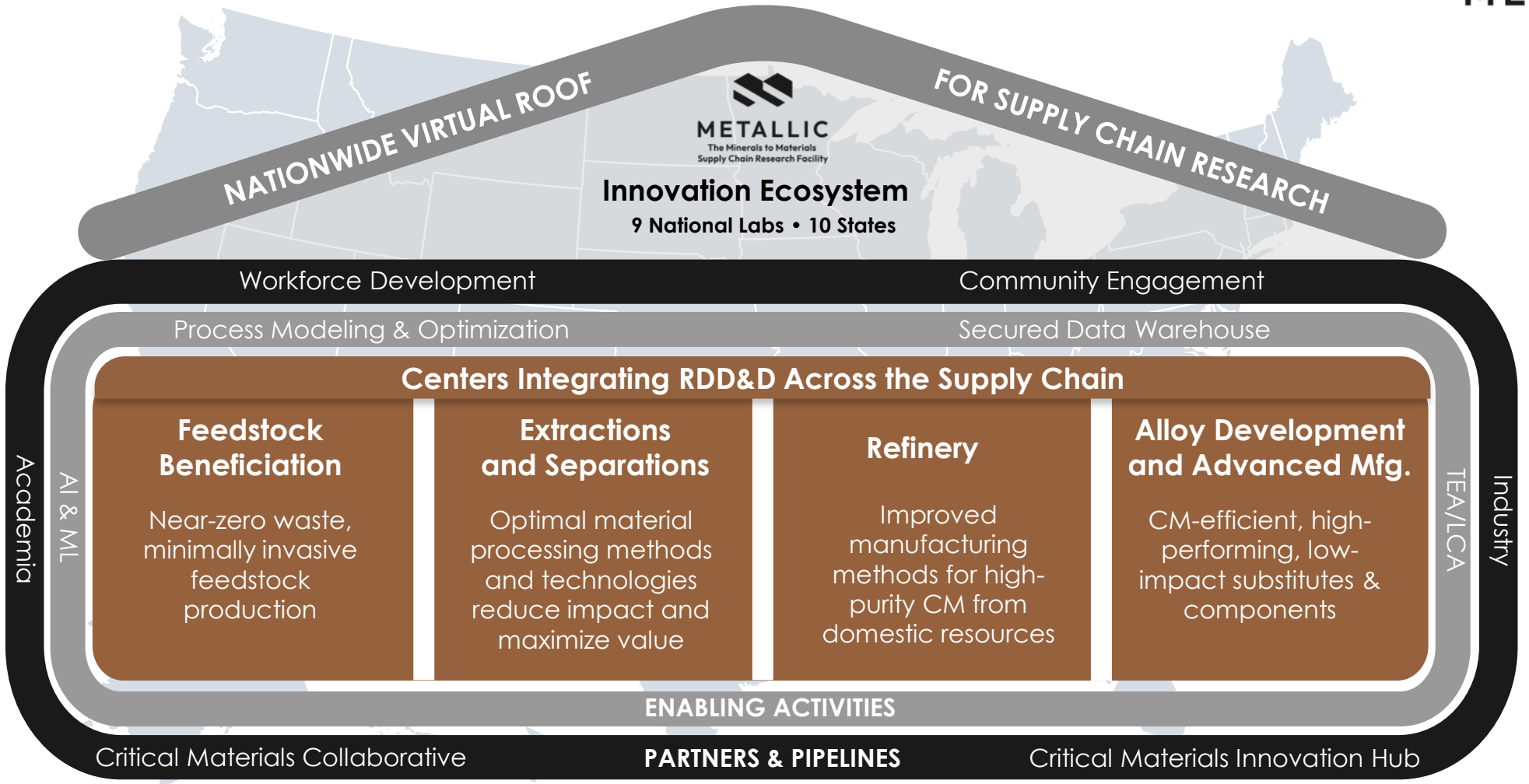
METALLIC: The Minerals to Materials Supply Chain Research Facility

Enabling Activities

MIP Stakeholder Meeting

July 27, 2026

An Innovation Ecosystem



NATIONAL ENERGY TECHNOLOGY LABORATORY · The Ames Laboratory · Argonne NATIONAL LABORATORY · BERKELEY LAB · INL Idaho National Laboratory · Lawrence Livermore National Laboratory · National Laboratory of the Rockies · OAK RIDGE National Laboratory · Pacific Northwest NATIONAL LABORATORY

Enabling Activities

Connecting Data, Analysis, and Innovation across METALLIC

Scope: Deliver the analytical and technical services that transform METALLIC research into results that matter. Support METALLIC Centers, Projects, and Industry Partners, advancing critical minerals from the lab to a competitive domestic supply chain.

