

AI for Faster and Cheaper Nuclear Cleanup

Applications for DOE-EM

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SRNL: Our Mission in Action



Environmental & Legacy Management

Provide risk-informed approaches that achieve sustainable regulatory end-states.



Energy Resilience

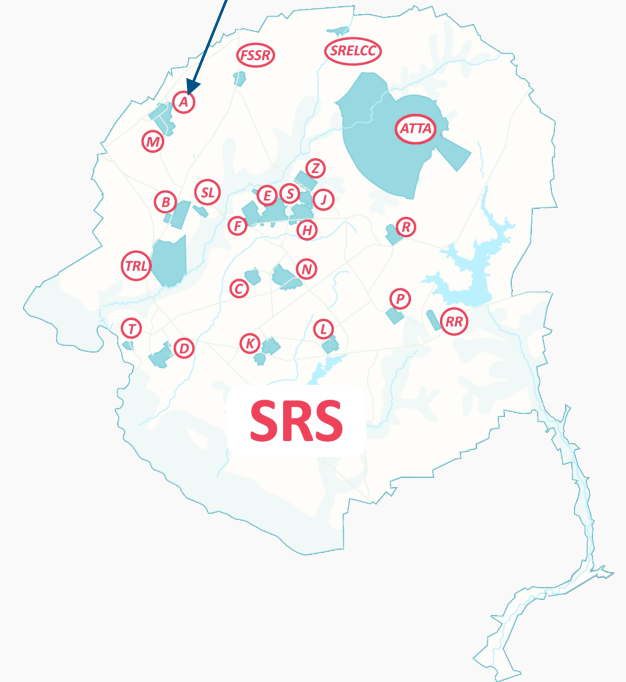
Develop environmentally responsible and secure energy strategies through advanced engineering of materials and chemistry.



National Security

Enable NNSA success by supporting a robust weapons stockpile while reducing threats through advances in proliferation detection technologies

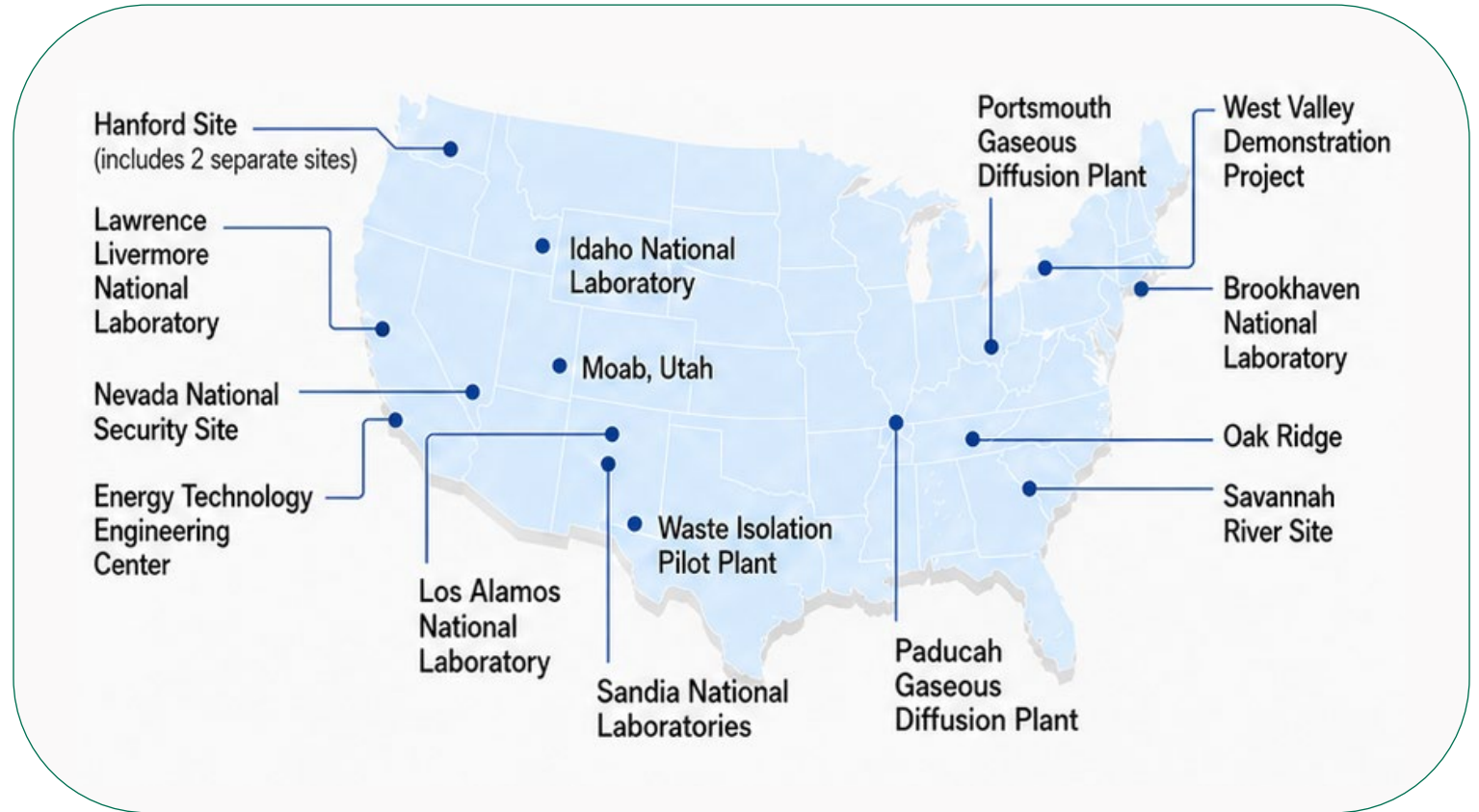
SRNL is located on the Savannah River Site in Aiken, SC



