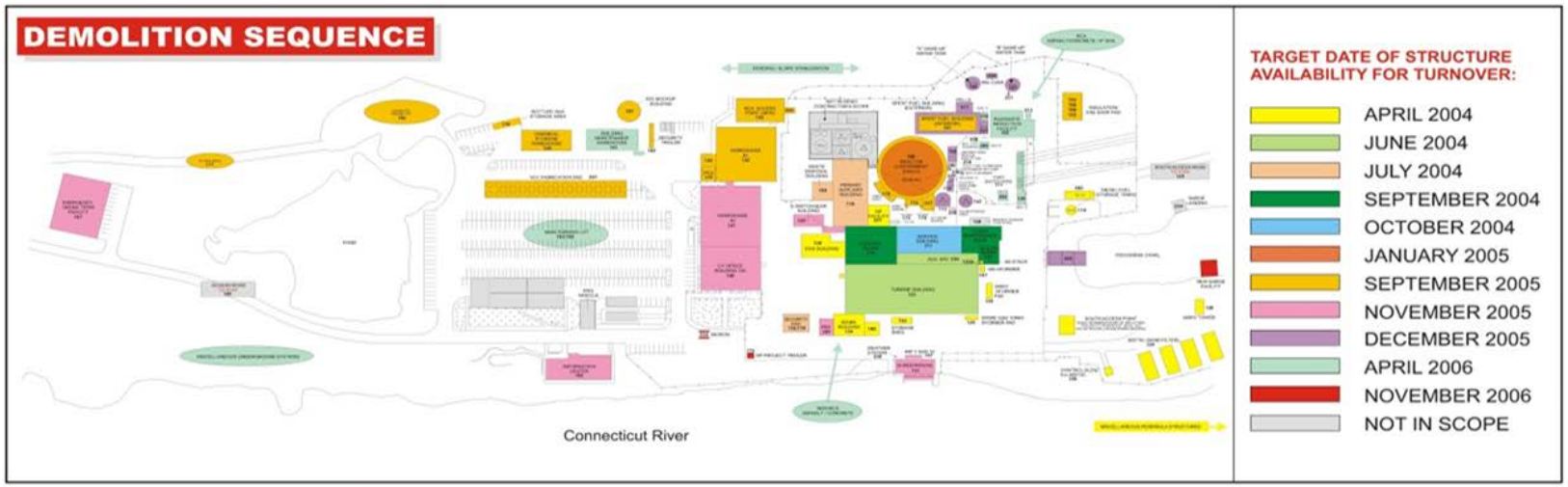
– AECOM has employed this demolition technique on another containment structure in the USA

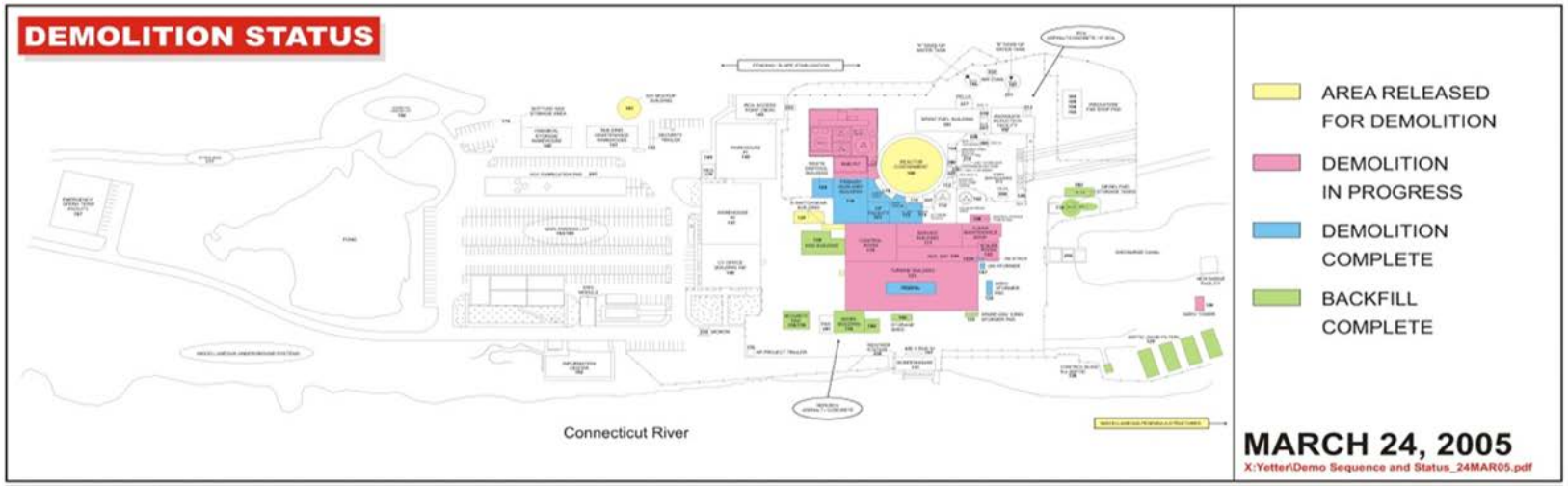
Schedule Reduction at CY from Lessons Learned at MY

