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Research Maps

– Tools for Aligning Fundamental and Applied Research with Operations

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Savannah River National Laboratory

November 8, 2016

SRNL-MS-2016-00204

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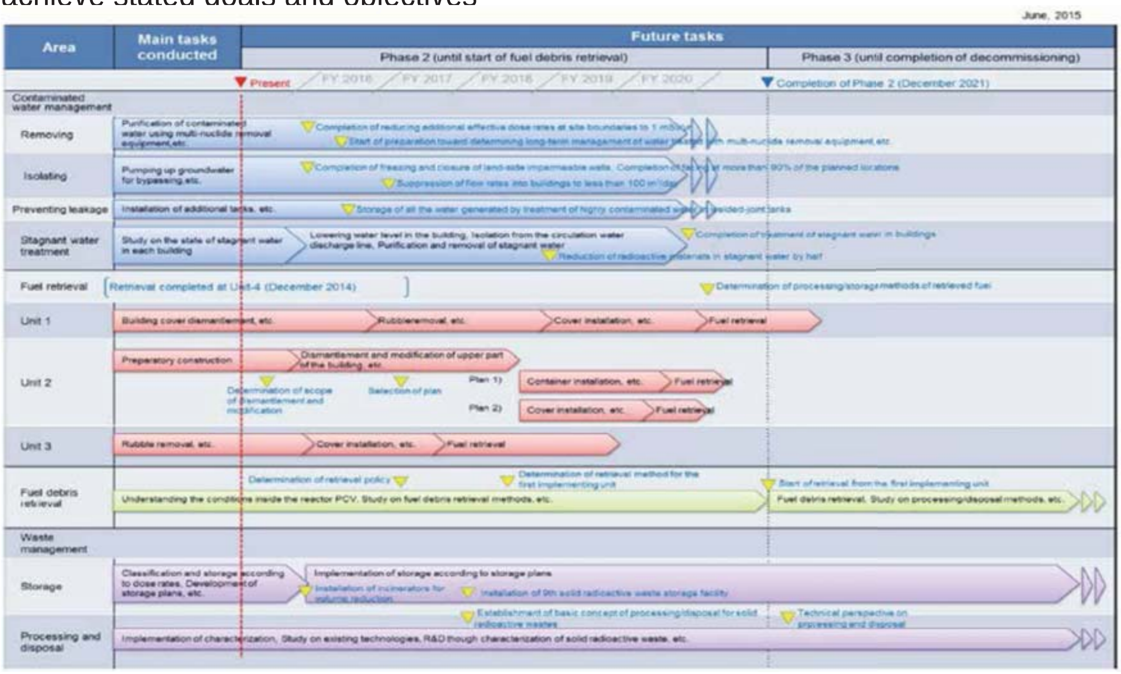
Presentation Outline

- Introduction
  – Roadmaps & Research Mapping
  – Tools & Process
- Examples
  – Environmental Remediation
  – Waste Treatment
- Value Proposition

Definitions / Context

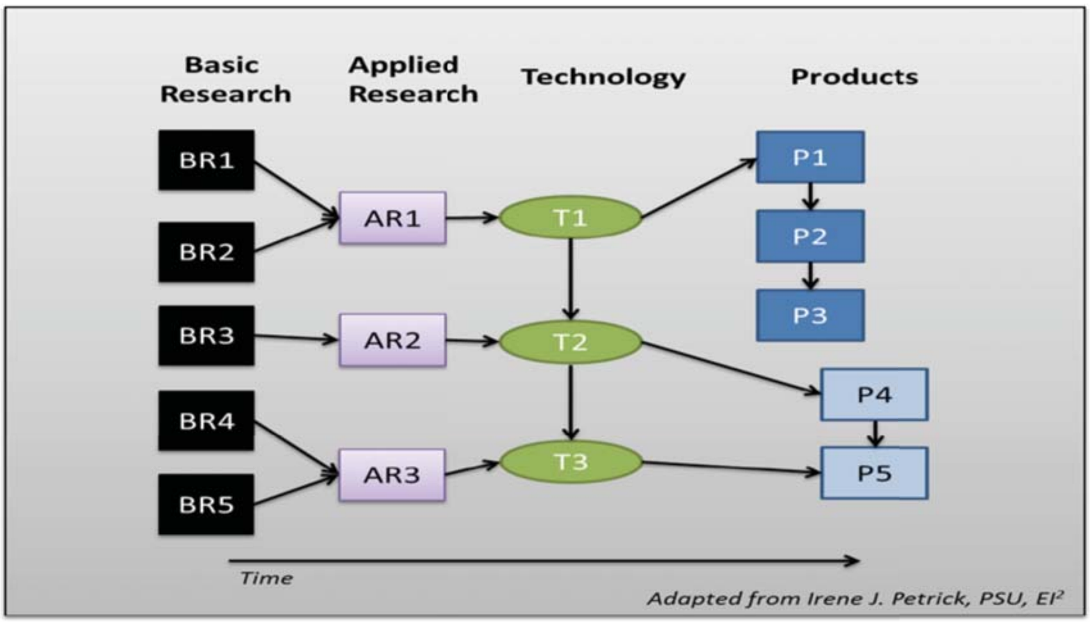
- Roadmaps
  - Graphical, long-range strategic plans that identify activities and schedules necessary to achieve stated goals and objectives



Source: Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station, June 12, 2015, Inter-Ministerial Council for Contaminated Water and Decommissioning Issues

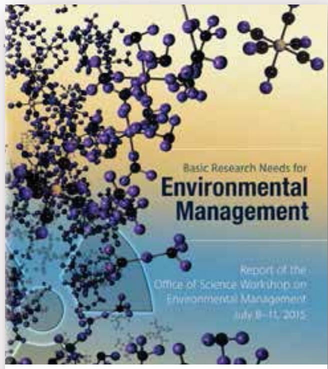
Definitions / Context

- Research Map
  - A type of Science & Technology Roadmap, focused on linking underlying scientific knowledge and technological advancements for desired improvements to existing (baseline) operations