DOE-EM Mission Landscape

Mission: Safely clean up the nation's nuclear legacy while restoring and revitalizing the communities that are home to these sites

- 15 sites, multiple contractors per site
- Upwards of 30,000 federal and contractor employees
- Mission extends 8 decades into the past and into the future



Scale of the Remaining EM Mission



~\$540B

estimated cleanup and disposal liability
as of Sept. 2025



~5,000

contaminated facilities



~90 million

gallons of highly radioactive liquid waste



~6.5 trillion

liters of contaminated groundwater



~115,000 m³

transuranic waste

~2,450

metric tons heavy metal of used nuclear fuel





~40 million m³

contaminated soil and debris





- 70% of the liability is attributed to **SRS and Hanford**
- 70% of the liability is attributed to **S&GW, D&D, and Tank Waste**
- 30-60% attributed to repetitive activities (e.g., maintenance, monitoring, etc.)



~700,000

metric tons of depleted uranium

[*FY25 DOE Agency Financial Report](#) [**EM Strategic Vision 2024-2034](#) [***DOE-ELM Home](#) [****S&GW Remediation](#)

How can we use AI to reduce this liability?

Enterprise Knowledge Management

AI-Enhanced Decision Support

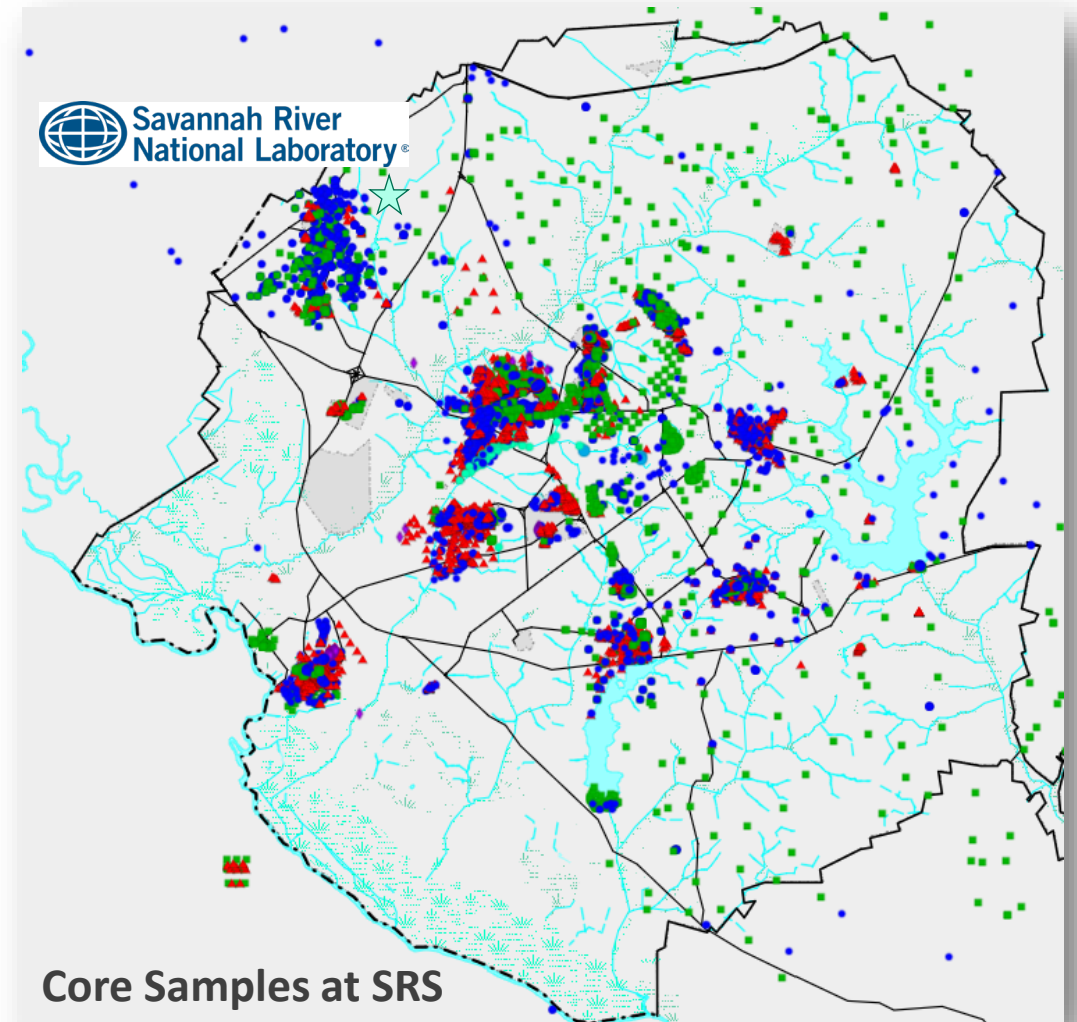
AI-Enabled Automation

AI for Subsurface Science

DOE has perhaps the *highest density of subsurface core samples in the world* across its sites