Flagship Activities/Pillars:

1. Automation and AI/ML
2. Advanced Characterization
3. Techno-economic Analysis and Process Modeling
4. Lifecycle Assessment
5. Supply Chain Analysis
6. METALLIC Engineering and Systems Hub (MESH)

EA Pillar - Autonomous & AI/ML

Objective: De-risk operations and accelerate domestic Critical Minerals and Materials (CMM) processes using AI/ML, overcoming inherent data scarcity to guide supply chain decision-making

Knowledge Under Data Scarcity

ML for design of experiments to maximize information gain while eliminating unnecessary testing

Autonomous, self-driving labs that accelerate technology readiness with advanced characterization and smart sampling

Secure, federated learning ecosystem to build shared models among stakeholders

AI Design and Optimization

AI process optimization and control co-design create flexibility to absorb feedstock volatility and meet different grade specs

AI-guided inverse design and inference to expand the space of feasible materials, processes, and feedstocks

AI assistants for direct database connection and nationwide CMM digital products

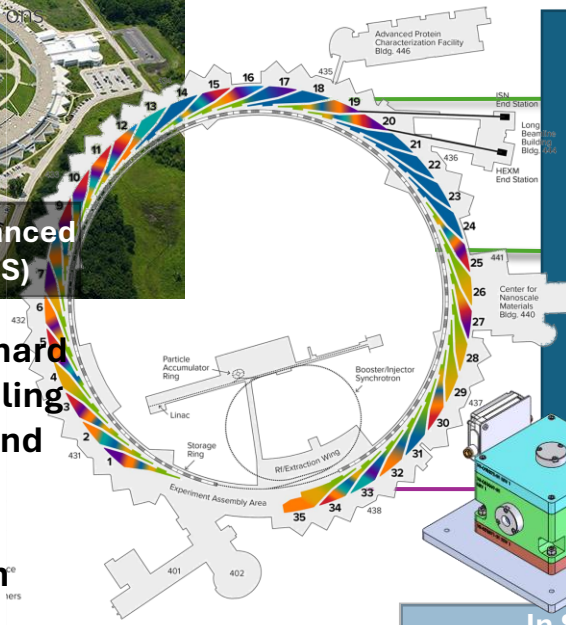
De-Risking Operation and Guiding Decisions

Predictive condition monitoring for reliable, traceable operation

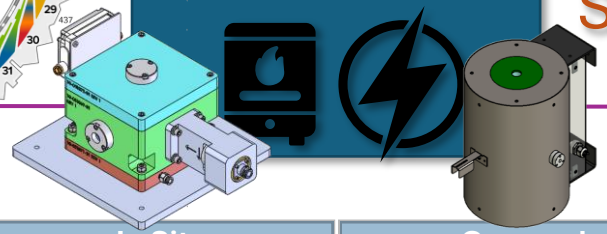
AI-accelerated LCA/TEA for real-time supply chain guidance

EA Pillar - Advanced Characterization

World's brightest hard X-ray source enabling high resolution and sensitivity for materials characterization



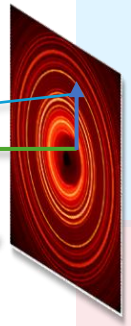
Custom-designed testbeds mimicking large-scale manufacturing processes for near-real-time detection



In Situ Microwave Furnace

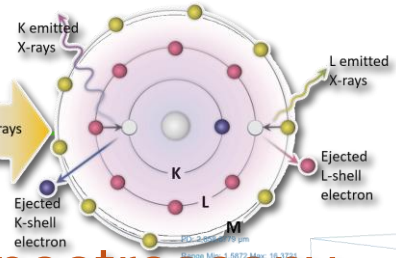
Operando Electrorefining Furnace

Diffraction



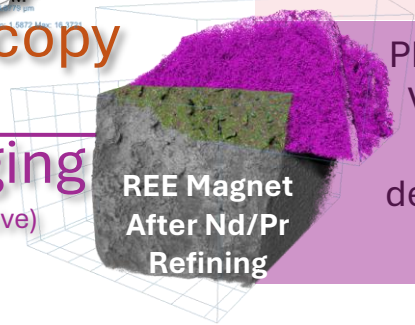
Structure
Strain
Defects
Crystal Size
Etc.