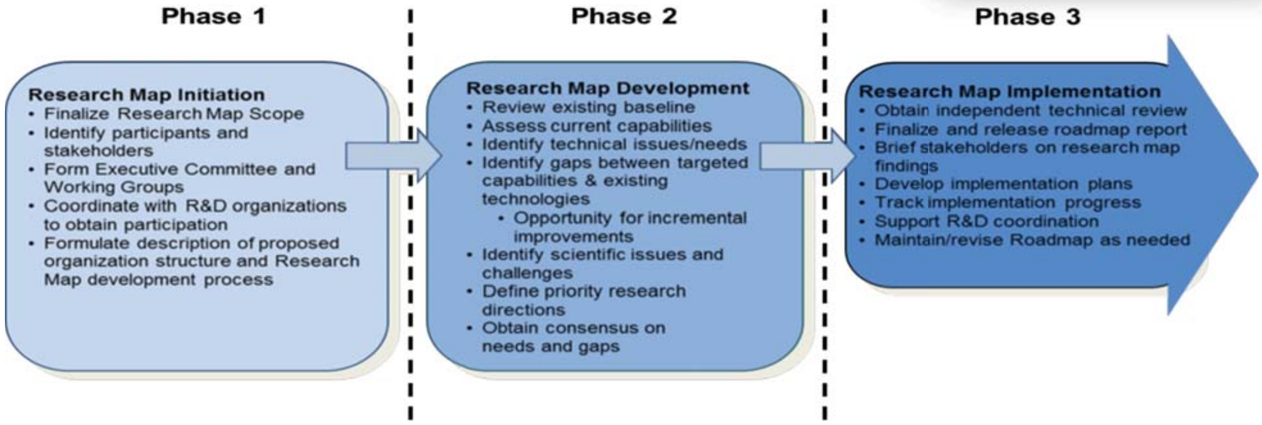


Definitions / Context

- Mapping (Process)
  - The flexible process by which a roadmap / map is created, implemented, monitored and updated.
    - *Structured framework*
    - *Various approaches / techniques / outputs*

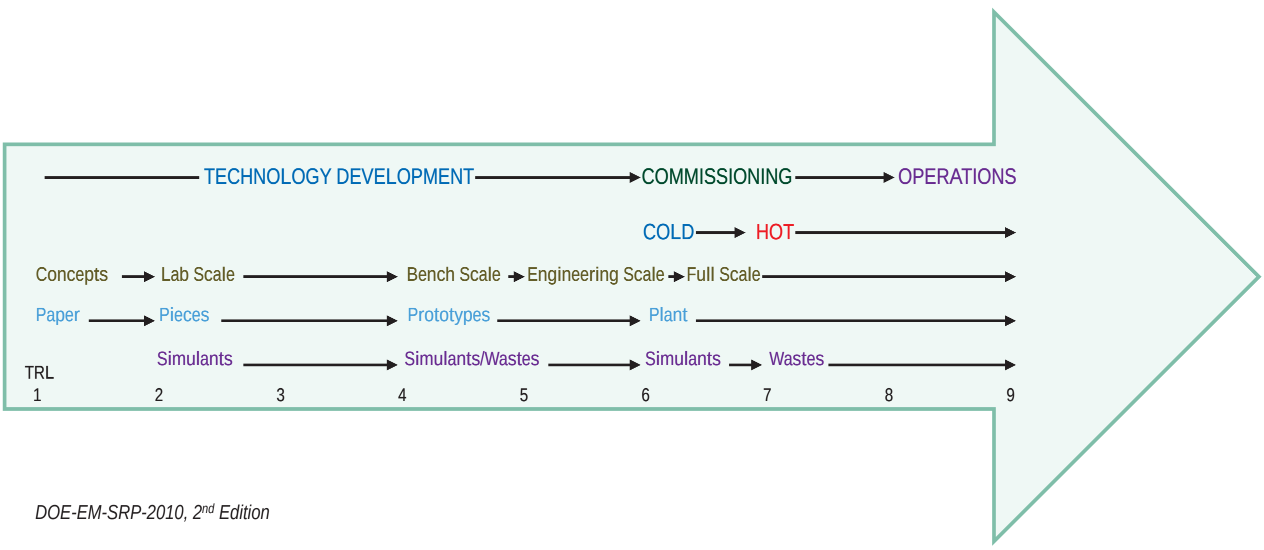


http://science.energy.gov/~/media/bes/pdf/reports/2016/BRNEM_rpt.pdf



Technology Readiness

- Technology Readiness Assessments
  - An assessment of technologies and their readiness for insertion into the project design and execution schedule
- Technology Readiness Levels (TRL)
  - An indication of the maturity of a given technology

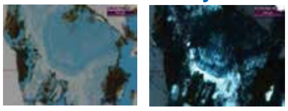


DOE-EM-SRP-2010, 2nd Edition

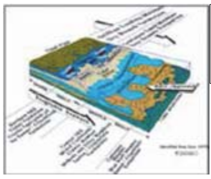
In Situ Groundwater Treatment System – Savannah River Site

Basic Geochemistry ⇔ Applied Lab and Field Studies ⇔ System Design and Optimization ⇔ Deployment

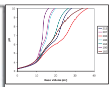
Subsurface Contaminant Geochemistry



Study of inter-related topics: solution-solid-contaminant interactions, potential treatment amendments, and long term stability of in-situ stabilized phases



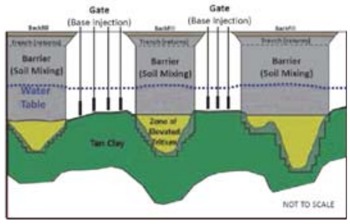
Focus on natural and plume induced facies and the chemical dynamics at the leading and trailing edges of the plume



Column studies and pH titrations of plume impacted aquifer sediments

Confirmatory field studies

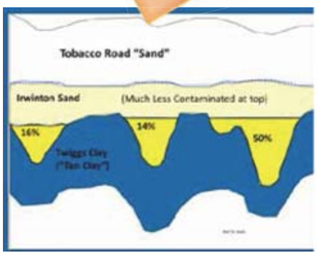
Development of innovative treatment reagents



In Situ Treatment using Wall and Gate for Combined Hydrologic and Geochemical Control

Problem: Groundwater Contamination from Seepage Basins

40 years of seepage basin operation resulted in low pH groundwater plume containing radionuclides and metals. 10 years of pump and treat had limited impact on the plume and cost over $12 million per year to operate.