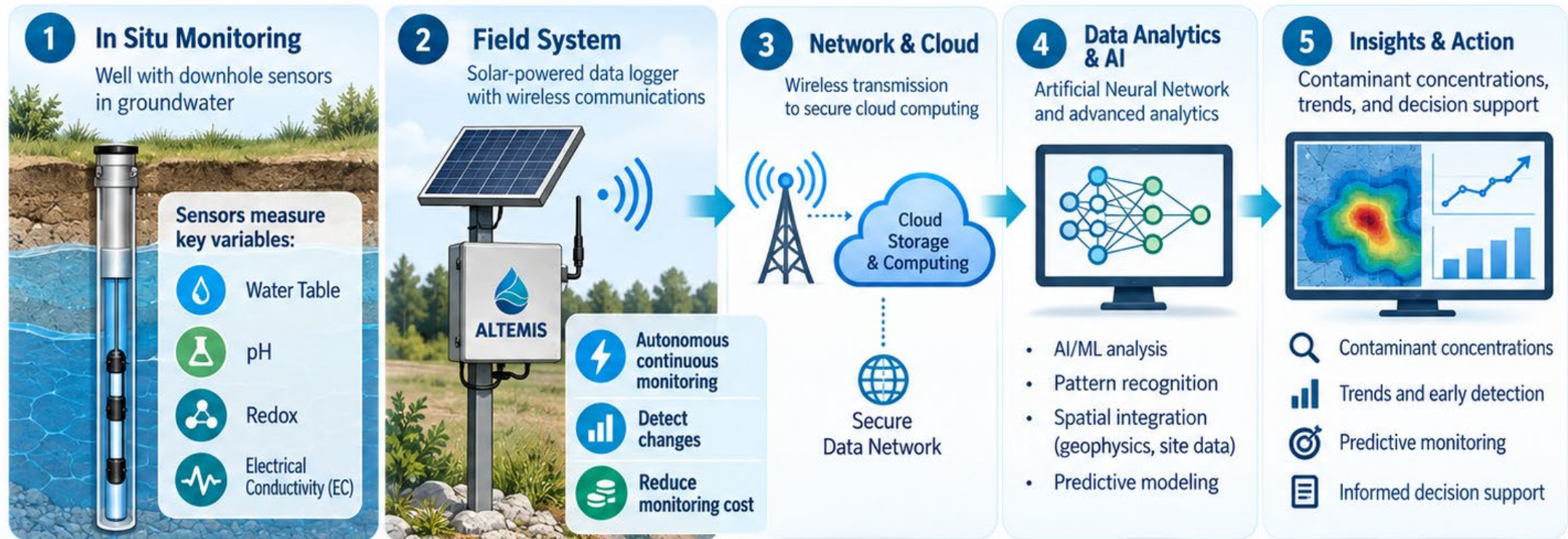
14,000 groundwater wells overall
~5,000 -6,000 active monitoring wells

~\$100M/yr in sampling cost



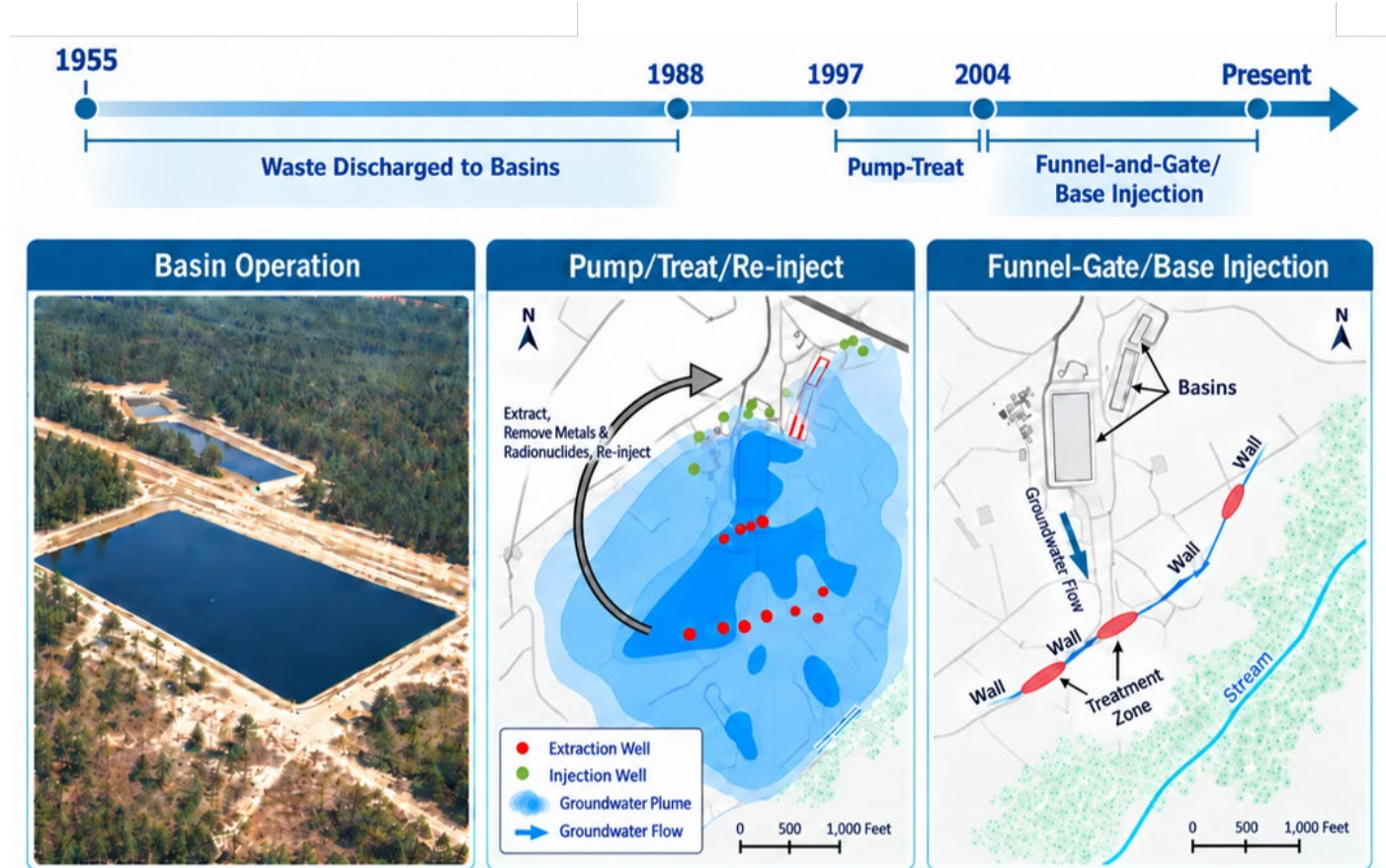
ALTEMIS: Advanced Long-Term Environmental Monitoring Systems