Spectroscopy



Chemical Concentration
Oxidation state
Bonding Environment
Etc.

3D Imaging
(Nondestructive)



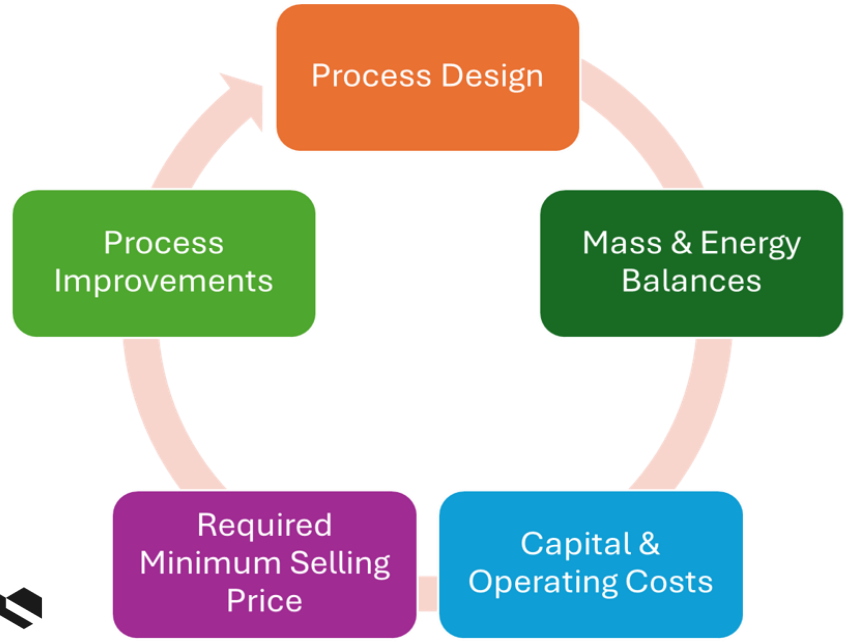
Phase Connectivity
Volume Changes
Tortuosity
depth-Profile Trends
Etc.

- **<u>Consultation</u>** to find the right synchrotron technique for your process or material to write highly competitive user proposals for experimental access.
- Analyze materials and **<u>feedstocks</u>** before and after processing to understand structure, composition, purity, etc. With high sensitivity and resolution.
- Design and build equipment that will mimic industrial processes developed with METALLIC to gain a **<u>kinetic</u>** understanding of extraction, refining, and material development.
- Gain high-fidelity data to **support modeling** and inform the **<u>choice of in-line sensing</u>**.

EA Pillar - Techno-Economic Analysis (TEA)& Process Modeling

Value Proposition of Process Modeling + TEA

- **Unify** process design and decision-making, **de-risking** the scale-up of industrial processes
- Rigorous Modeling to Estimate Performance and **Cost at Scale**
- **Quantify and optimize** current and prospective process **cost performance** and **increase efficiency** across parameters, configurations, and other factors, e.g., feedstock variability
- **Focus and iterate with R&D on high-impact areas** across all technology readiness levels (TRLs)