Refined geological conceptual model and identified target areas of opportunity for in situ treatment deployment

Active work with stakeholders and regulators to facilitate transition from baseline pump & treat system to innovative in situ treatment

Installed bariers ("walls") to block plume and force water through treatment zones ("gates")

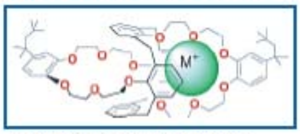
Alkaline treatment solution periodically injected into the gate area to create permeable reactive treatment zone to immobilize contaminants

Savings: $300M

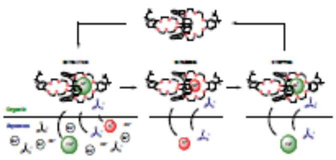
Solvents for Cesium Removal – Savannah River Site

Molecular Modeling ⇔ Solvent Performance Applied Studies ⇔ Performance Optimization ⇔ Deployment

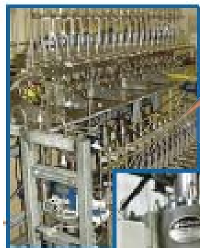
First Generation Solvent



First Generation Cesium Solvent BobCalixC6 formulated by ORNL



Cesium Capture and Release Process Optimization for BobCalix

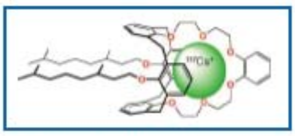


DOE-EM Process Optimization Testing

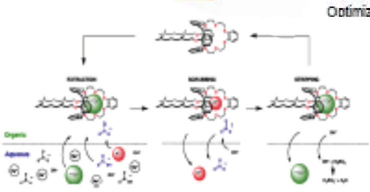
Full-scale Testing

ARP-MCU – Pilot Scale Operating Facility

Next Generation Solvent



Leveraged additional basic research for a more soluble extractant called MaxCalix