- Shifting the monitoring paradigm from reactive to proactive
- In situ monitoring approaches focused on measurement of controlling/proxy variables
- Spatially integrative technologies including geophysics/contaminant detection

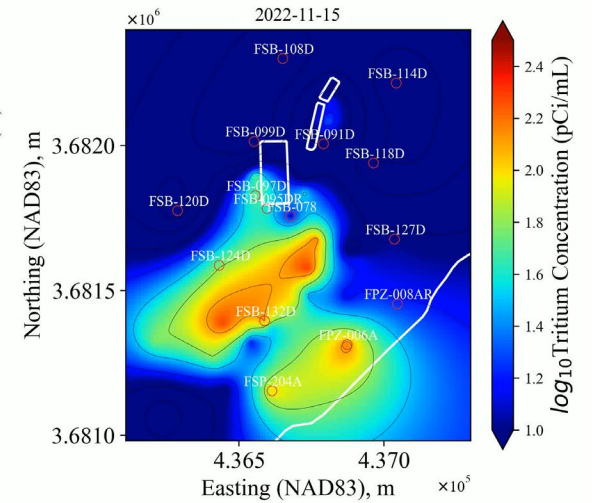
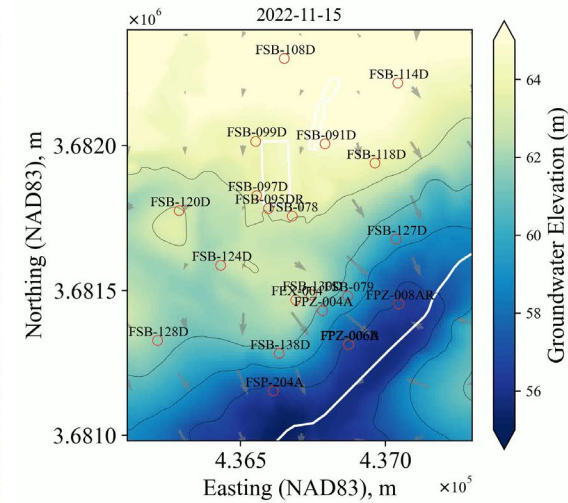
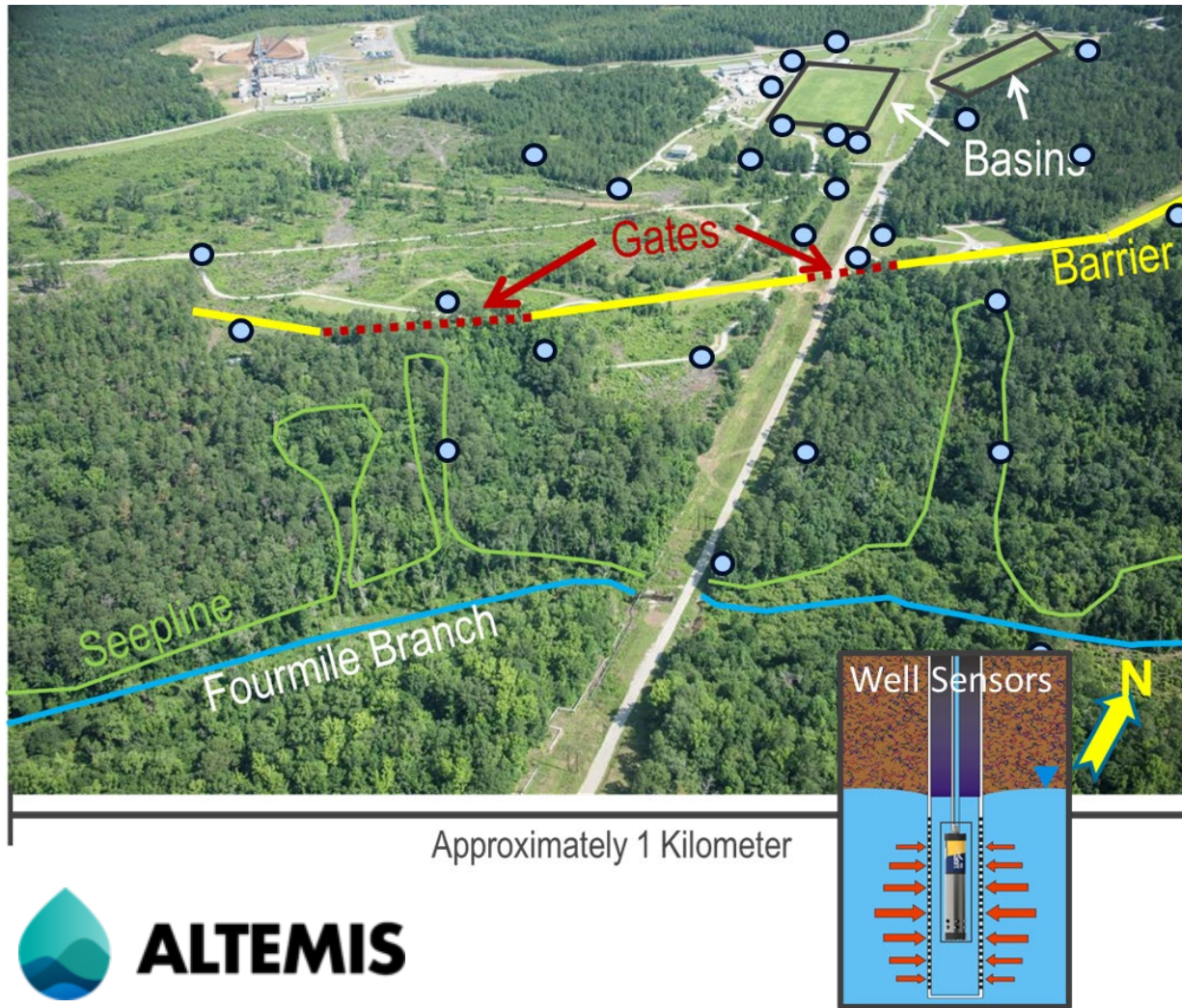