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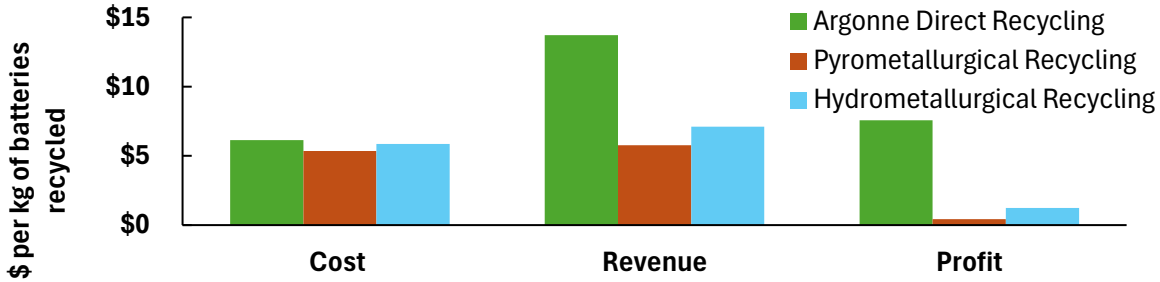
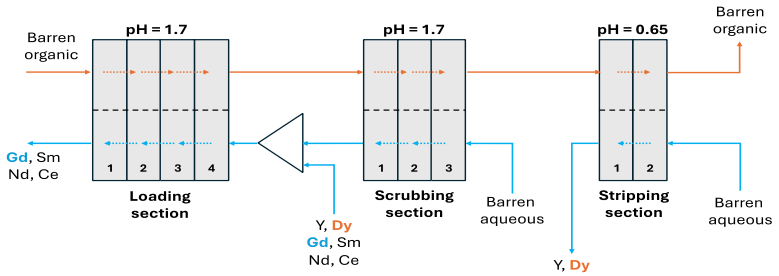
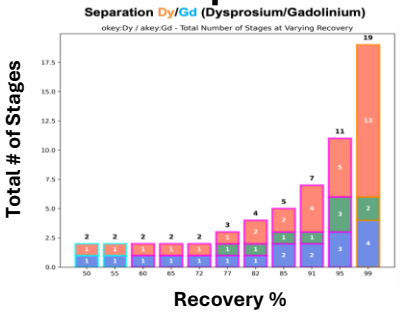
Cost, Revenue, and Profit vs. Conventional Methods

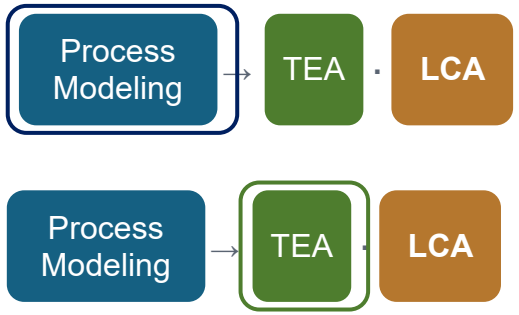


Conceptual Design: Optimize Performance Across Options





What are Techno-economic Analysis & Process Modeling?



- **Process modeling** develops mathematical mass and energy balance models, providing inputs for economic and environmental assessments.
- **TEA** helps achieve cost-optimal design and lower production costs through economic tradeoff evaluation for market competitiveness

Available tools, customized for critical mineral processing:

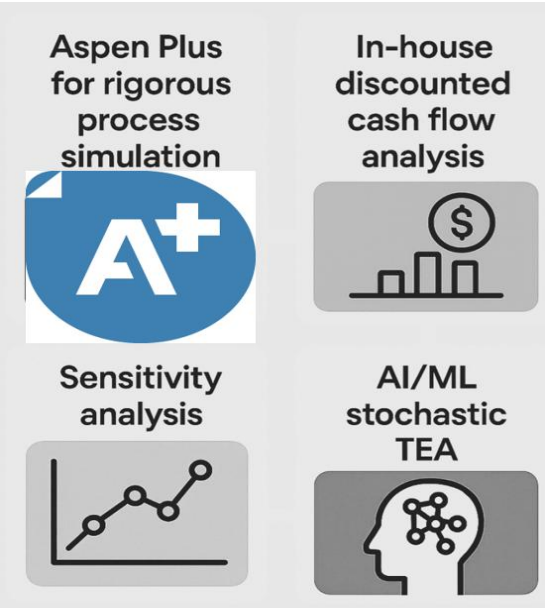
EVERBATT

EverBatt and EverGreen Models
Cost and Environmental Impacts of Recycling Critical Materials from Batteries and other EOL products

PrOMMiS
Process Optimization and Modeling for Minerals Sustainability

IMPACT

IMPACT Models
Innovative Manufacturing and Processing Assessment Comparison Tool.



