Savannah River National Laboratory™

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We put science to work.™

Process Intensification and Smart Manufacturing: Technology Innovation for Department of Energy's Nuclear Chemical Processes

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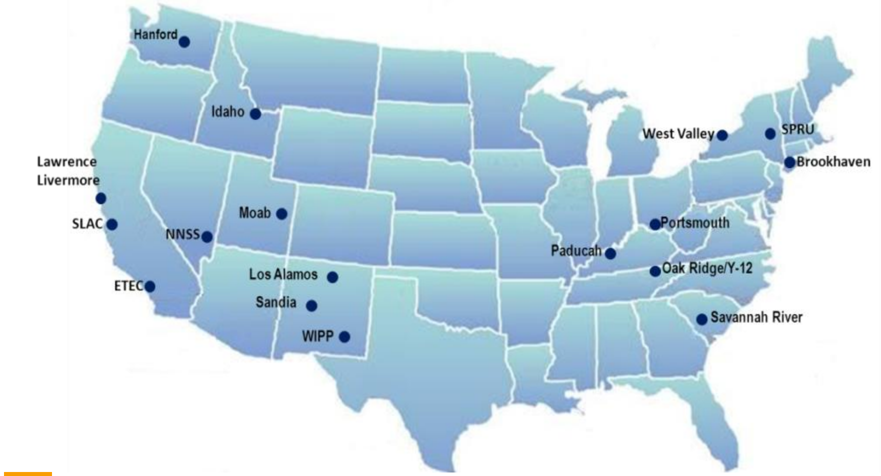
FLUOR • NEWPORT NEWS NUCLEAR • HONEYWELL

SRNL is Critical to DOE Environmental Success

- Strategic partner at other DOE Sites

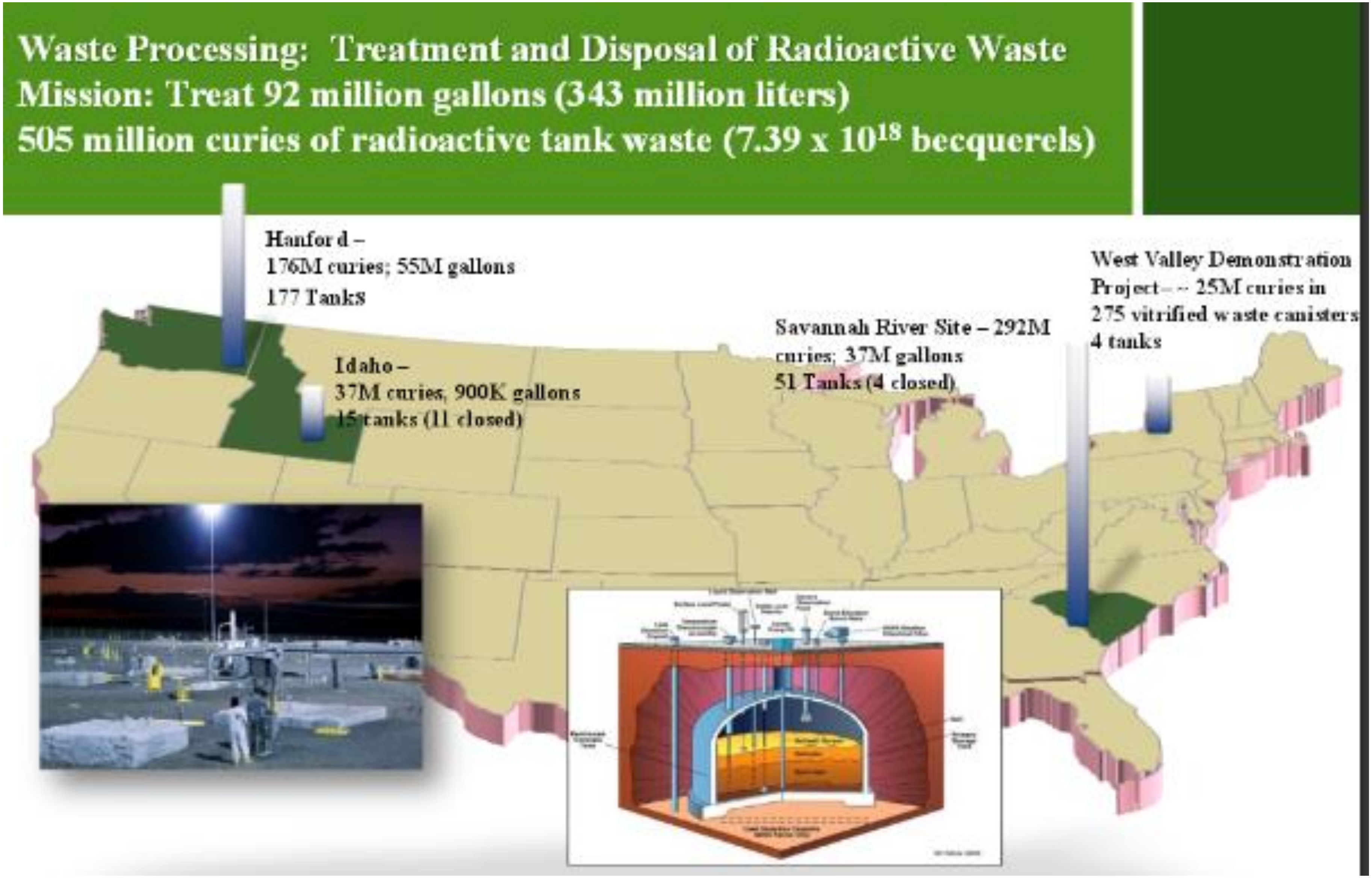


- Over $5 billion in projected savings in past five years

- Fukushima support

- Constructed Wetlands, in partnership with Clemson

Mission: Treatment & Disposal of 92 Million Gallons



Waste Processing: Treatment and Disposal of Radioactive Waste
Mission: Treat 92 million gallons (343 million liters)
505 million curies of radioactive tank waste (7.39 x 10^{18} becquerels)

Hanford –
176M curies; 55M gallons
177 Tanks

Idaho –
37M curies, 900K gallons
15 tanks (11 closed)

Savannah River Site – 292M
curies; 37M gallons
51 Tanks (4 closed)

West Valley Demonstration
Project – ~ 25M curies in
275 vitrified waste canisters
4 tanks

