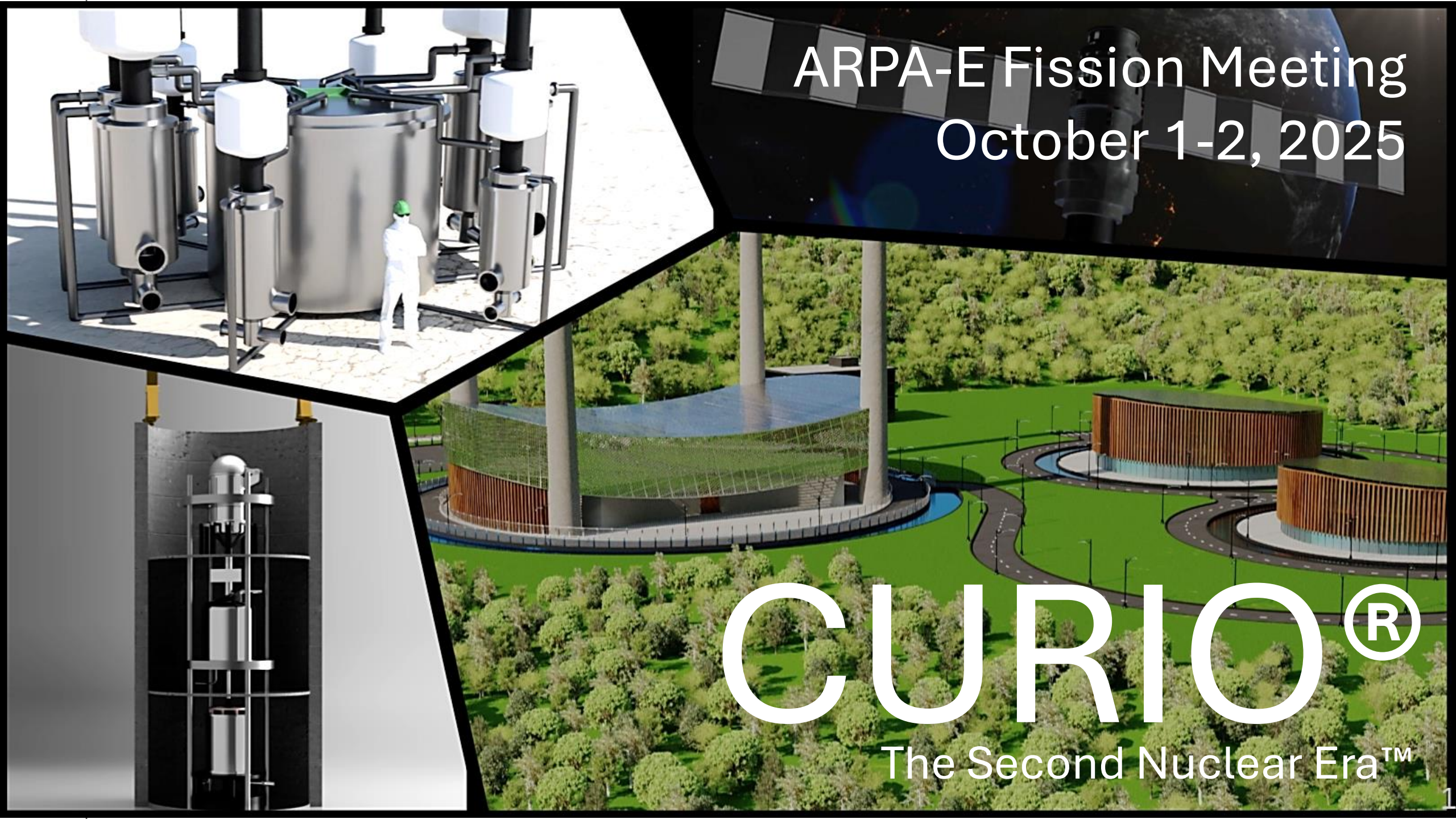

ARPA-E Fission Meeting
October 1-2, 2025
CURIO®
The Second Nuclear Era™

Overview

- Discuss the on the overall goal of the project
  - To demonstrate NuCycle flow sheet at lab scale with UNF
  - Use SIMFUEL and UNF to learn as much about the engineering of these systems through applied chemistry
  - Incorporate safeguards and security by design (SSeBD)
- Team composition and roles
- Technical Achievements
  - Progress with SIMFUEL
  - Success with NF_3 selective fluorination
  - Off-gas capture at INL
  - SSPM modeling
- T2M approach and progress