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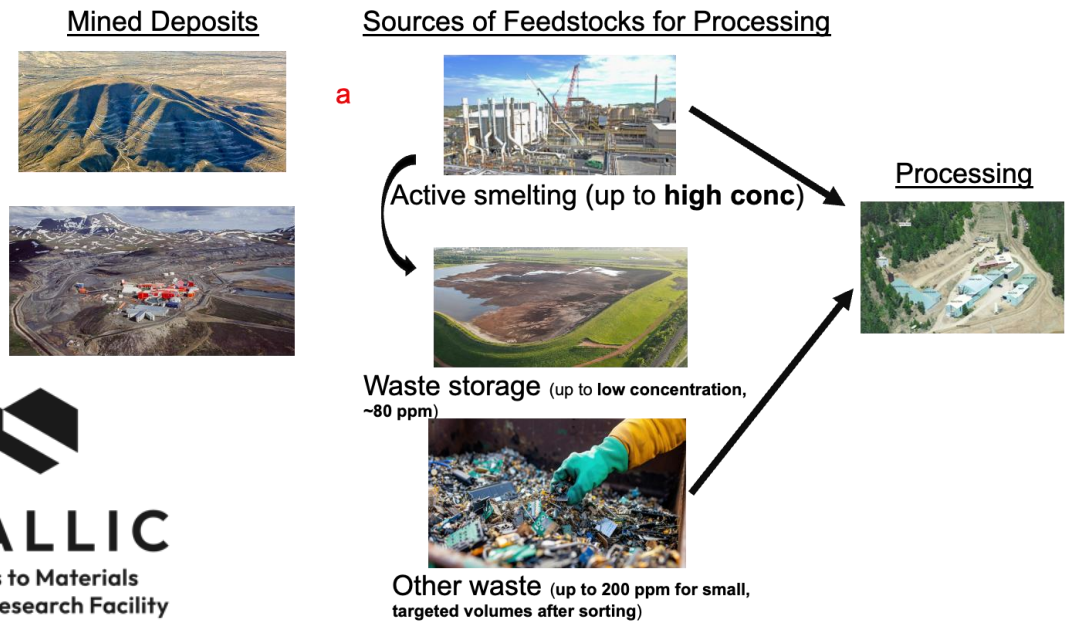
EA Pillar: Supply Chain Analysis

Conduct comprehensive assessments of critical material supply chains across up-, mid-, and down-stream activities to identify dependencies, bottlenecks, trade vulnerabilities, and supply disruption risks

Process Routes for Mineral Recovery



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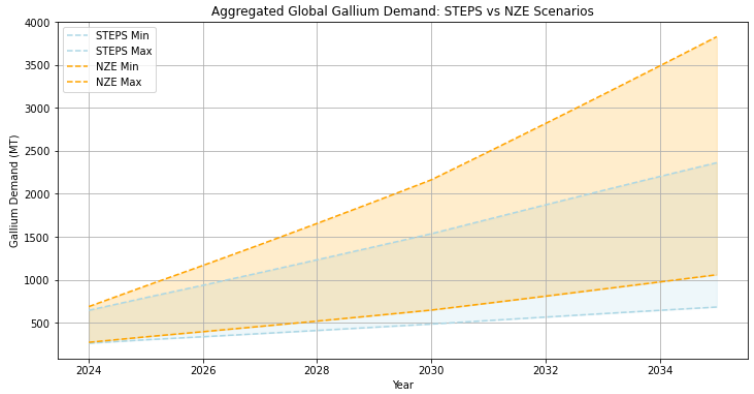
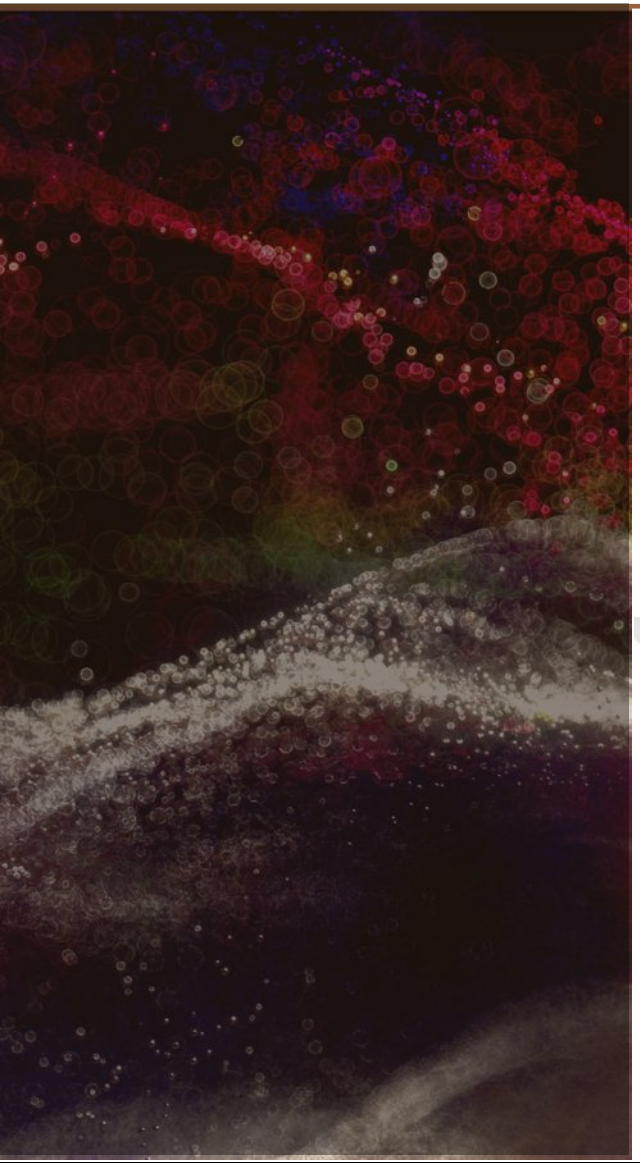
Projected Mineral Demand