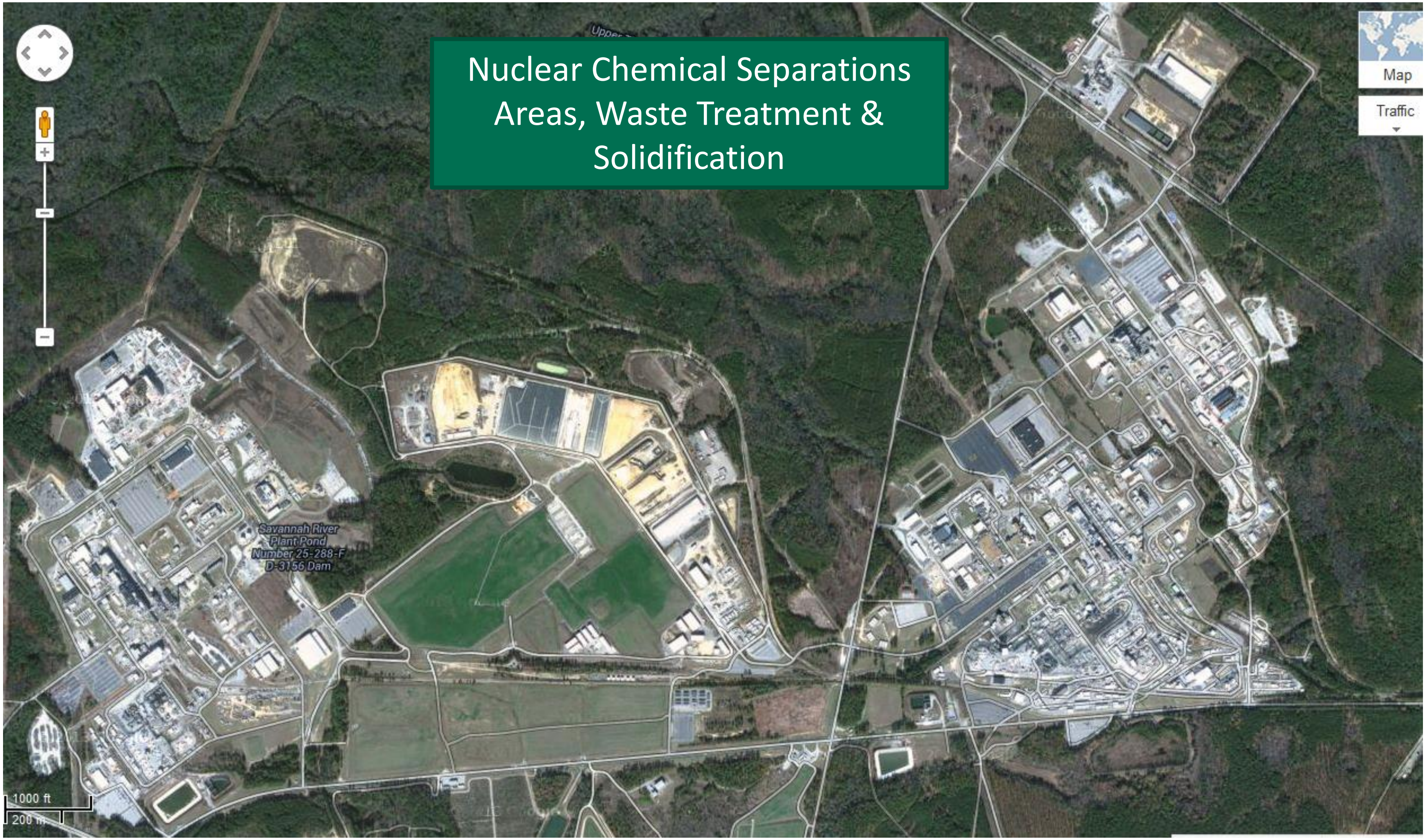
Ken Picha, Dec 3, 2013, http://energy.gov/sites/prod/files/TAB%204.1%20Picha%20EMAB%20Presentation.pdf

How Much is 92 Million Gallons?