ALTEMIS F-Area Testbed

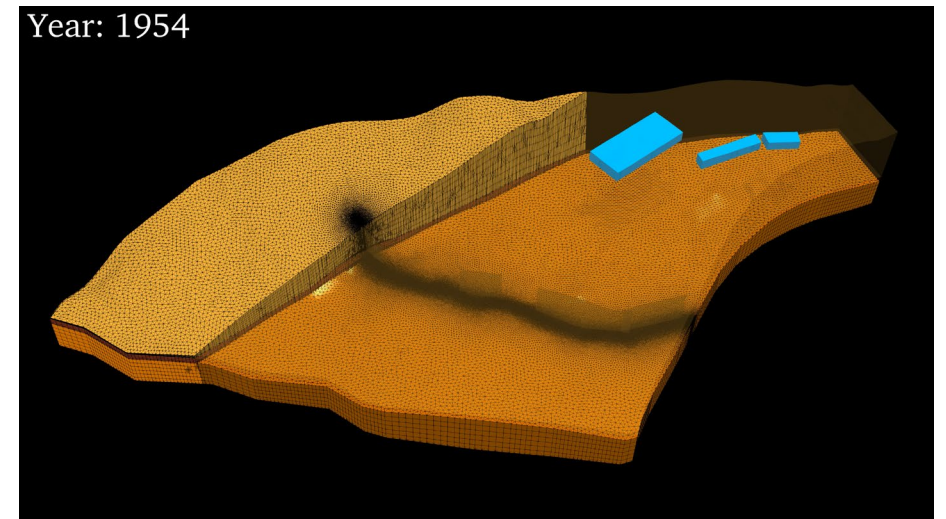
- **Phased Remedial Strategy** – Source Zone Isolation, Active Remediation, Enhanced Attenuation
- Potential for **secondary source terms** (e.g., I^{129} , U^{238} , Sr^{90}) from attenuated contaminants
- Require **continuous monitoring** over the course of the next **several decades** to ensure regulatory compliance



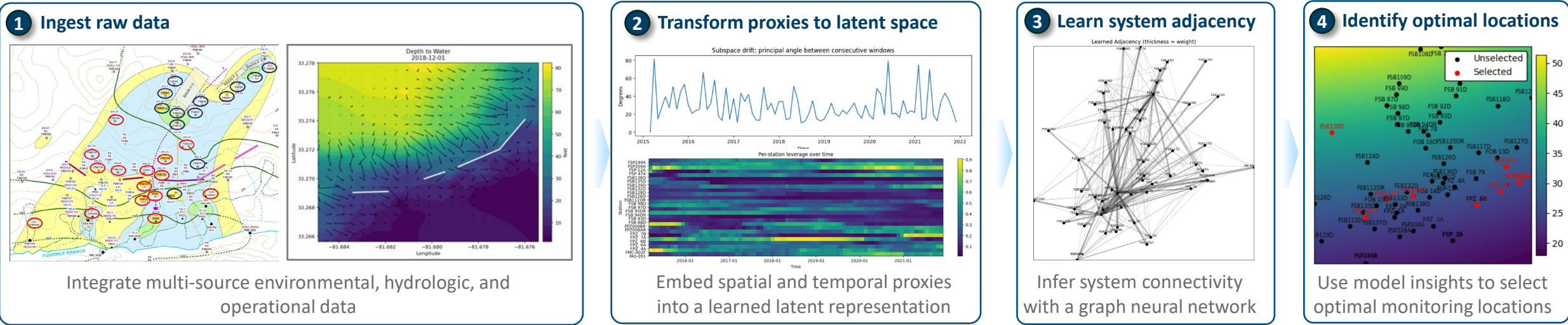
A New Paradigm for Long-Term Monitoring and Stewardship