Critical Process Chemicals and Equipment

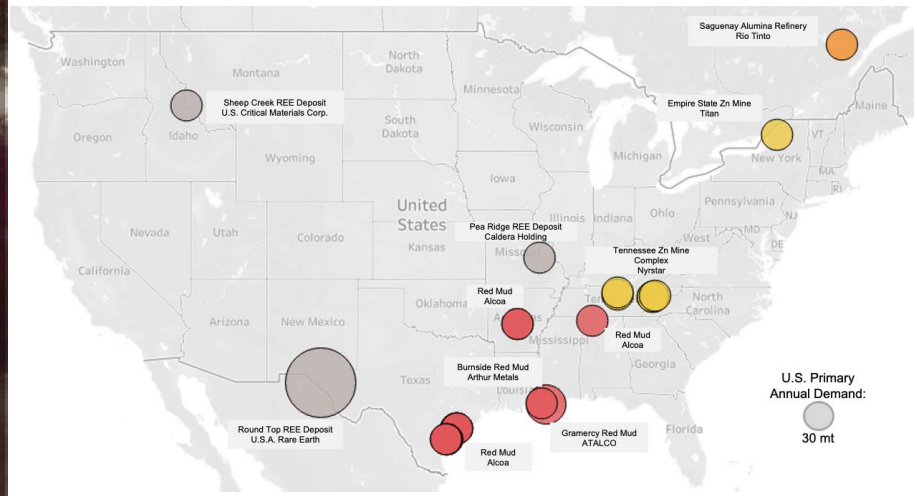
Risk	Chemical/Equipment	Supplying Countries
High	N-235[1] (ZLR)	All commercial sources in China
High	Kelex-100[2] (Bayer)	All commercial sources in China
Med	Amidoxime (Bayer)	Ecolab Purolite only U.S. source, all others in China
Med	Tannic Acid (ZLR)	Spectrum Chemical only U.S. source, Italy, Belgium
Med	Oxalic Acid (ZLR)	Spectrum Chemical only U.S. source, Poland, Spain, Japan, India)
Med	XAD1180 (Bayer)	DuPont only U.S. source, all others in China
Med	Electrolytic Cells (all)	Canada, South Korea
Low	Adsorption Towers (Ion Exchange)	Some U.S. companies but none for mining Canada, Sweden, Finland, Spain