- Demolition Approach: “Rubblization and Direct Disposal”
  - Demolishing a structure with some systems still in place
  - Processing all of the resulting materials as Exempt or BSFR waste (in Japan, Level 3)
- Advantage: Despite higher waste volume, lower overall project cost and reduced risk compared to labor-intensive decontamination and surveying
- Result: 1 year schedule savings for the last 70% of the CY project
- Additional Considerations
  - Shorter schedule → Rate of off-site waste shipments must increase
  - Avoid double handling & processing: integrate packaging where possible directly from the demolition activities



CY Demolition Sequence & Status Map



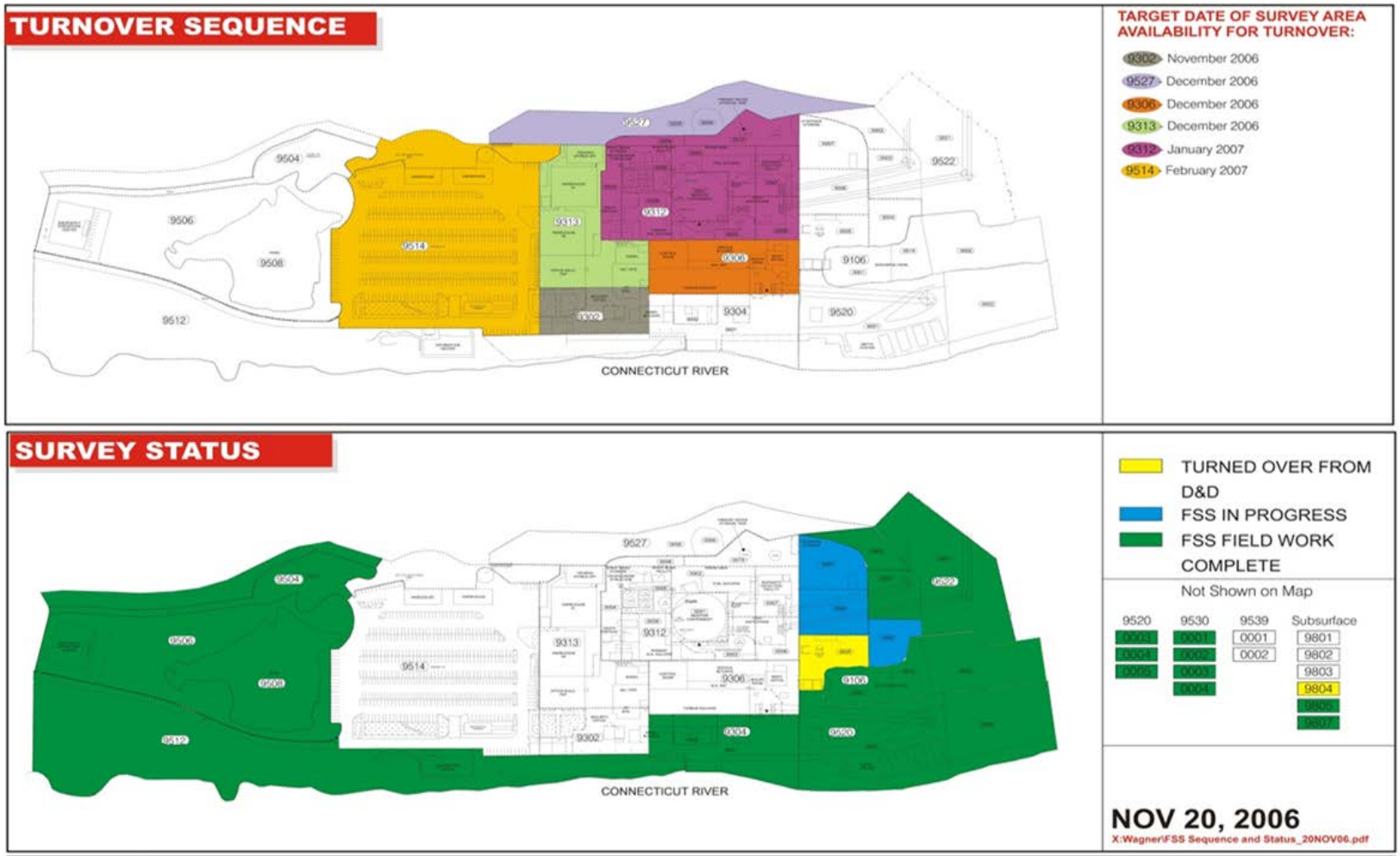


Plant North

CONNECTICUT YANKEE ATOMIC POWER COMPANY
GENERAL ARRANGEMENT DRAWING

DEMOLITION SEQUENCE AND STATUS

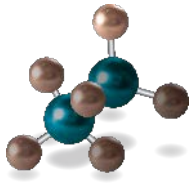
CY Final Status Survey (FSS) Sequence & Status Map



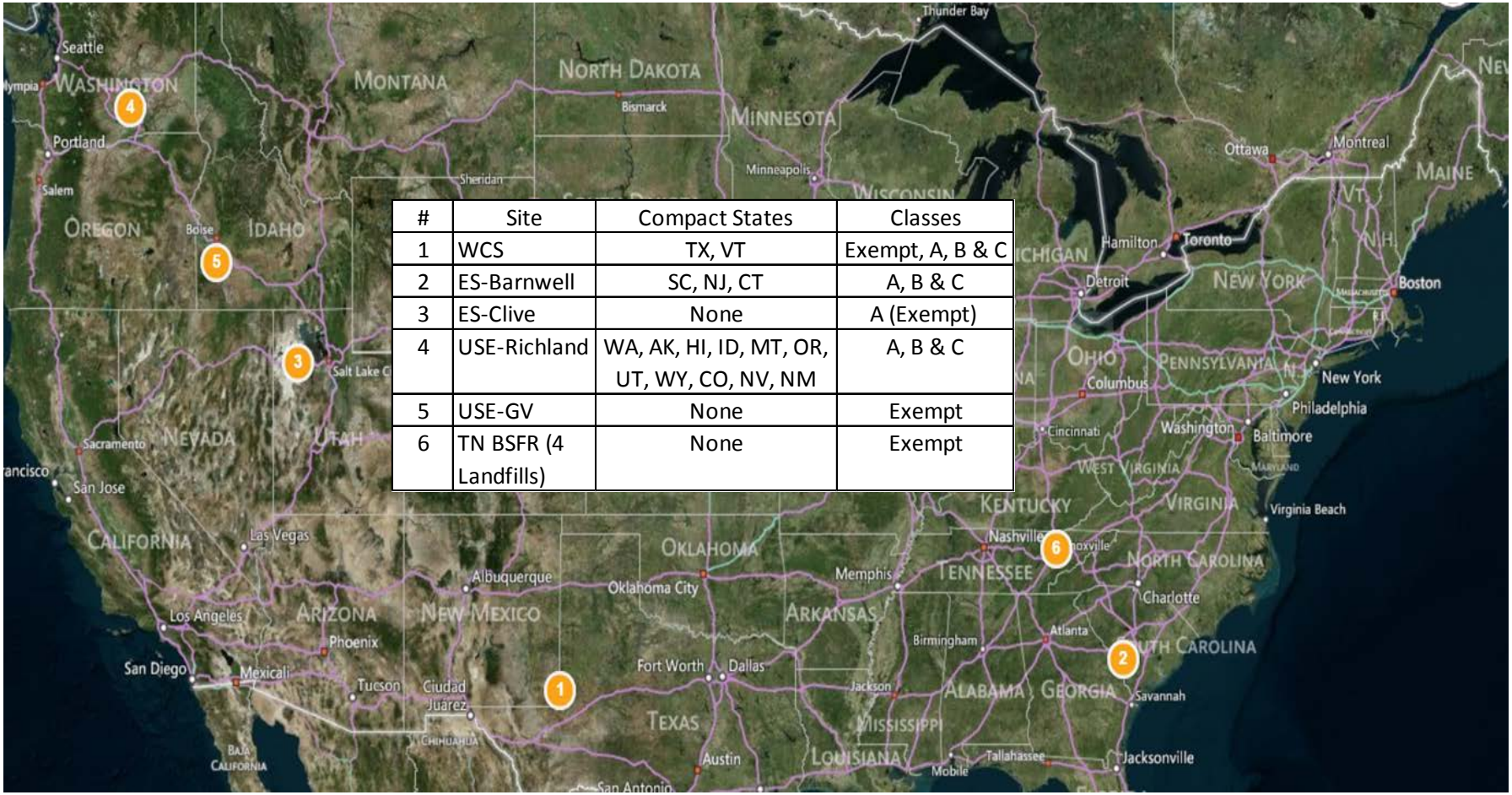
Waste Treatment and Disposal Options in the USA