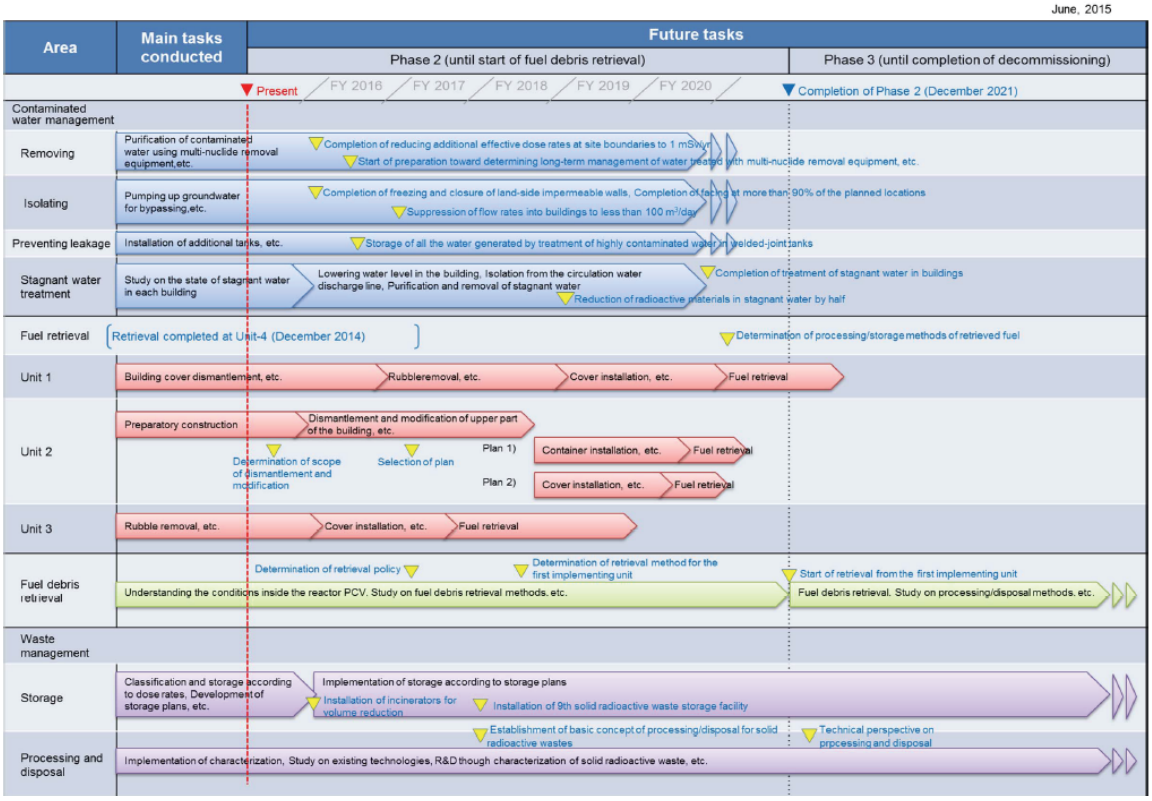


Cesium Capture and Release Process Optimization for MaxCalix

SWPF – Full Scale Operating Facility

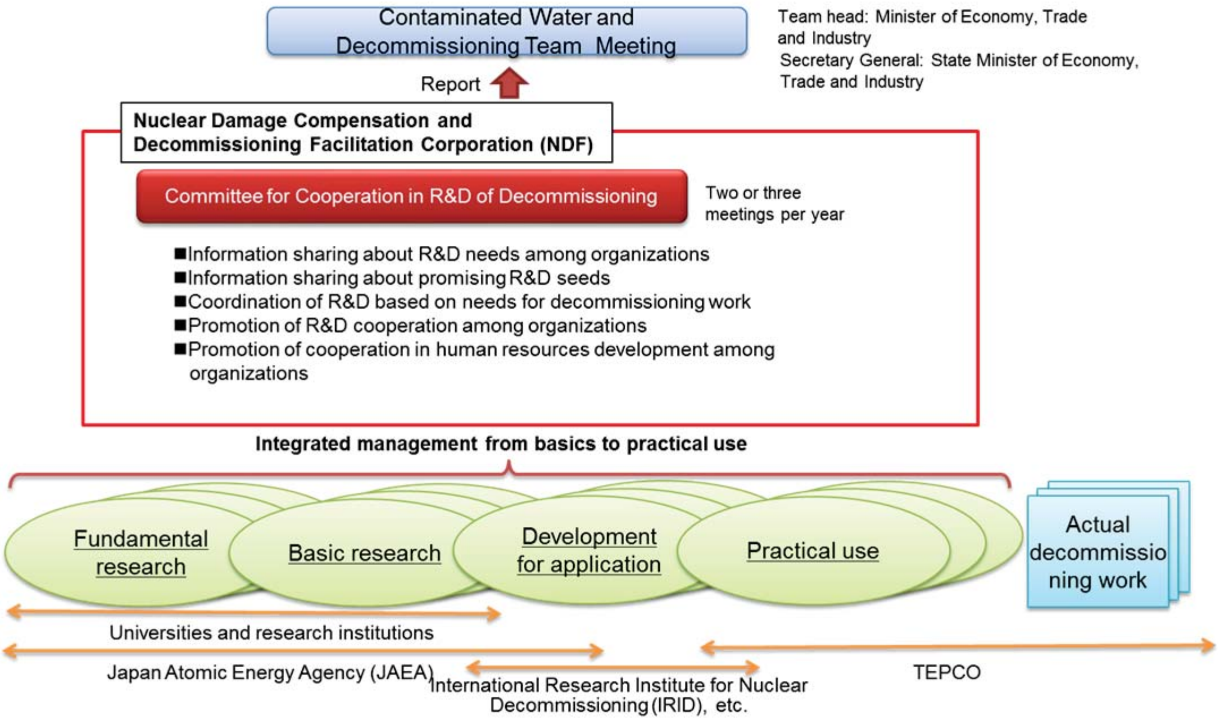
Savings: $600M to $1.8B

Main Processes for the Decommissioning of Fukushima Daiichi NPS



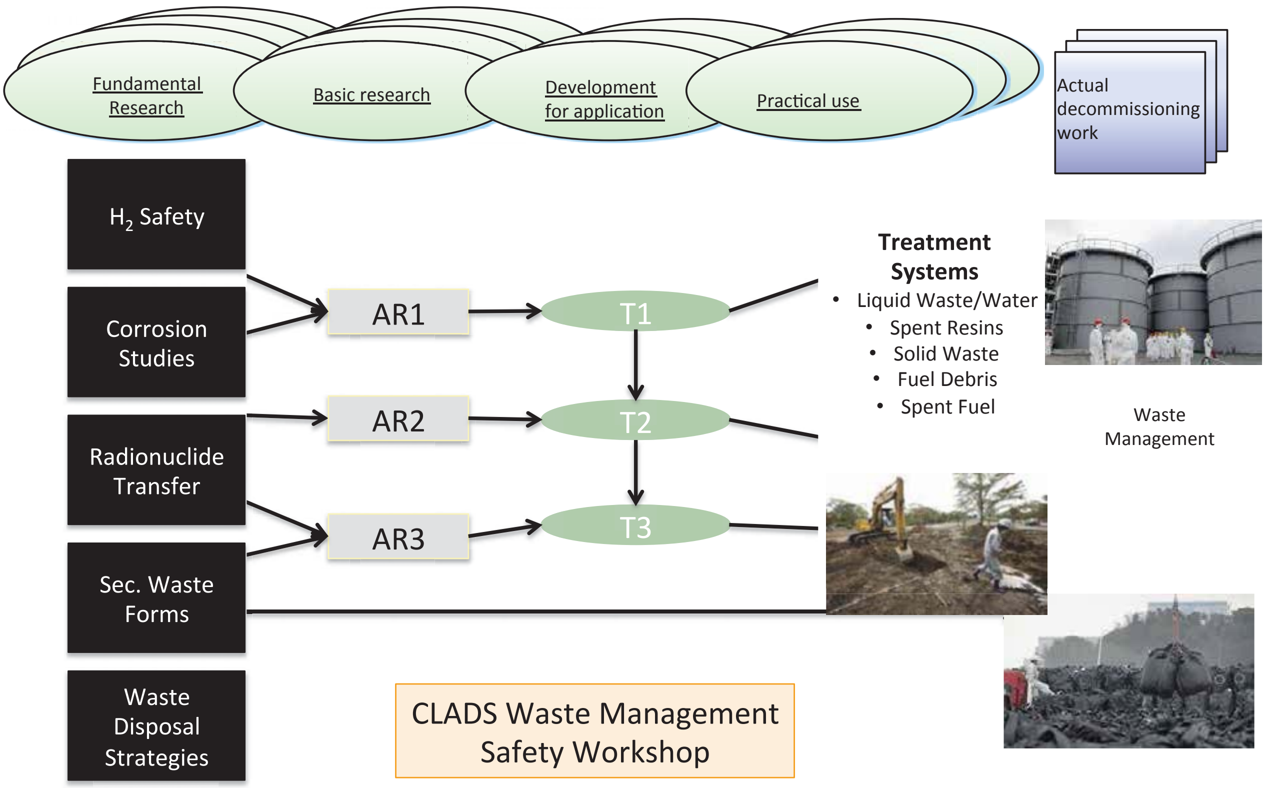
Source: Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station, June 12, 2015, Inter-Ministerial Council for Contaminated Water and Decommissioning Issues