Supply Chain Analysis

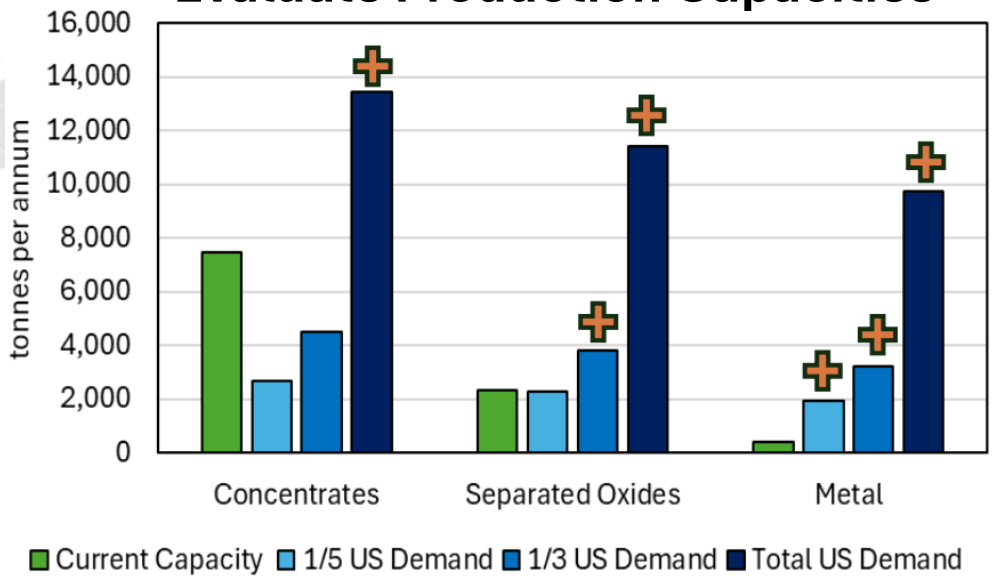


- Evaluate the commercialization status, manufacturing readiness, and competitive landscape for critical materials processing and emerging processing technologies.
- Analyze cost competitiveness, supply chain economics, and market impacts associated with critical materials and emerging technologies.

Map Feedstocks and Processing



Evaluate Production Capacities



EA Pillar: METALLIC Engineering & Systems Hub (MESH)

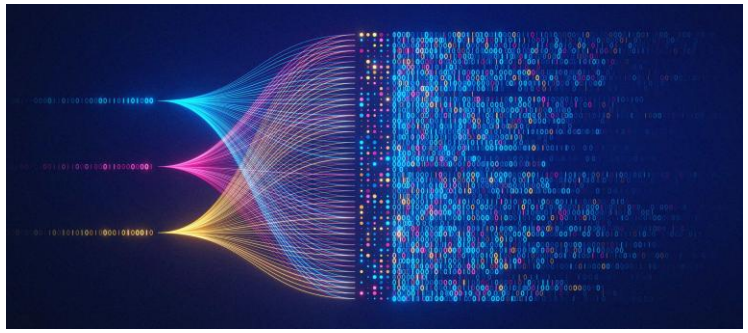
Enhancing CMM data workflows and technology integration

Scope: Adapt public and private capabilities of the EDX ClaiMM platform to improve stakeholder ability to capture and leverage generated data, as well as contextual information on technologies throughout the CMM supply chain

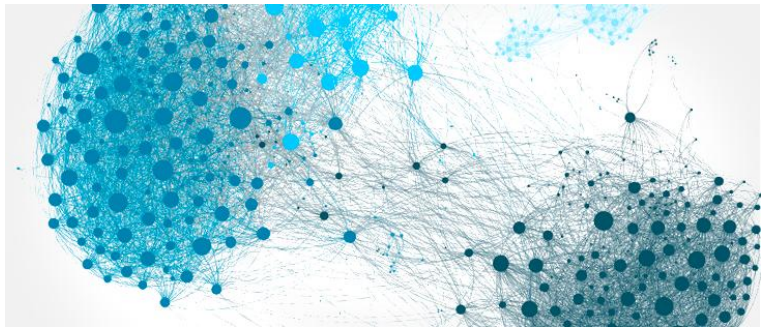
Flagship Activities:

1. **Common Data Platform:** Identify, federate, curate, and make accessible qualified, interoperable data from a common data platform to support METALLIC Centers, techno-economic analyses, and lifecycle analyses.
2. **System Integration Framework:** Develop a system integration framework to seamlessly inter-connect METALLIC Center field and laboratory technology, including autonomous technology, with decision-making tools that support cost-benefit analyses for data and technology investments.
3. **Advanced Analytic Hub:** Identify and deploy an advanced analytics hub that minimizes the duration of data preprocessing and facilitates the development, demonstration, and deployment of ML/AI/LLM-based simulation and forecasting capabilities.