Radwaste Classifications In the USA

- Exempt / Bulk Survey for Release (BSFR)
  State of Tennessee BSFR Program & NRC 10 CFR 20.2002
  - Allows for disposal in RCRA-type landfills (non-radioactive hazardous waste)
  - Must provide dose analyses showing less than 10 µSv/year to the public
  - Criteria similar to the Level 3 waste category in Japan
- Class A waste (NRC 10 CFR 61.55)
  - Suited for shallow land disposal
  - Usually segregated from other waste types in the disposal site
  - Most waste fits within Level 2 waste category in Japan
- Class B/C waste (NRC 10 CFR 61.55)
  - Waste must meet more rigorous requirements on form to ensure disposal stability
  - Class C waste requires additional measures at the disposal site to prevent inadvertent intrusion
  - Falls between Level 2 and Level 1 waste categories in Japan
- Greater than Class C waste (NRC 10 CFR 61.55)
  - Primarily RPV internals
  - Stored with the spent fuel on ISFSI pads
  - Level 1 waste category in Japan



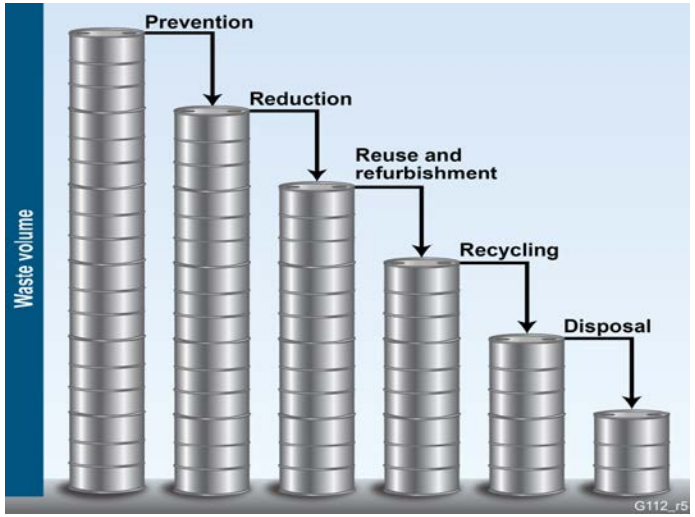
Location of LLW and Exempt / BSFR Disposal Sites in the USA



#	Site	Compact States	Classes
1	WCS	TX, VT	Exempt, A, B & C
2	ES-Barnwell	SC, NJ, CT	A, B & C
3	ES-Clive	None	A (Exempt)
4	USE-Richland	WA, AK, HI, ID, MT, OR, UT, WY, CO, NV, NM	A, B & C
5	USE-GV	None	Exempt
6	TN BSFR (4 Landfills)	None	Exempt