Roughly 3 of These

375’ Diameter, 40’ Tall, 32 Million Gallons

A Large Nuclear Chemical Complex

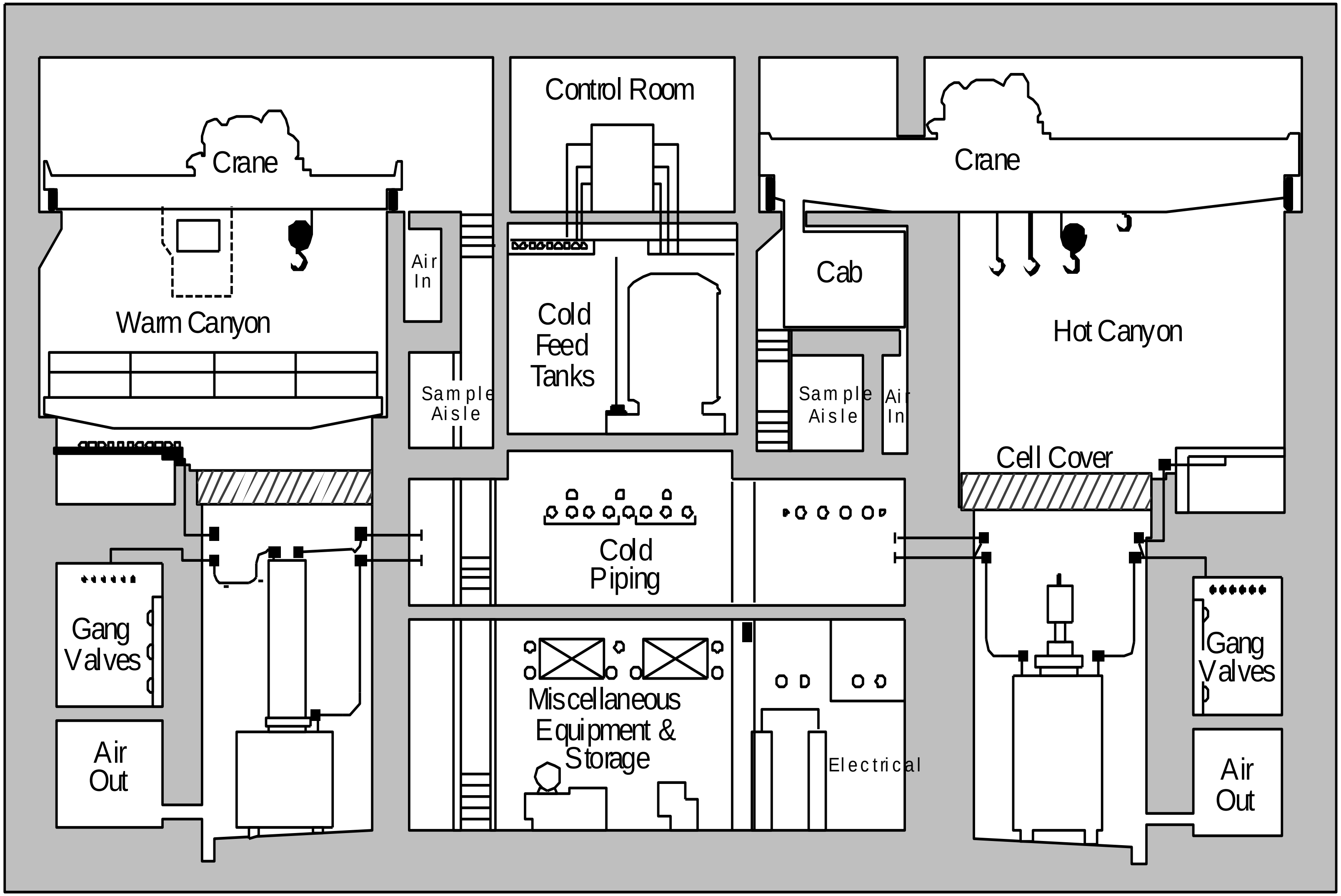


Nuclear Chemical Separations Areas, Waste Treatment & Solidification

> 3 Miles

And Even Larger Complex at Hanford Site in Washington

Canyon Cross-Section



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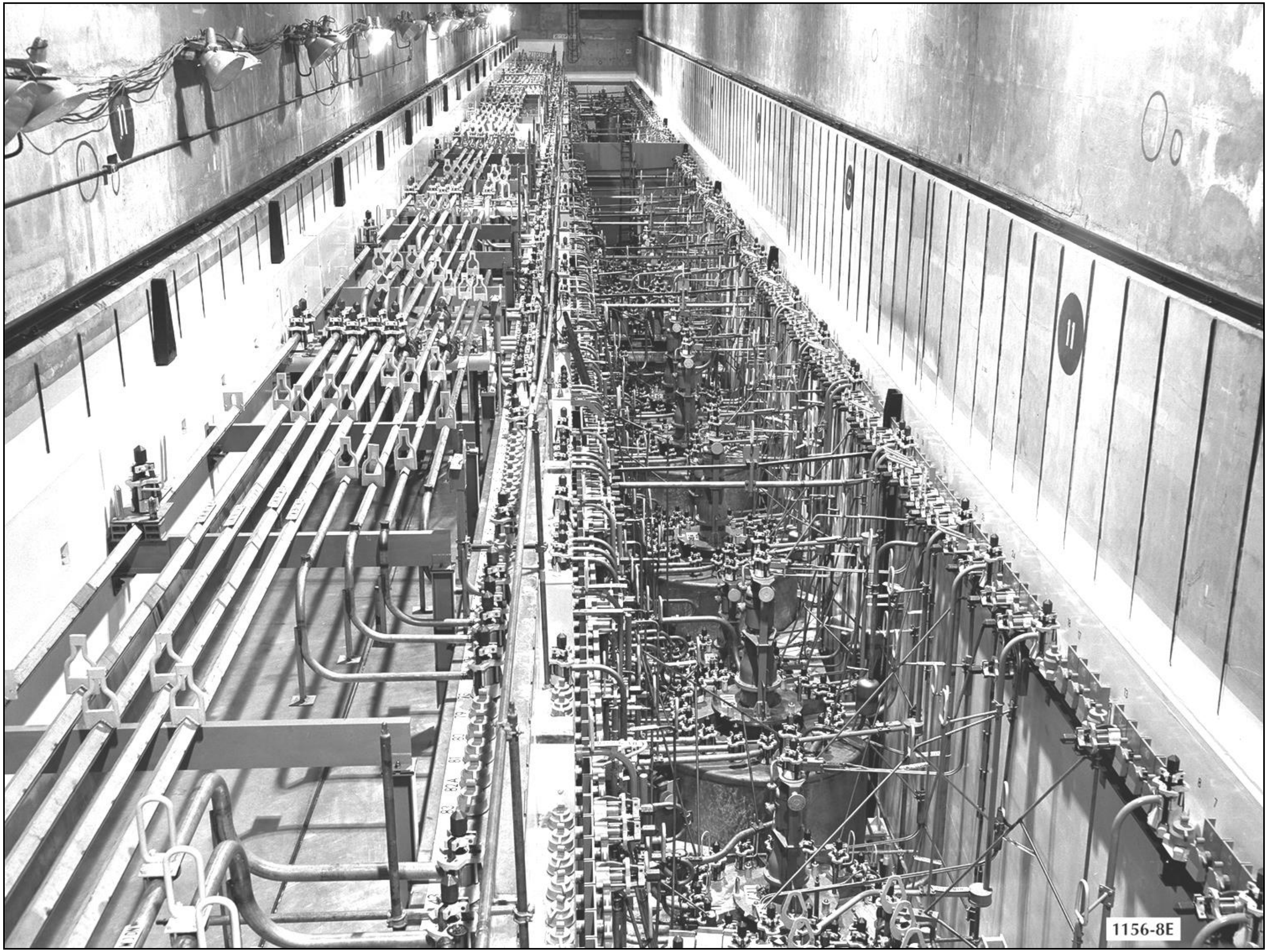
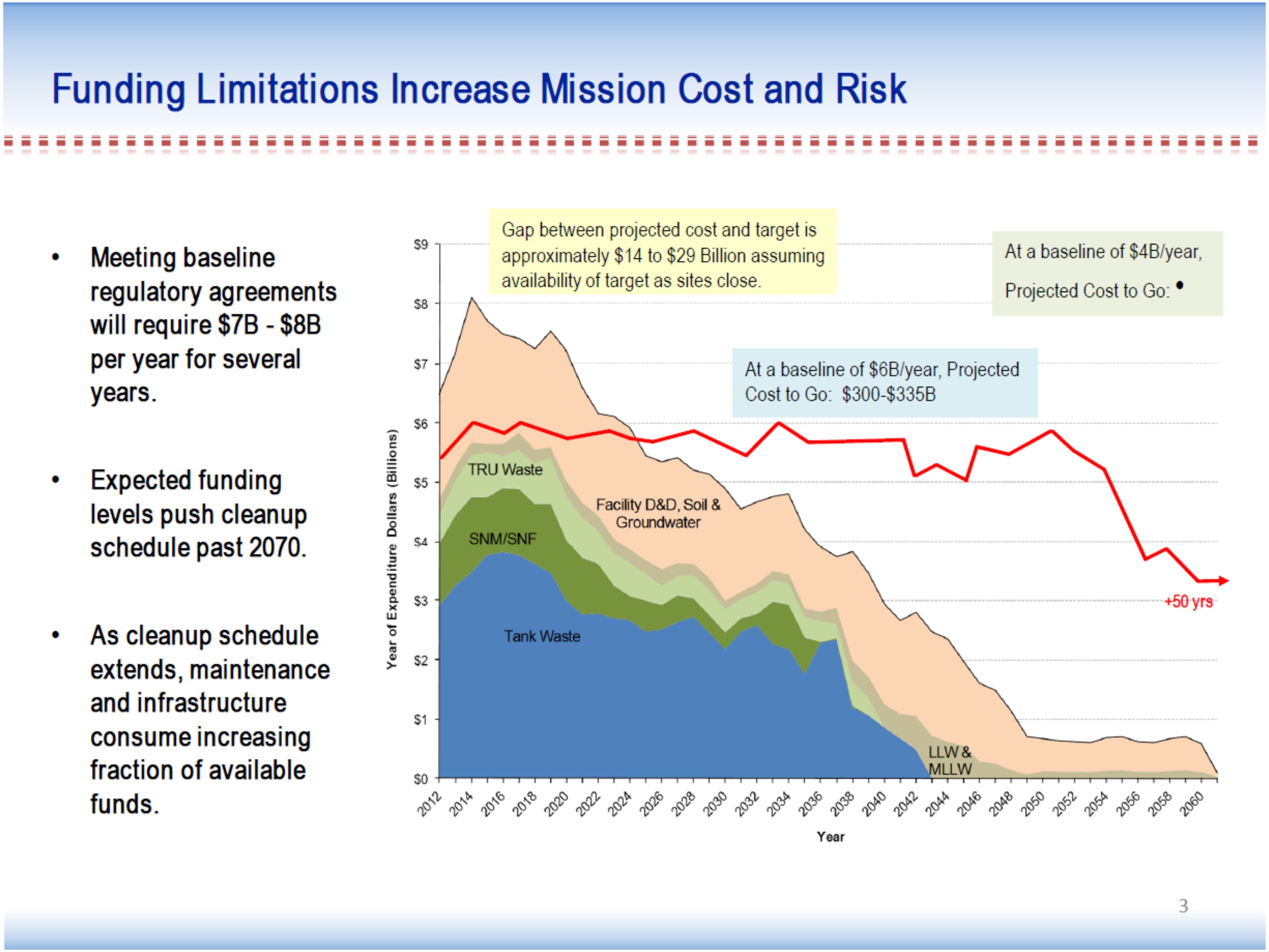
Piping Gallery in Canyon Chemical Separations Facility