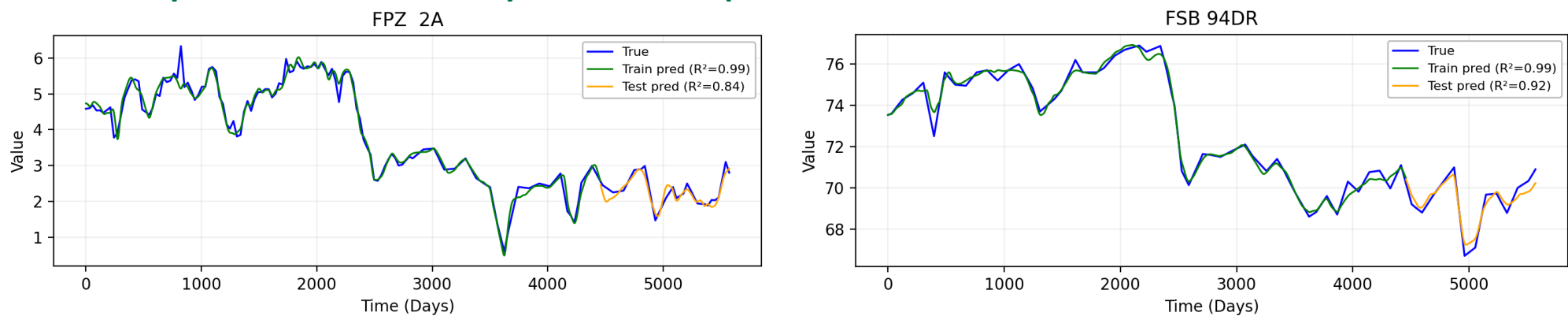
Year: 1954



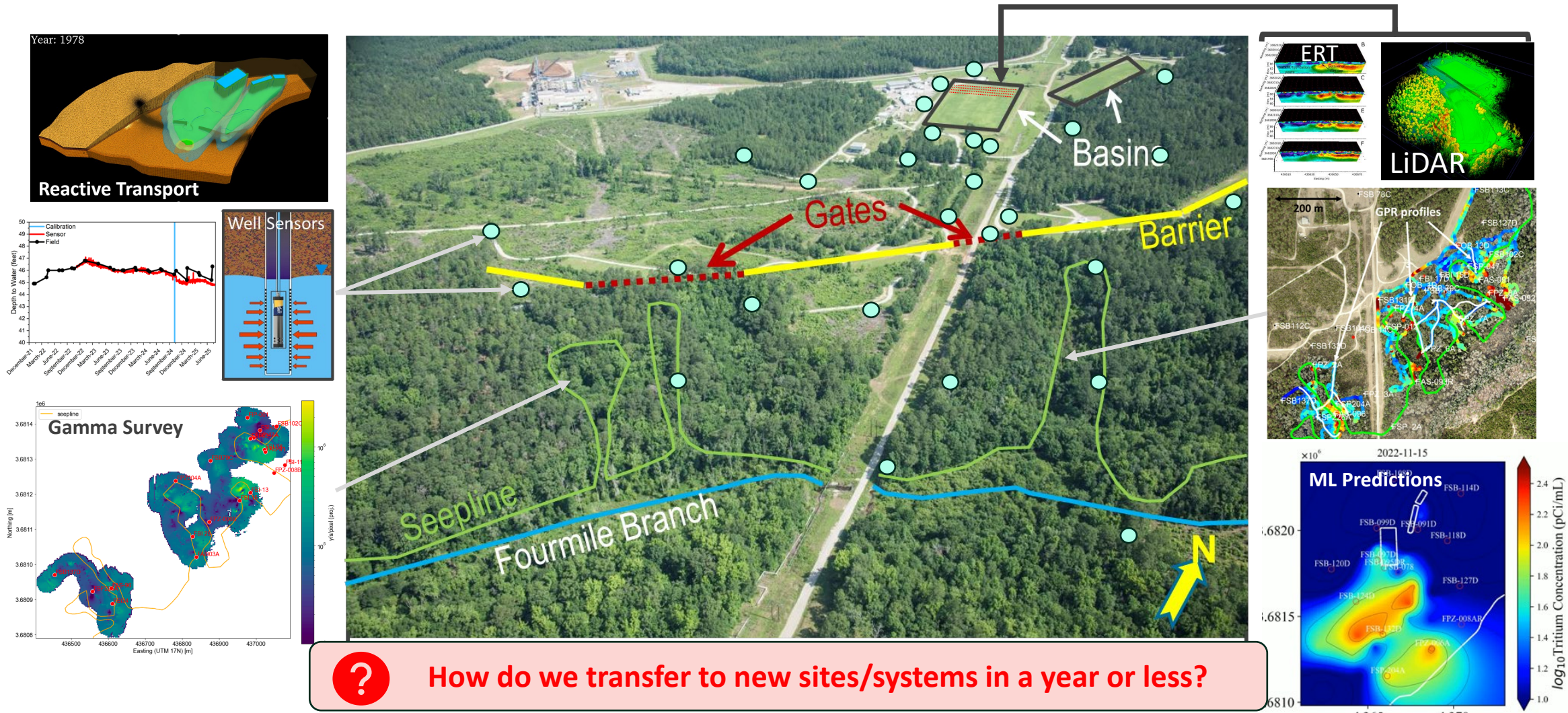
Forecasting/Optimization with Graph Neural Networks



Predictive performance at example locations | Accurate Predictions · Smarter Monitoring