Off-Site Waste Treatment Options in the USA

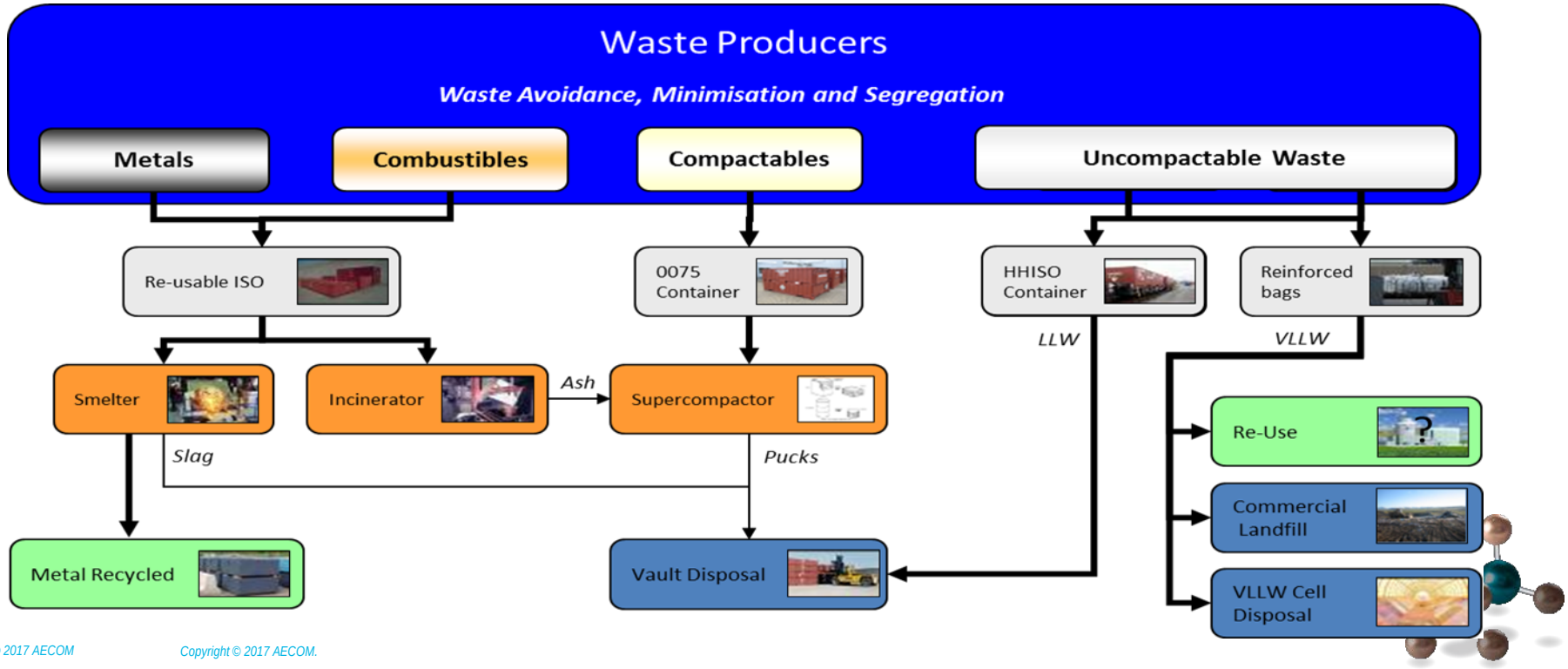
- Bear Creek Processing Facility
  - Sort and Segregation
  - Compaction: VR 6:1 (Dry Active Waste)
  - Incineration: VR 100:1
  - Metal Melt (Recycling into shield blocks)
- Resin processing (THOR process) Erwin, Tennessee
- Other facilities exist for Specialty Wastes with limited potential for use during D&D operations



Classification	Typical Processing	Reason
BSFR Class A	None, direct disposal	Treatment not cost effective • Disposal options available • Competition reduces disposal costs
Class B Class C	Off-site Treatment & Volume Reduction	Avoiding high disposal costs justifies treatment

Waste Optimization - UK

- Limited disposal options or direct disposal costs are too high
  → Processing and treatment becomes cost-effective
  - On-site or at dedicated process and treatment facilities
- In the UK, AECOM manages the country's Low Level Waste Repository (LLWR) and the National LLW Strategy
  - Manage the destiny of all the UK's LLW to minimize the amount disposed in the LLWR
  - Segregation, packaging, transport, recycling, incineration, supercompaction, and metal melt