Reinventing the Approach to DOE Priorities



Funding Limitations Increase Mission Cost and Risk

- Meeting baseline regulatory agreements will require $7B - $8B per year for several years.
- Expected funding levels push cleanup schedule past 2070.
- As cleanup schedule extends, maintenance and infrastructure consume increasing fraction of available funds.

Gap between projected cost and target is approximately $14 to $29 Billion assuming availability of target as sites close.

At a baseline of $4B/year,
Projected Cost to Go: •

At a baseline of $6B/year, Projected Cost to Go: $300-$335B

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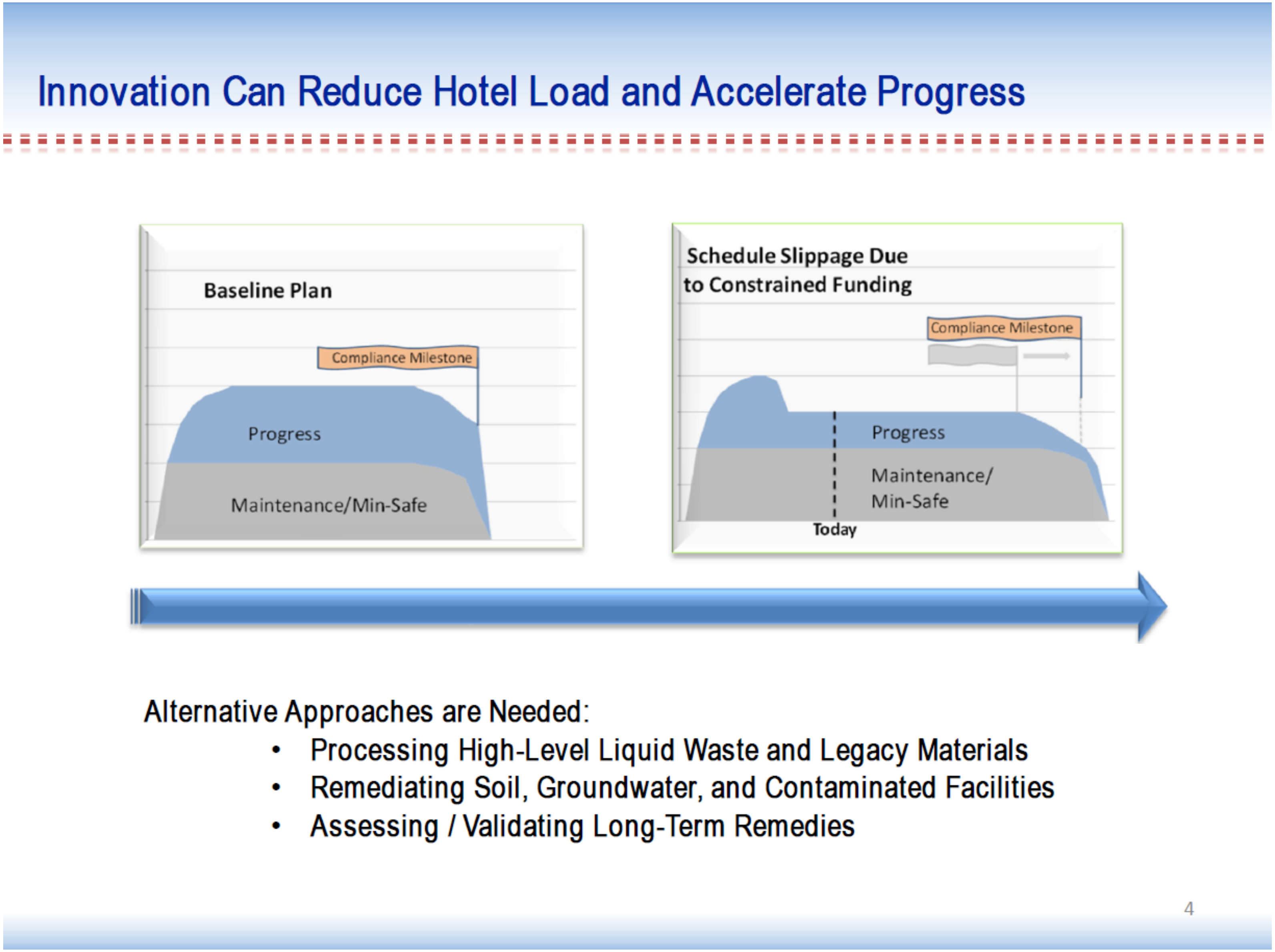
Reinventing the Approach to DOE Priorities



Innovation Can Reduce Hotel Load and Accelerate Progress

Alternative Approaches are Needed:

- Processing High-Level Liquid Waste and Legacy Materials
- Remediating Soil, Groundwater, and Contaminated Facilities
- Assessing / Validating Long-Term Remedies

Nuclear Processing is 30+ Years Behind the Chemical Industry

Old Bigger is better;