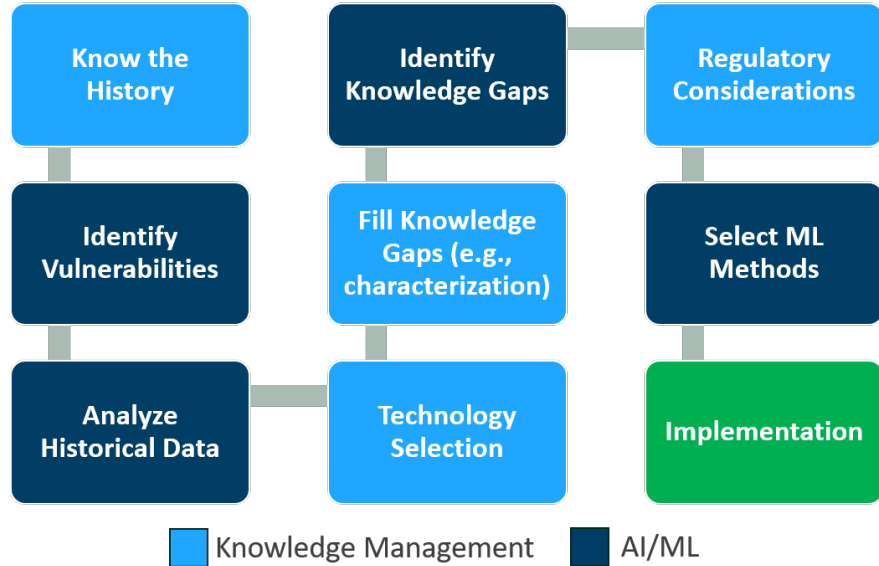


Monitoring Complex Environmental & Physical Systems



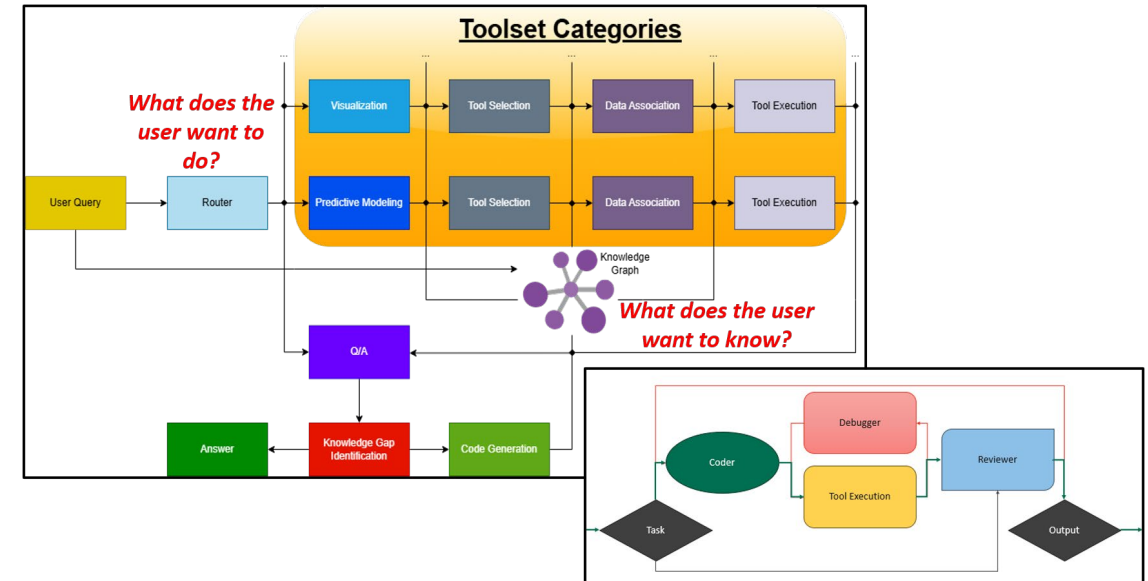
AI-Accelerated Strategies and Solutions in Environmental Technology

Generalized Knowledge Management + AI/ML Workflow



- End state recommendations for site closure
- Monitoring solutions
- Technology recommendations
- Data retrieval

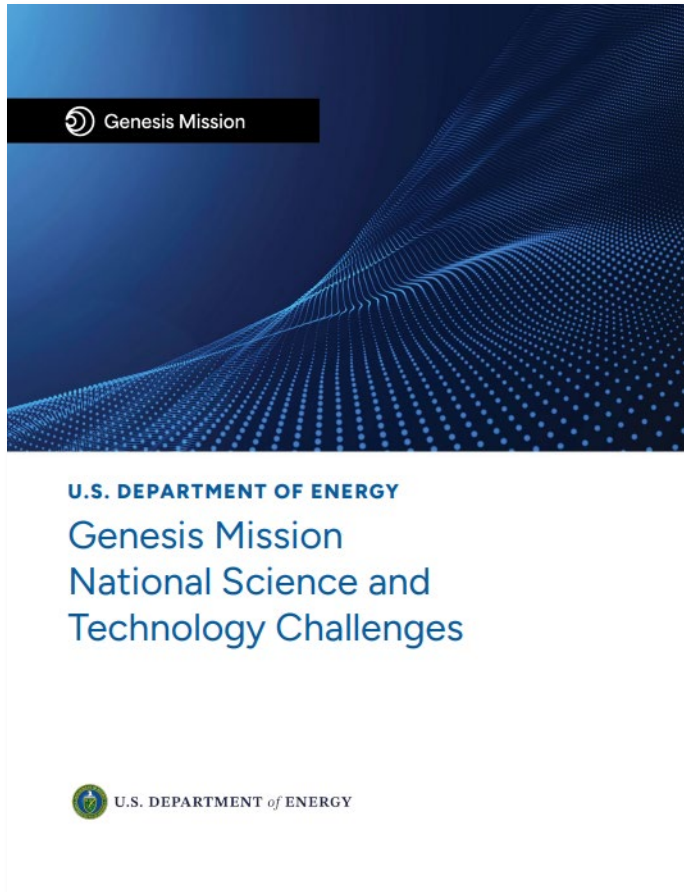
AI-ASSET Architecture



- Data analytics and ML prediction
- Site characteristics/site histories
- Regulatory considerations
- “Zone of vulnerability” identification



Genesis Mission Activities



Transforming Nuclear Cleanup and Restoration

- *~90 million gallons of highly radioactive liquid waste*
- *AI approaches for process optimization and enhanced decision making related to liquid waste processing mission*
- *How can historical data at SRS be used to propel the Hanford liquid waste mission?*