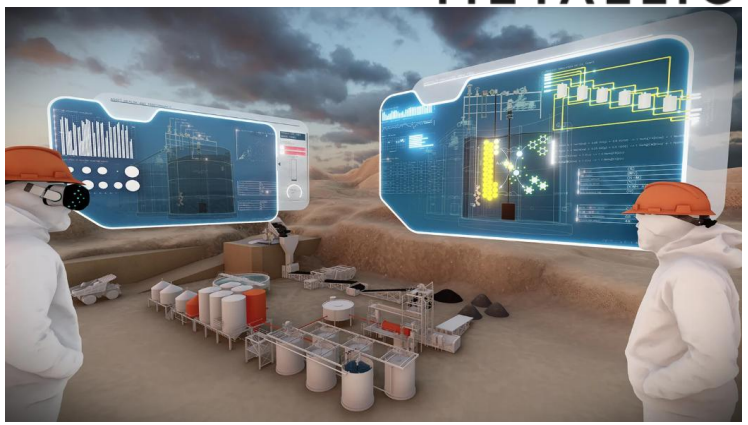
EA Pillar: MESH



1. Automated Data ingest

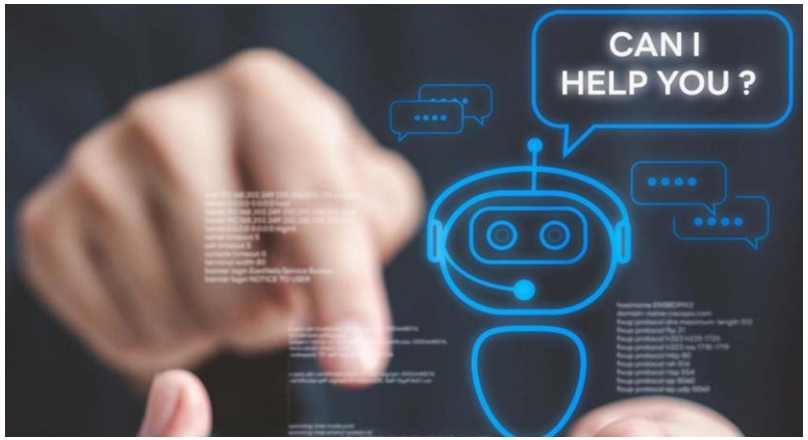


4. Demonstrate modular digital twins for technology scenario testing



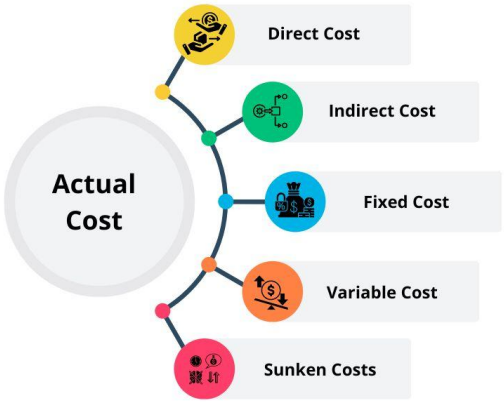
FY26-Q2 *Q3* *Q4* **Capability Deployment Timeline** *FY27-Q3* *FY28-Q3*

2. Operational Guidance on Data Quality, Sharing, and Governance



3. Demonstrate AI Chatbot for METALLIC Data

5. Demonstrate data & technology CBA tool to private stakeholders



We couldn't do it without YOU!

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Together we are Family!

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AMES NATIONAL LABORATORY

INL Idaho National Laboratory

National Laboratory of the Rockies

OAK RIDGE National Laboratory

Argonne NATIONAL LABORATORY

Pacific Northwest NATIONAL LABORATORY

Lawrence Livermore National Laboratory

THANK YOU

Contact Us

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