Cost ~ Production Capacity$^{2/3}$

New Smaller, Modular, Flexible

Key Concept – Process Intensification (PI)

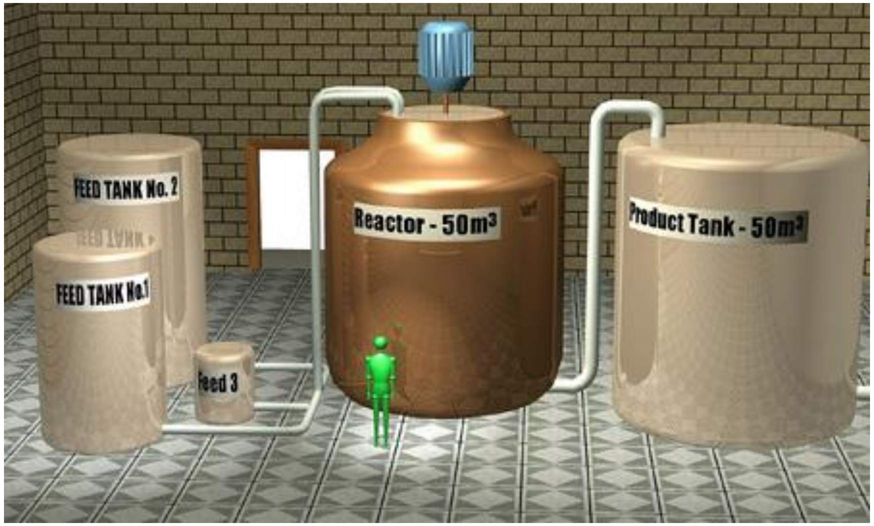
Old Output Based Process Control; Production decisions made offline

New Online Process Models; Budget/Production decisions made online

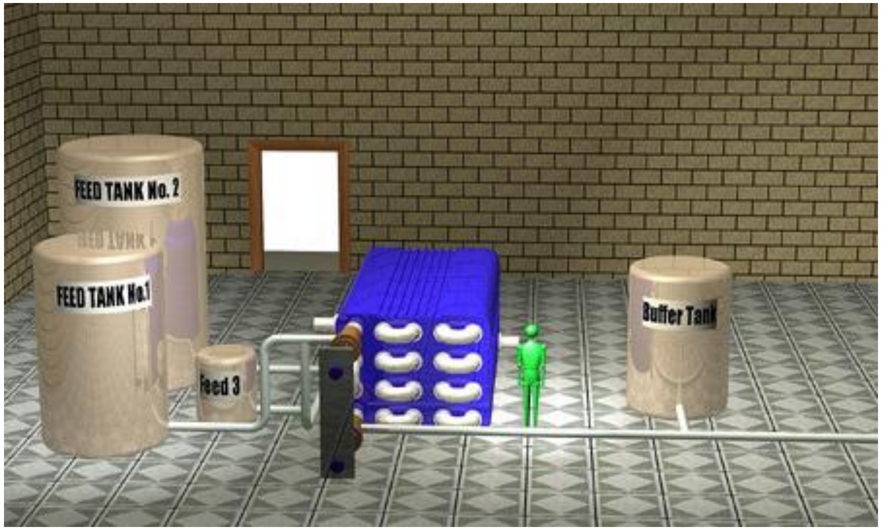
Key Concept – SMART Manufacturing(SM)

https://smartmanufacturingcoalition.org/

DOE Nuclear Processing Today (Chemical industry Before PI)



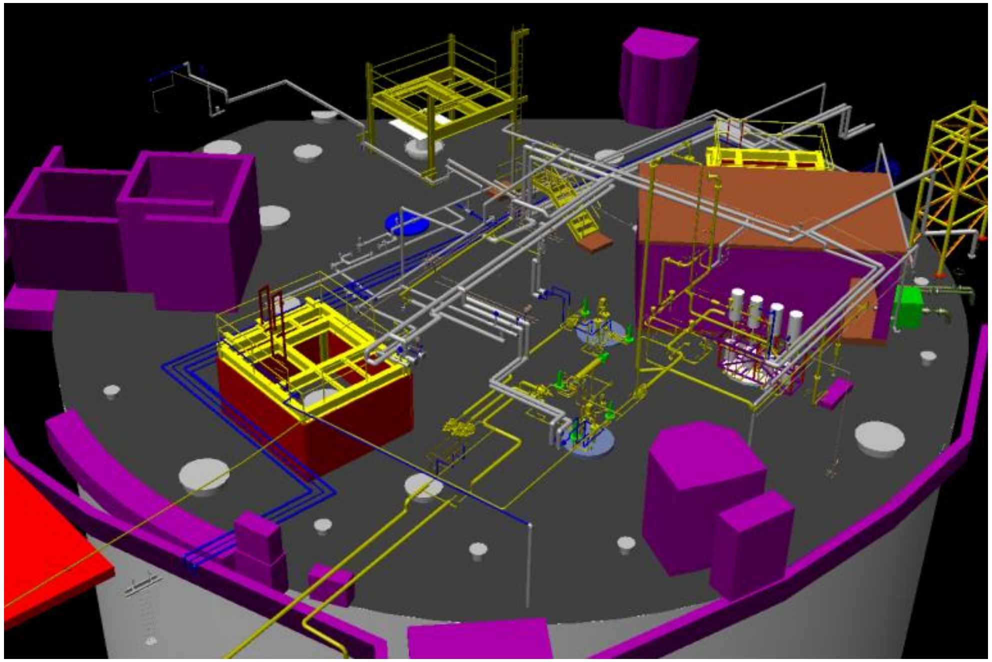
DOE Nuclear Processing Future (Chemical industry Now)

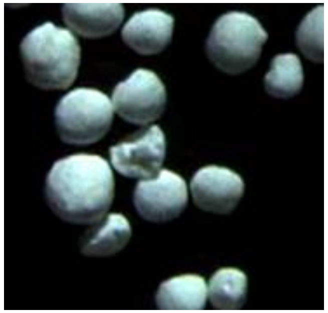


http://www.ceb.cam.ac.uk/pages/ofm-process-intensification.html

SRNL's Process Intensification Example: Rotary Microfilter/Small Column IX Benefits

- No new buildings
- Reduced schedule risk
- Rotary Microfilter uses high shear to produce high filter flux in small footprint
- Small Column IX Processing eliminates heat loading concerns with large columns
- Low volume of Cs waste in solid form
- Minimize impacts to downstream facilities





Process Intensification Involves Both Fundamental Chemistry, Material Science & Engineering