Integrated Management from Fundamental/Basic Science to Practical Use



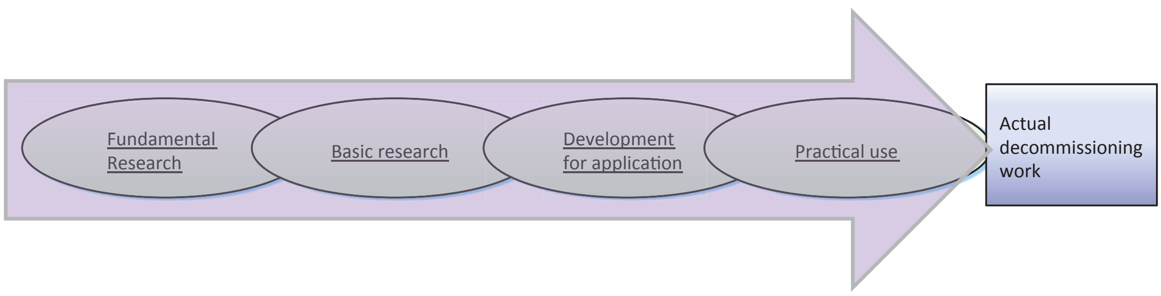
Source: Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station, June 12, 2015, Inter-Ministerial Council for Contaminated Water and Decommissioning Issues

Research Maps help bridge the gap between Basic Science & Application



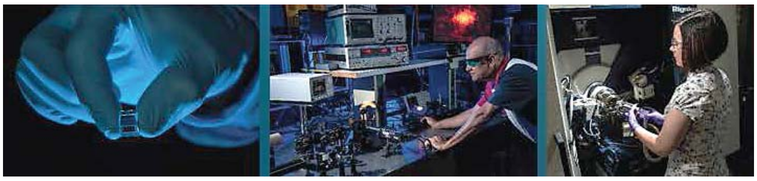
Research Mapping Value Proposition

- Solution-oriented method for aligning R&D with operational needs
- Illustrates the integration of Science, Technology and Practical Application
- Defensible basis for an R&D investment strategy
- Flexible to support decision-makers, scientists, general public
- Opportunity for broad, transparent stakeholder consensus building
- Applicable to long-term timelines



Thank You

Questions ?



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– Begin with the outcome in mind and match the solution to the problem

Legacy Waste Management in the United States

Roger Seitz
Environmental Restoration Technologies

Research Conference on Post-accident Waste Management Safety
Hosted by JAEA/CLADS
Iwaki, JAPAN

November 7, 2016

SRNL-MS-2016-00213

Introduction

The United States Department of Energy – Office of Environmental Management (USDOE-EM) is responsible for the largest cleanup program in the world

- Large quantities of waste containing radionuclides and non-radiological hazards are being managed
- Robust multi-criteria decision-making process involving external regulation and input from stakeholders

107 USDOE-EM sites - As of September 2012, cleanup has been completed at 90 of those sites (DOE Graphic)

Contents

- Waste Management Strategic Considerations
- D&D and Remediation Waste Disposal Examples
- Regulatory Approach
- Waste Management Strategy – Example Considerations for Solid Secondary Waste

Waste Management Strategic Considerations

Waste Hierarchy

– Prevent → Reduce → Reuse → Recycle → Dispose

Interdependence (Integrated Technical and Regulatory strategy)

- Costs, disposal needs, regulatory policies, etc. are factors for D&D, characterization, segregation, and treatment options
  – Treatment can increase volume & decrease concentration or vice versa, Potential for improper characterization?
- Waste Acceptance Criteria (store, transport, treat, dispose)?
- Volume of different categories of waste?
- Packaging and Transportation requirements ?
- Plans for reactor vessels and reactor components
  – Potential Intermediate-level waste/Greater than Class C in USA ? Disposal and/or storage needed?

Photos Courtesy USDOE

All Three D&D Options Applied in USDOE-EM (Safe Storage, Immediate Dismantlement and Entombment)


Hanford C Reactor – Safe Storage Enclosure

Safe Storage


Idaho - Reactor Vessel Disposal

Dismantlement/Disposal


SRS Vessel Disposal (HWCTR)


SRS Entombment (R Reactor)

Entombment

Photos Courtesy USDOE

Disposal Options for Remediation and Decommissioning Wastes

- USDOE-EM has the option of developing on-site disposal cells, disposal at the Nevada National Security Site (NNSS) or using commercial disposal facilities
- On-site disposal has been selected as the preferred alternative for large amounts of the waste (can be combined with off-site disposal of some waste)
- Transuranic (Intermediate-level) waste is disposed at the Waste Isolation Pilot Plant
- Spent-Fuel and High-Level Waste currently being stored


Energy*Solutions'* Clive disposal facility
(Courtesy: Energy*Solutions*)