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National Laboratory®**

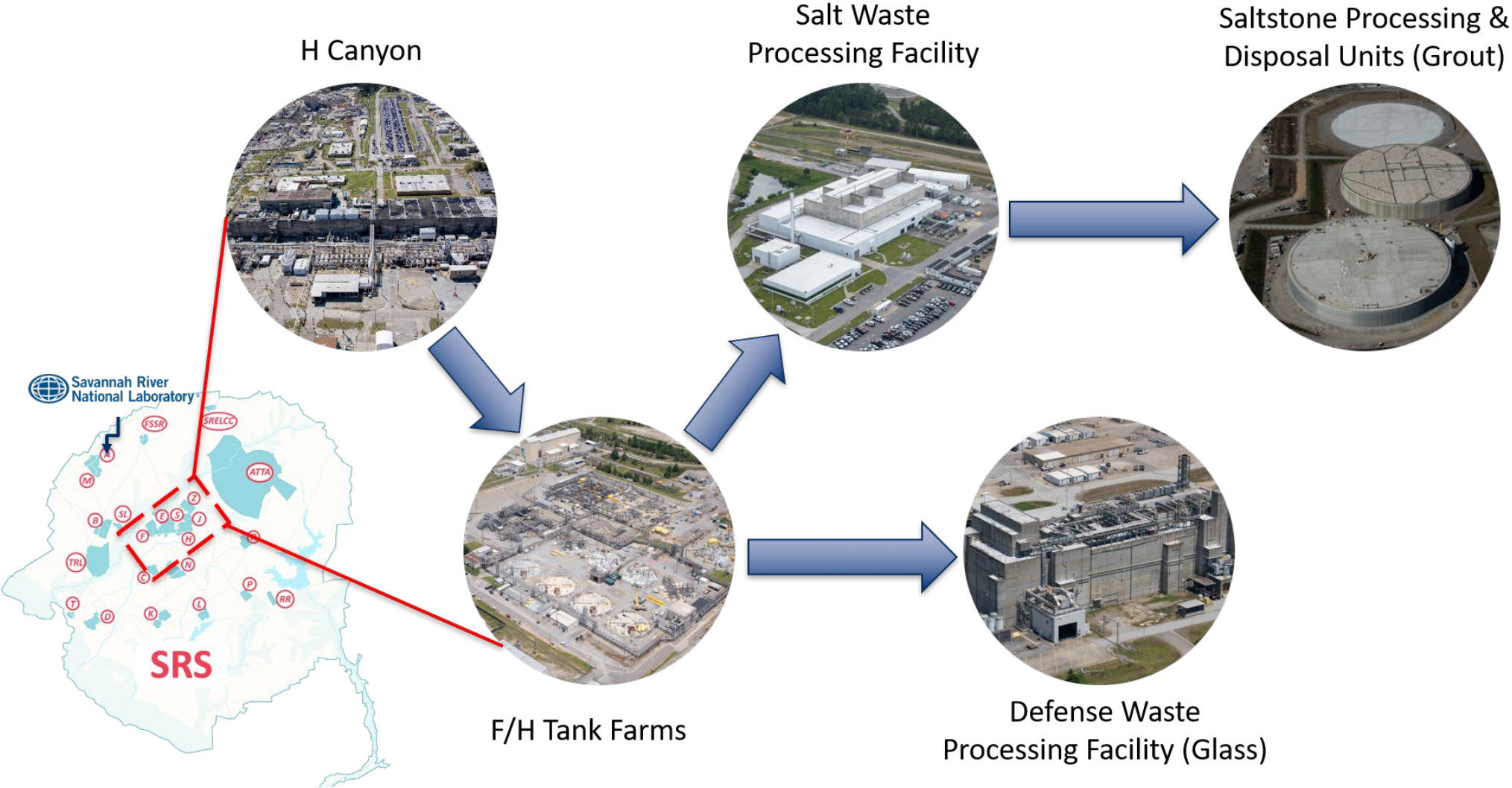


<https://www.energy.gov/documents/genesis-mission-science-and-technology-challenges>



Savannah River National Laboratory®

EM's Liquid Waste Mission at SRS



Salt Characterization Optimization and Prediction Engine



Tank Farm Data

- 51 SRS Tanks
- Transfer histories
- Sampling history

What possible upset conditions may occur?

Evaluation Case #1 (of many): Dissolution of NaNO_3 in NaOH Solution

$d_i = e^{-\Delta E_i}$

Legend:
Water Molecule (blue)
 NO_3 ion (green)
 OH ion (yellow)
 Na ion (red)

$\text{NaNO}_3(s) \rightarrow \text{Na}^+(l) + \text{NO}_3^-(l)$
 $\text{NaOH} \rightarrow \text{Na}^+(l) + \text{OH}^-(l)$

Step 1: Use ALCHEMI to derive Chemical descriptors (d) that are expected to be related to solubility rate constants (k)

$\frac{d[\text{NaNO}_3(s)]}{dt} = k_1[\text{Na}^+(l)][\text{NO}_3^-(l)] - k_2[\text{NaNO}_3(s)] \quad k_1 \propto d_1$
 $\frac{d[\text{NaOH}(s)]}{dt} = k_3[\text{Na}^+(l)][\text{OH}^-(l)] - k_4[\text{NaOH}(s)] \quad k_2 \propto \omega_2 d_2 + \omega_3 d_3 + \omega_4 d_4$



Salt Waste Processing Facility



Defense Waste Processing Facility (Glass)



Concluding Remarks

- AI presents a multi-billion dollar opportunity for DOE-EM to reduce cost and schedule for DOE, while providing improved safety

**Enterprise Knowledge
Management**

**AI-Enhanced
Decision Support**

**AI-Enabled
Automation**

- Applicability of technologies developed as part of the EM mission extends beyond environmental cleanup
 - Critical minerals
 - Isotope production
 - Fuel cycle design



ALTEMIS Collaborators

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