Science Discovery | Basic Research | Use-Inspired Research

Office of Science

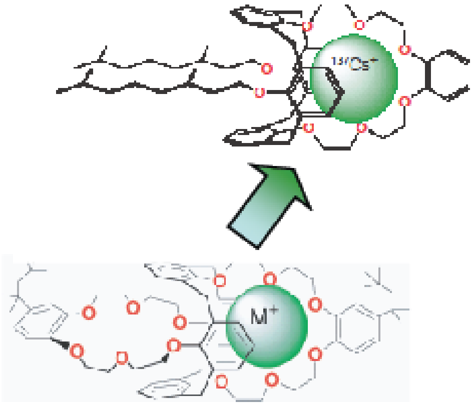
Applied Research | Technology Development | Technology Maturation

Office of Environmental Management

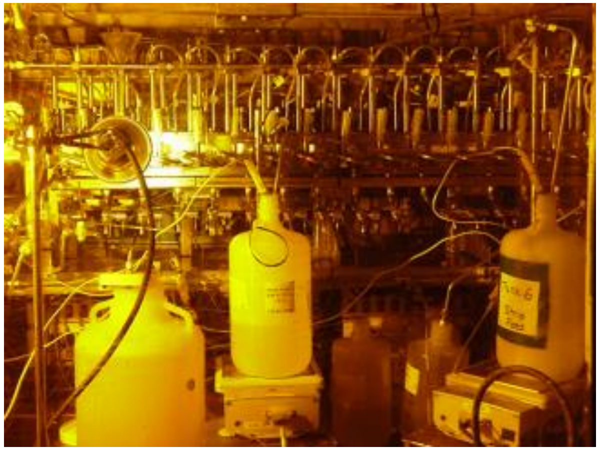
Technology Implementation | Commercialization

Site Contractors

Partner Businesses



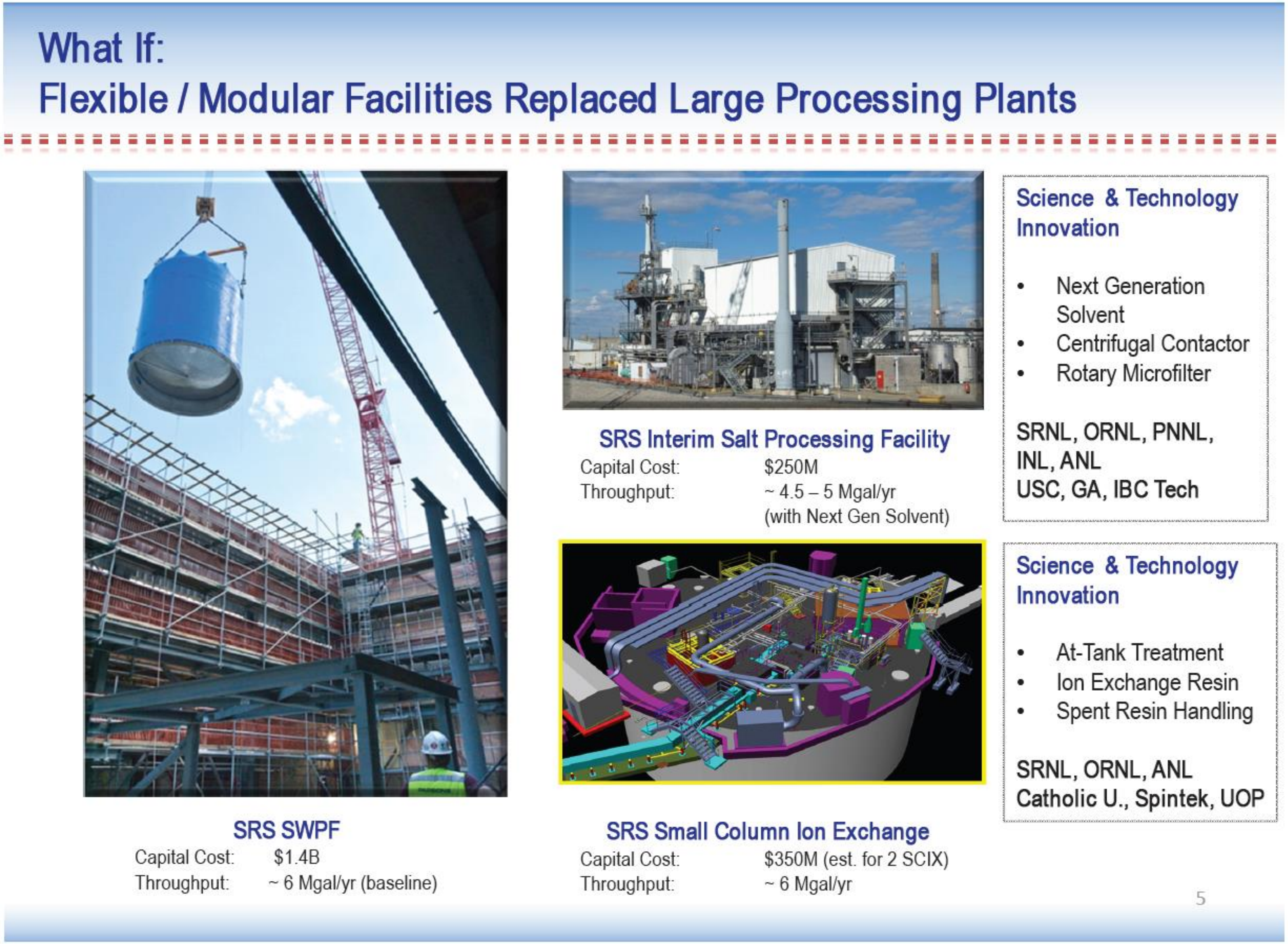
BOBCalixC6



The final laboratory demonstrations of MST and CSSX were performed with waste samples in a hot cell at SRNL.

Modular Caustic Side Solvent Extraction Unit

Reinventing the Approach to DOE Priorities



What If:
Flexible / Modular Facilities Replaced Large Processing Plants

SRS SWPF
Capital Cost: $1.4B
Throughput: ~ 6 Mgal/yr (baseline)

SRS Interim Salt Processing Facility
Capital Cost: $250M
Throughput: ~ 4.5 – 5 Mgal/yr (with Next Gen Solvent)

Science & Technology Innovation

- Next Generation Solvent
- Centrifugal Contactor
- Rotary Microfilter

SRNL, ORNL, PNNL, INL, ANL
USC, GA, IBC Tech

SRS Small Column Ion Exchange
Capital Cost: $350M (est. for 2 SCIX)
Throughput: ~ 6 Mgal/yr