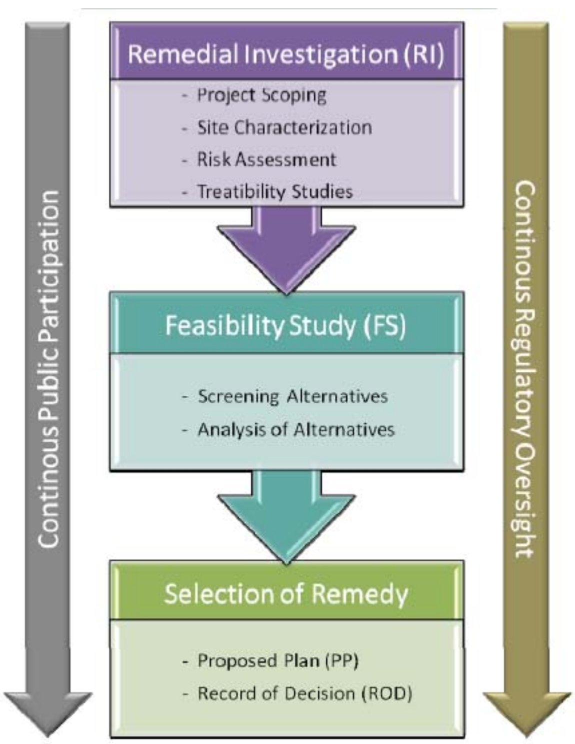
Waste Control Specialists Texas disposal facility
(Courtesy: Waste Control Specialists)

Examples of On-Site Disposal of Cleanup Waste (USDOE)

Photos Courtesy USDOE

Regulatory Context - Decision-Making Framework

- Most cleanup decisions are being developed under a US Environmental Protection Agency (USEPA) Regulatory Process
- Decision-making through formal process with continuous involvement of USDOE, USEPA, and State regulators and the public



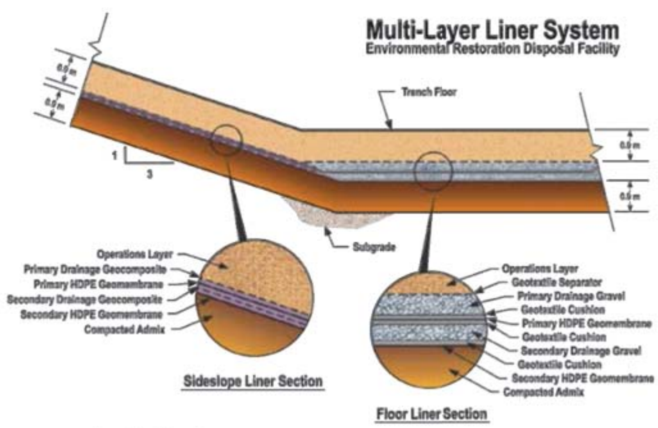
Key Elements of USEPA Process Applied to Remediation Waste

- **Risk goals rather than constraints**
- **Design standards for disposal facilities and treatment standards for hazardous waste forms (industrial waste) - "Prescriptive" regulation**
- **Modeling and characterization efforts to support decision-making**
- **Must meet USEPA requirements and USDOE requirements (USDOE and external regulator review processes are often conducted independently)**
- **Considers cleanup alternatives**
- **Nine criteria - Quantitative and qualitative assessment of potential impacts of different alternatives**
- **Following action, routine reviews (~5 year) are conducted to assess effectiveness of solution**

Nine Criteria
REGULATORY
Protect health and environment
Comply with Federal and State regulations
OPTIMIZATION
Long-term effectiveness (WAC)
Short-term effectiveness (workers, transportation)
Implementability (WAC, siting)
Cost-effectiveness
INTERESTED PARTIES
Regulatory acceptance
Community acceptance

Prescriptive Regulation – Advantages and Disadvantages

- Disposal facilities for cleanup waste are often designed to meet USEPA standards for hazardous waste disposal to address the non-radioactive hazards ("Prescriptive design-based standard")
- Use of standardized and accepted design helps to build public confidence, but introduces challenges if it is necessary to conduct long-term safety assessment
- USEPA prescribes specific treatment approaches for hazardous wastes
- Standard approaches are not always the best option for special cases, need flexibility to consider optimal solution (e.g., grouting of ion exchange resins)



Liner design at the Hanford Site

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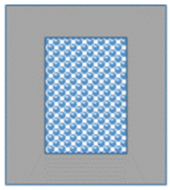
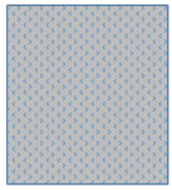
Solid Secondary Waste - Background

- Examples of solid secondary wastes and contaminants
  - HEPA Filters (e.g., Tc-99, Cr, I-129)
  - Ion Exchange Resins (e.g., Cs-137, I-129, Tc-99, Cr)
  - Activated Carbon Beds (e.g., I-129, Hg)
  - Silver Mordenite (e.g., I-129, Silver)
  - Miscellaneous Debris