Connecticut Yankee Waste Disposition

Connecticut Yankee — Waste Volumes and Categories

Estimated waste masses & volumes from the Connecticut Yankee D&D

	lbs	ft^3	tons	MT	m^3
Contaminated Structures / Soils	374,001,107	3,667,033	187,001	169,647	103,838
Large Components	2,751,812	25,309	1,376	1,248	717
Systems and Components	28,247,081	500,309	14,124	12,813	14,167
Total - Contaminated SSCs	**405,000,000**	**4,192,651**	**202,500**	**183,708**	**118,722**

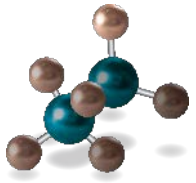
Approximate breakdown by waste classification

	Mass (Metric Tons)					
	Class A	Class A - Shielded	Class B/C	GTCC	Class A / BSFR	Total
Contaminated Structures / Soils	1,808	-	-	-	167,839	**169,647**
Large Components	901	178	33	9	129	**1,248**
Systems and Components	3,848	203	-	-	8,762	**12,813**
Total - Contaminated SSCs	**6,557**	**380**	**33**	**9**	**176,730**	**183,708**

~80% to 85% of materials inside of the RCA can meet BSFR / Exempt requirements

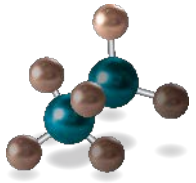
CY - General Highlights of Treatment and Disposition

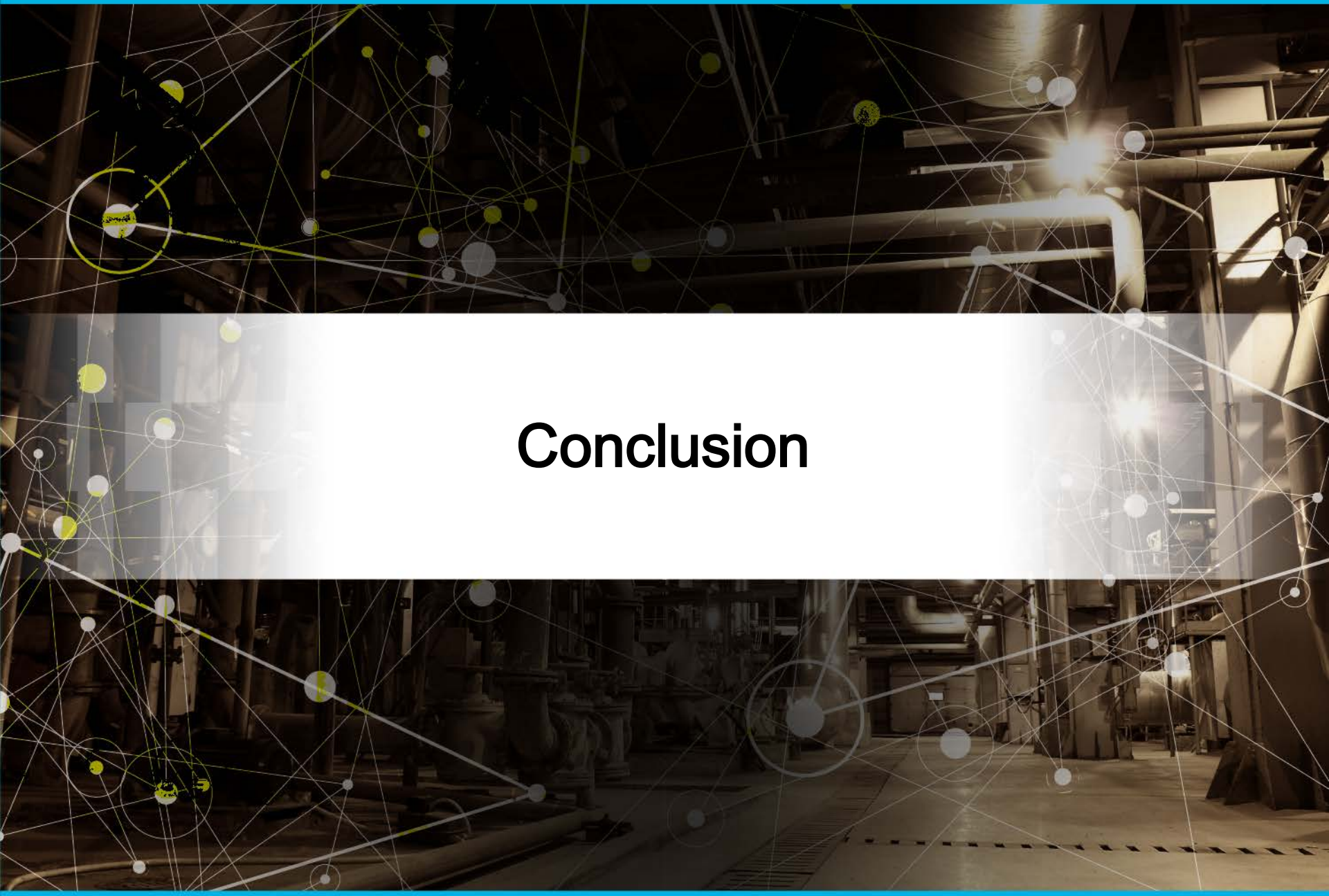
- Segregation of waste → Maximize BSFR sent to Tennessee landfills
- Concrete debris → Size Reduced for lower disposal cost
- Waste sent to Clive Disposal Facility
  - Majority classified as Exempt Quantity (49 CFR 173.436)
  - This waste could also have met requirements to be BSFR material
- Direct burial of large components
- Resins and filters (Class B/C) → Sent to off-site processing
- Debris and soil (Class A) → Direct burial
- Waste water treatment operations in parallel with D&D operations
- Various transportation methods
  - Truck with intermodal container
  - Barge slip
  - No on-site rail available
  - Heavy haul transport
  - Truck → Transfer to rail