Science & Technology Innovation

- At-Tank Treatment
- Ion Exchange Resin
- Spent Resin Handling

SRNL, ORNL, ANL
Catholic U., Spintek, UOP

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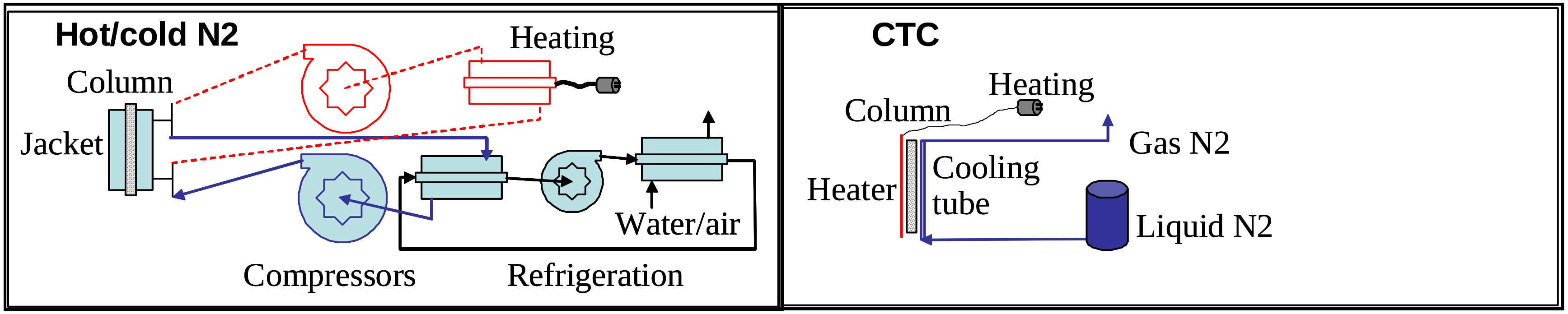
Process Intensification Continues to Shrink Volume / Energy



First Generation TCAP (left) versus CTC-TCAP (right, 1/10th footprint)

Scaled Representation of Thermal Cycling Adsorption Process

Smart Manufacturing Opportunity to Reduce Operating Costs

Today

Antifoam Conc. (Melter Feed) = TOC – Formate Ion – Oxalate Ion; Analytical Method – **High Uncertainty**

Replaced by Antifoam Conc. = Antifoam IN – Antifoam in Heels; **Low Uncertainty – Wider Operating Region**

Online Antifoam Mass Balance Equation replaces Analytical Sample Control for Safety Basis Analysis in DWPF – Reduces analysis uncertainty by 50%

Near Term

Could we run all our plants with online mass balances models?

Vision

- **Online plant models and data networks are connected to make nuclear enterprise decisions**
- **Budget/Production/Capital Expenditure planning decisions made in near real time**

Why not? The ROI is likely very large

Some European Centers of Excellence in Process Intensification

EUROPIC/Delft University of Technology	Industry Consortium /Delft, Netherlands
DSM	Chemical Company/Geleen, Netherlands
Newcastle University/Process Intensification Network	University/Newcastle, UK
Solvay	Chemical Company/Lyon, France
Bayer- Dormund University of Technology INVITE Center	Industry Center/Leverkusen, Germany
Institute for Micro Process Engineering/Karlsruhe Institute of Technology	University-National Laboratory/ Karlsruhe Germany

European Trip Findings

- PI has evolved from a “toolbox” of technologies approach to an **integrated multidisciplinary approach for understanding the relationships between fundamental science and process engineering**

- PI efforts start by asking the basic question: “**What is the limiting factor (rate, environmental, safety, capital cost, etc.) in the process or enterprise**?” This fundamental question was consistently brought up by all institutions visited;

- PI efforts involve **analyzing the underlying elementary physical and chemical processes with the goal of providing the optimal pathway for each molecule processed**;

- **All scales within an enterprise (molecular to plant to enterprise) should be considered** when applying PI;

Additional Findings

- **Metrics for PI should be set to achieve a step change** in plant footprint, environmental release, capital/operating cost, or other metric of interest. PI disrupts cost paradigms and is not business as usual process optimization;

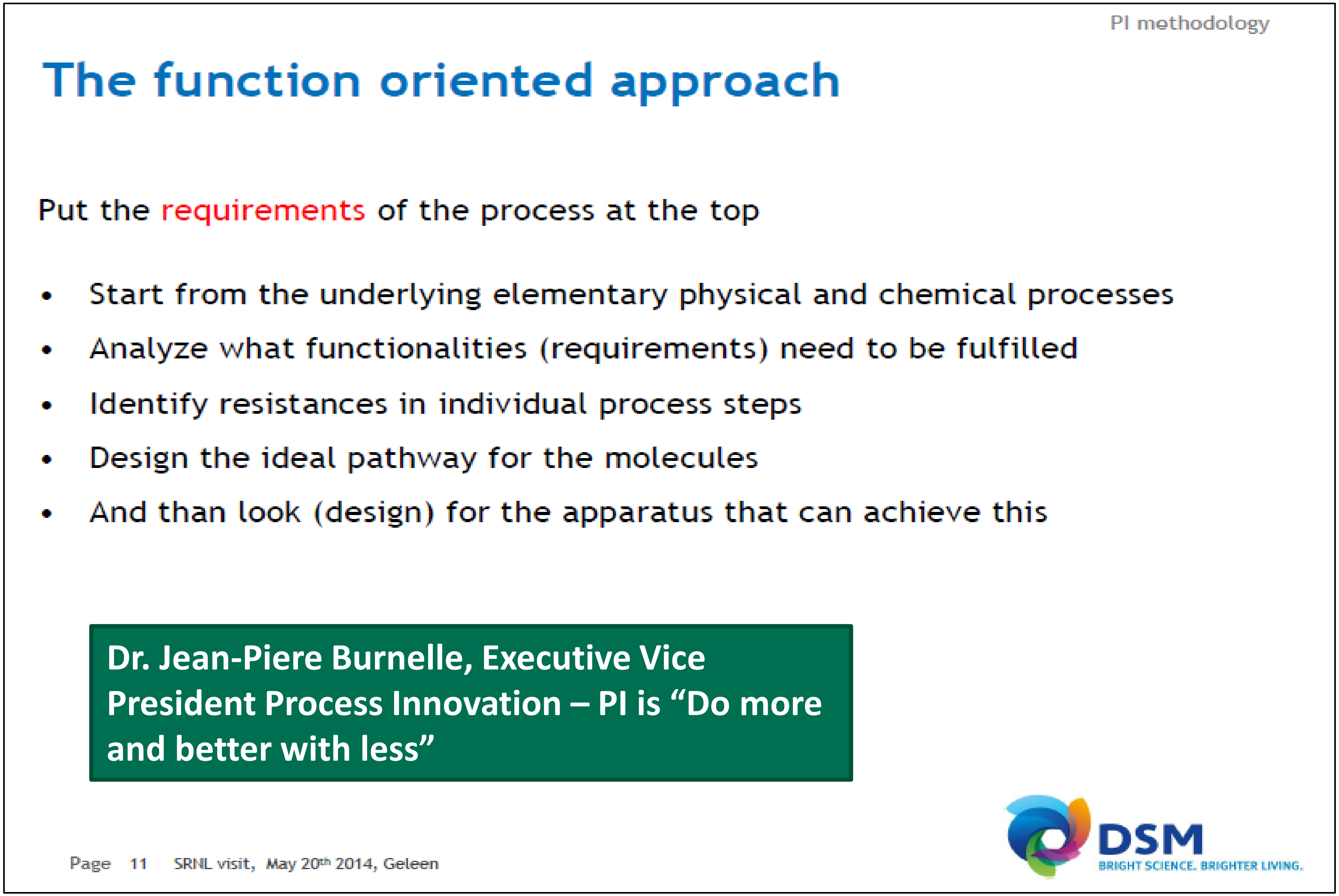
- A database and library of PI technologies are maintained by EUROPIC. ***SRNL plans to join EUROPIC;***

- **PI is a culture that needs to be disseminated to be effective**;

- The EU continues to fund large programs associated with PI and SM;

- Both DSM and Solvay are involved in SMART Manufacturing and supply chain modeling efforts.