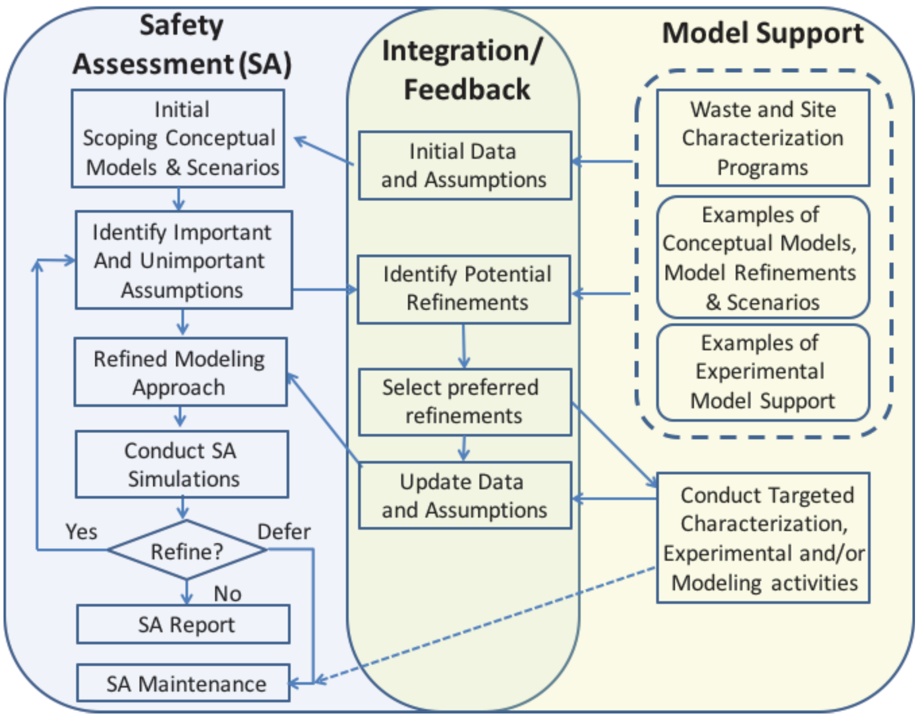
Encapsulation



Solidification

- Prescriptive treatment and disposal approaches in regulations for hazardous waste ("debris" and "non-debris") – e.g., encapsulation and solidification/stabilization using cementitious materials
- Safety assessment models for radioactive waste require numerous inputs (e.g., hydraulic conductivity, moisture characteristics, diffusion coefficients), but limited data are available
- Important to understand significance of uncertainties (inventory and properties) to help guide research priorities

Directly Link Research to Needs of the Safety Assessment (SA)



Flow of Information

"Model Support" is a term used to describe research and other supporting activities for the SA

Linking initial SA results with prioritization of data collection

Waste Form	Assumptions	Potential Data Needs	Vulnerabilities
HEPA Filter *Initial SA results suggest emphasis on this waste*	• Minimal credit for K_d and diffusion in HEPA filter • Encapsulated in oxidized material with paste properties	• Properties of clean encapsulation material, including redox • Diffusion coefficients and K_d (Iodine, Tc) for encapsulation	• Properties based on literature • Oxidizing conditions increase K_d for I-129
Organic Ion Exchange Resin	• Oxidized resin with no retention of contaminants • Stabilized, waste form has properties of oxidized mortar • K_d of waste form based on weighted average of K_d in waste & grout	• Confirm material properties of final waste form • Redox of final waste form • K_d of resin and diffusion coefficients in waste form	• Properties based on literature (mortar) • Hydraulic properties • Oxidizing conditions increase K_d for I-129
Activated carbon *Release rates are expected to be low, even with pessimistic K_d*	• Stabilized waste form has properties of oxidized mortar • K_d of waste form based on weighted average of K_d in waste and grout	• Confirm material properties of final waste form • Redox of final waste form • K_d of waste	• Defensibility of K_d and durability

Diffusion coefficients can be misunderstood

Organic Ion Exchange Resins – Considerations and Options

- Prescriptive treatment standard for “hazardous” resins (solidification/ stabilization in cementitious materials)
- Resins dewatered and sent for treatment in hydrogen form – oxidizing conditions (favorable for I-129, not favorable for Tc-99)
- Organic resins expand posing challenge for cementitious materials (hydraulic properties of solidified matrix may not be maintained)
- Grout formulation/waste form pretreatment needs to address potential expansion and provide sufficient long-term performance (Key question: Safety assessment can help determine what is sufficient?)
- Example Options (Blending, Place in container – no pretreatment, Pretreatment to swell resin (Na or Ca form) and solidify, etc.)



Strategic Considerations Tied to Road Map for Cleanup

- How well are the wastes characterized (what is the range of uncertainty)? How could uncertainty impact transportation, treatment, storage, disposal options?
- Is treatment increasing or decreasing concentration and volume of contaminants? Will there be limitations of effluents from treatment facility?
  - Disposal facility capacity and WAC considerations (will a more robust facility be needed for smaller volume of waste or is it more effective to dispose of larger volumes?), Will it be more difficult to store and transport a higher concentration waste?
- Would prescriptive regulations be helpful or limit availability of good options? Could solidification of the waste reduce performance (e.g., activated carbon or resin stabilization in cementitious material)
- If Tc-99 and I-129 are both present, would oxidizing or reducing conditions be more favorable? Need input from safety assessment.
- How to address "evolution" of a waste form over time (improve or degradation of properties) in safety assessment? (e.g., fracture behavior in unsaturated conditions)

Conclusions

- Variety of different approaches for D&D and remediation waste management in the USDOE-EM Complex
- Decision-making is based on multi-criteria approach with engagement of external regulators and public involvement
- Prescriptive regulations can be helpful (public perception, consistency), but can also limit optimization for special cases
- Safety Assessment helps to identify priority areas for research activities (process helps to provide sound basis for need for research)
- Many competing factors when identifying optimal waste management strategy, research inputs can help to identify and assess critical assumptions that could result in changes in the strategy

For further information, please contact:

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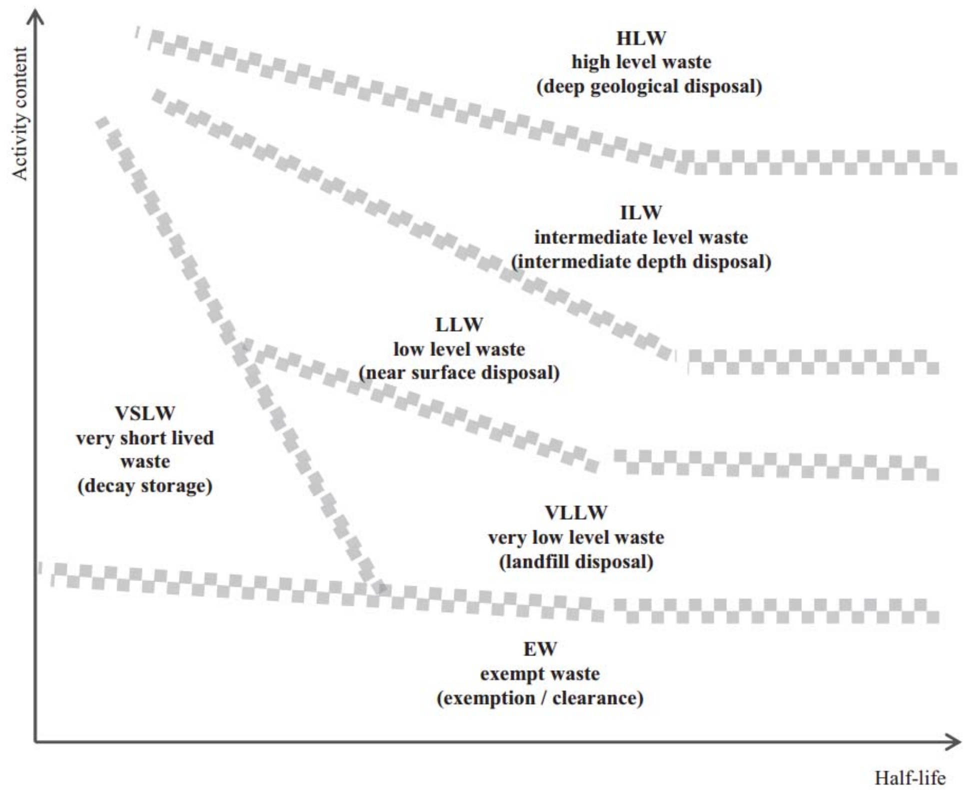
Backup Slides

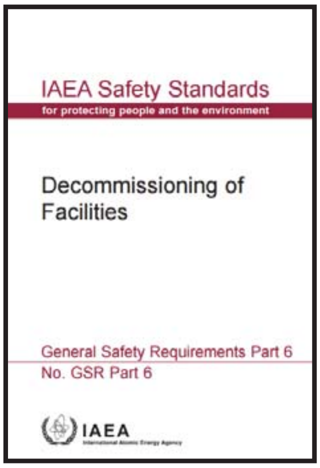
Strategic Considerations - IAEA Waste Classification



Background - Terminology

International Atomic Energy Agency Options for Reactor Decommissioning

- Immediate Dismantling (DECON)
  - Equipment, structures, and parts of facility containing radioactive contaminants are removed or decontaminated to a level that permits facility to be released for unrestricted use or with restrictions imposed by the regulatory body.
- Deferred Dismantling (SAFSTOR)
  - Parts of a facility containing radioactive contaminants are either processed or placed in such a condition that they can be safely stored and maintained until they can subsequently be decontaminated and/or dismantled to levels that permit facility to be released for unrestricted use or with restrictions imposed by the regulatory body.
- Entombment
  - Radioactive contaminants are encased in a structurally long lived material until radioactivity decays to a level permitting unrestricted release of a facility, or release with restrictions imposed by regulatory body
  - Position paper specific to entombment being prepared



Decommissioning Considerations

Institutional

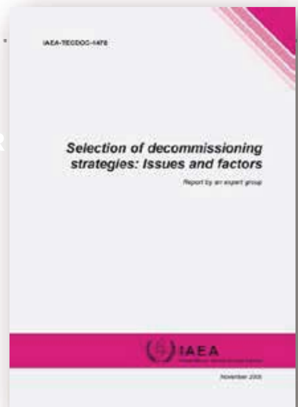
- Roles and responsibilities (government, regulator, licensee, interested parties)
- Policy, laws and regulations (health and environmental standards, worker protection, end states, risk assessment, clearance process for radioactive waste)
- Availability of
  - Funding/cost estimates
  - Experienced staff (challenge for deferred actions)
  - Waste management system (processing, storage, disposal)

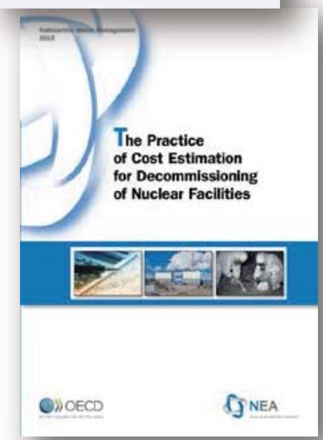
Facility State

- Future use of facility or site, co-located facilities with shared infrastructure
- Type of facility and physical status
- Residual activity in facility, characterization information
- Soil and groundwater contamination outside of the buildings/structures
- Transportation of waste - proximity to disposal/storage site(s)

Example Lessons Learned

- Accurate surveys at beginning of process (well informed plans, waste planning)
- Availability of disposal options (commitment to accept waste)
- Setting expectations for final surveys and monitoring (ranges of values)
- Cost estimation reassessed as site conditions evolve
- Efficient characterization
- Effective clearance process and waste segregation (soil and potential groundwater contamination)
- Quality assurance, independent samples
- Areas where deeper contamination can occur (e.g., joints)
- Removal of surface contamination on concrete structures resulting in non-radioactive debris
- Fukushima – transparency, land use, public engagement

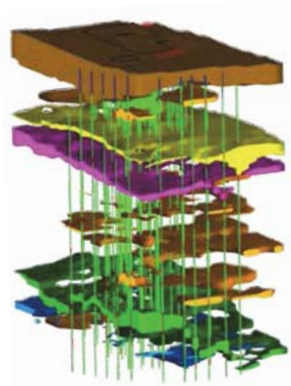




Building Stakeholder Confidence

- Physical models
- Graphical visualization of the subsurface
- External reviews
- Meeting requirements of DOE regulations and external regulators
- Routine public briefings (e.g., Citizens Advisory Board)
- Clear waste acceptance criteria
- Formal process to address unexpected conditions (e.g., new waste forms, monitoring results, data)

Physical model of proposed disposal facility with removable layers (liner, waste, cover)



Subsurface in one region of the Idaho Site