Connecticut Yankee — Waste Management Challenges

- Additional volume of waste generated due to contaminated soil removal
- Off-site waste shipments could not keep up with waste generation from D&D activities
  - CY had no on-site rail connection
  - ➢ Waste management had to be horizontally integrated into all site project operations
- Competitive disposal pricing: Connecticut Yankee faced higher prices

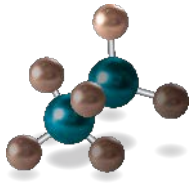




Conclusion

Lessons Learned

- *"Rubblization and direct disposal"* is generally more cost effective than a *"decontaminate and segregate"* approach
  - Choice is based on a project specific cost benefit analysis driven by waste disposal options and disposal pricing for each plant
  - AECOM has utilized both approaches in prior D&D work
- 80% or more of the LLW will be classified as BSFR or Exempt
- Waste stream characterization must be accurate, thorough, and early
  - Waste characteristics known prior to waste generation
  - Develop a comprehensive plan for disposition of all waste streams
- Decommissioning → High volume and high production-rate waste disposal
  - Vastly different scale from waste management during operations
  - Relevant experience and processes are critical to success
- Start by fully understanding the existing waste options and create opportunities that may not presently exist
  - For example, dispose of Exempt (Level 3) waste on site if it meets the site release criteria



Lessons Learned

- Decommissioning is often referred to as a “large waste project”, but understanding the full scope of the work is critical
  - Reliance on waste experience alone → Missed opportunities for efficiencies and cost savings
- Plan for establishing a Waste Management area on site
  - Waste Handling & Packaging areas require a large dedicated footprint
  - Storage areas can impact background radiation levels in areas planned for characterization or Final Status Surveys
  - Plan the eventual relocation and elimination of the waste handling, packaging, and shipping area
- Waste Management inefficiency can slow the entire project
  - Maintain redundancy in handling equipment (fork trucks, survey instruments, scales, etc.)
  - Perform on-site inspection and repair of shipping containers
    - Maintain at least a rudimentary welding program
    - Set-up a repair area and segregated storage for damaged containers
    - Establish a simple process to visibly identify damaged containers
  - Invest in simple equipment to support safe inspection and survey of shipping containers such as stair towers
  - Develop a simple and robust process for releasing waste shipments from the site