DSM PI Methodology



PI methodology

The function oriented approach

Put the requirements of the process at the top

- Start from the underlying elementary physical and chemical processes
- Analyze what functionalities (requirements) need to be fulfilled
- Identify resistances in individual process steps
- Design the ideal pathway for the molecules
- And than look (design) for the apparatus that can achieve this

Dr. Jean-Piere Burnelle, Executive Vice President Process Innovation – PI is “Do more and better with less”

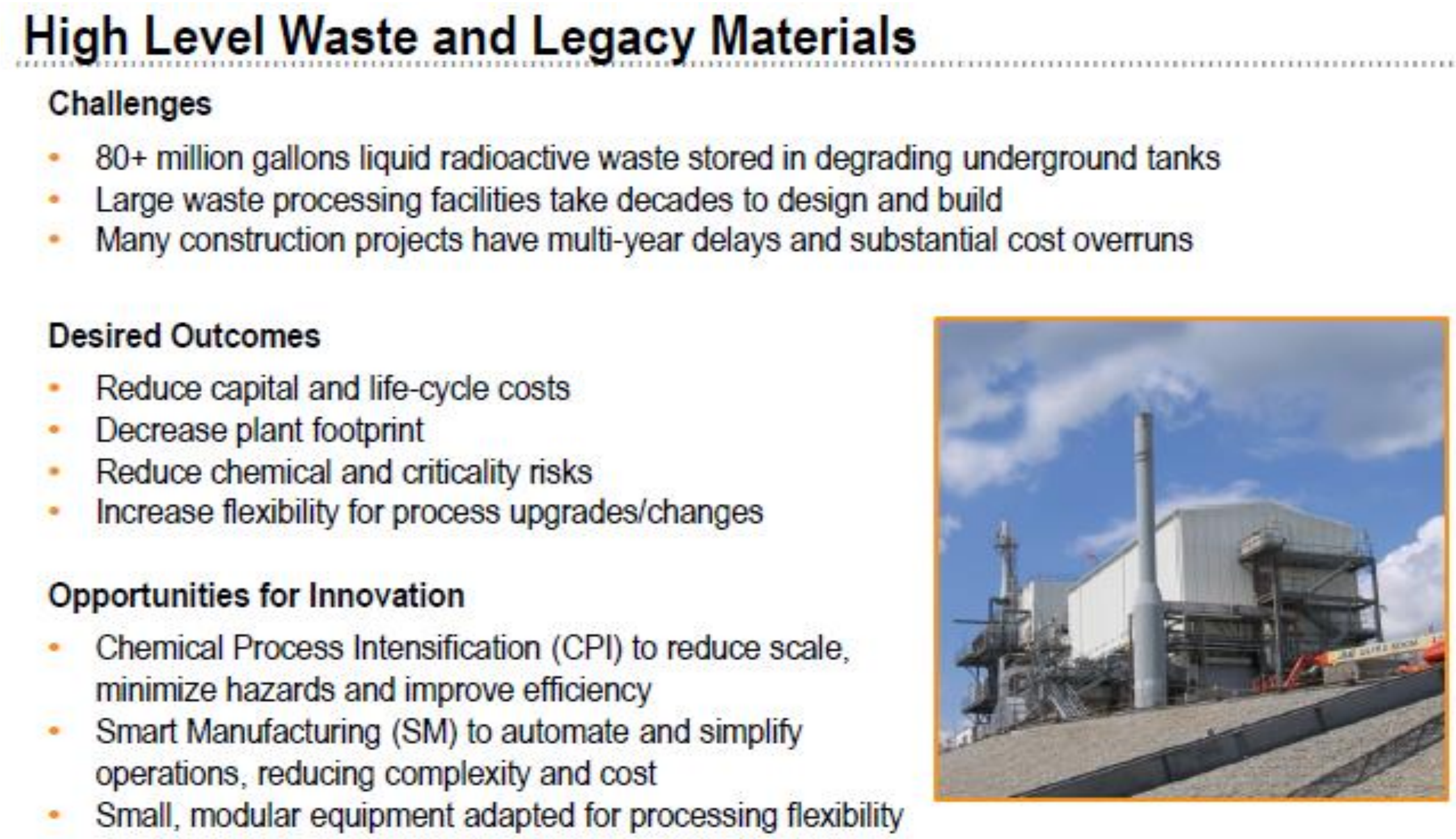
Page 11 SRNL visit, May 20th 2014, Geleen

DSM
BRIGHT SCIENCE. BRIGHTER LIVING.

Needs

- Separations – Evaporation, Solvent Extraction, Ion Exchange, Gas Phase Separation, Solid-Liquid-Gas Separation
- 3 Phase Mixing
- Mitigation of Foams, Gas Holdup
- Enterprise Modeling
- Smart Manufacturing Techniques that reduce sampling
- High Temperature Thermodynamic/Kinetics - Molten Salts, Acids, Glass Forming Systems
- High temperature materials
- Acid-Base Reactions in Complex Systems
- Linkage between chemical-physical properties for predictions of future processing problems

Conclusions



High Level Waste and Legacy Materials

Challenges

- 80+ million gallons liquid radioactive waste stored in degrading underground tanks
- Large waste processing facilities take decades to design and build
- Many construction projects have multi-year delays and substantial cost overruns

Desired Outcomes

- Reduce capital and life-cycle costs
- Decrease plant footprint
- Reduce chemical and criticality risks
- Increase flexibility for process upgrades/changes

Opportunities for Innovation

- Chemical Process Intensification (CPI) to reduce scale, minimize hazards and improve efficiency
- Smart Manufacturing (SM) to automate and simplify operations, reducing complexity and cost
- Small, modular equipment adapted for processing flexibility

New Approaches Are Needed that Bring Modern and Advanced Commercial Industry and Academic Approaches that Solve This Problem and Provide for the Work Force of the Future