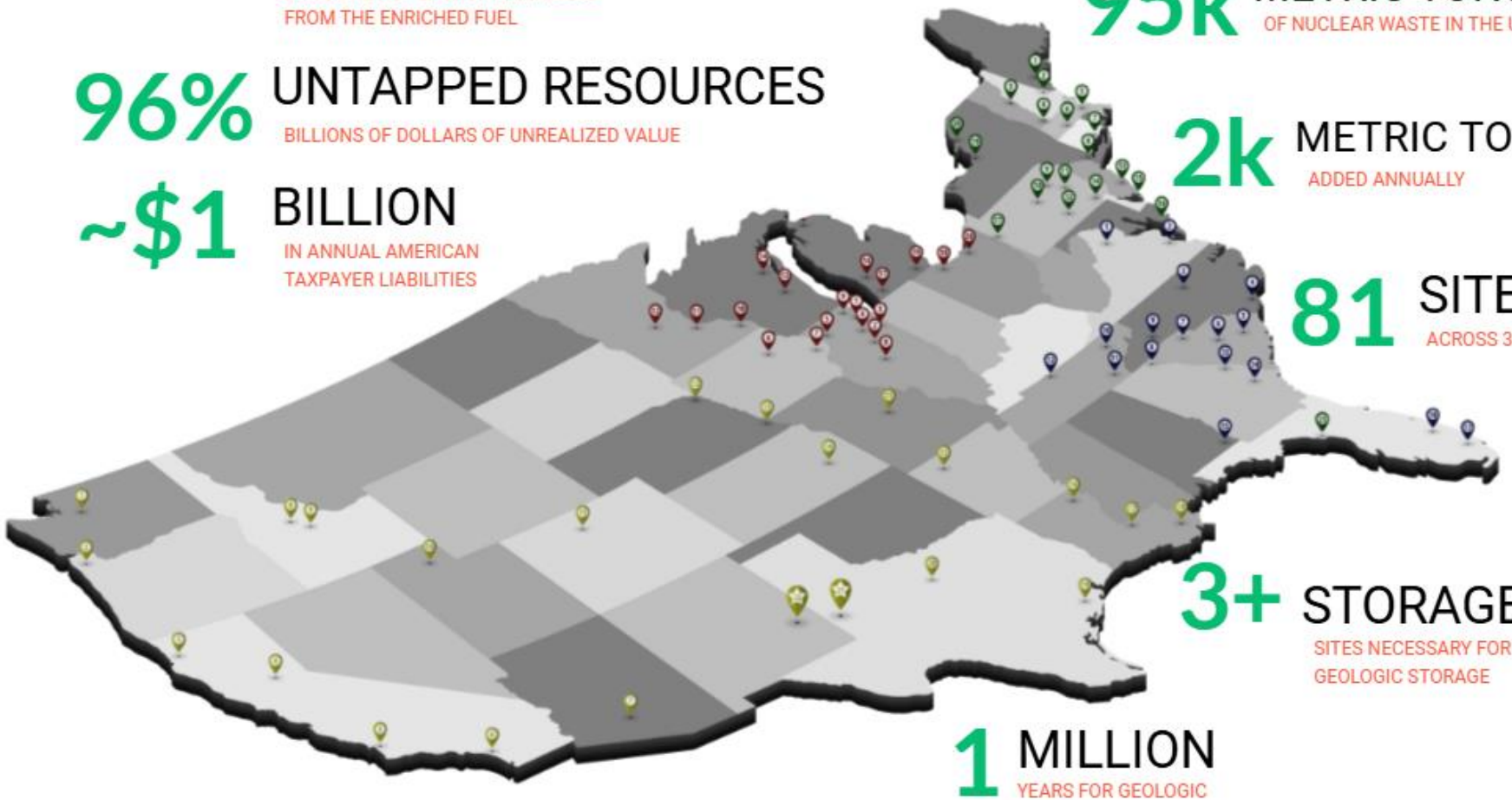
CLOSING THE CYCLE WITH NUCYCLE®

The UNF Inventory & Nuclear's PR Problem

4% FUEL UTILIZATION
EFFICIENCY OF ENERGY HARNESSED FROM THE ENRICHED FUEL

96% UNTAPPED RESOURCES
BILLIONS OF DOLLARS OF UNREALIZED VALUE

~$1 BILLION
IN ANNUAL AMERICAN TAXPAYER LIABILITIES



95k METRIC TONS
OF NUCLEAR WASTE IN THE U.S.

2k METRIC TONS
ADDED ANNUALLY

81 SITES
ACROSS 38 STATES

3+ STORAGE
SITES NECESSARY FOR GEOLOGIC STORAGE

1 MILLION
YEARS FOR GEOLOGIC STORAGE

12
STATES
have moratoria on new nuclear power, with six tied directly to demonstration of UNF disposal or reprocessing

National Conference of State Legislatures: *States Restrictions on New Nuclear Power Facility Construction*, Sep 2023

Goal of Curio CURIE project – enable pathway to commercialization!

- NuCycle is a novel nuclear recycling flowsheet that will being tested with both surrogates and UNF under ARPA-E CURIE
- NuCycle uses oxidation for decladding and powderization, selective fluorination for gas-solid bulk uranium separation, and electrolysis for coextraction of Pu, U and other MA/FPs
- To demonstrate NuCycle flow sheet at lab scale with UNF
  - Novel integrated process
  - Limited contemporary research on recycling using UNF
- Use SIMFUEL and UNF to learn as much about the engineering of these systems through applied chemistry
  - Avoiding time consuming research program approach
  - Evaluating SIMFUEL for possible UNF replacement during scaleup
- Incorporate safeguards and security by design
  - Avoid pitfalls of past reprocessing plants

CLOSING THE CYCLE WITH NUCYCLE®

NuCycle™

GAIN Gateway for Accelerated Innovation in Nuclear

arpa·e CHANGING WHAT'S POSSIBLE

ADVANCES:

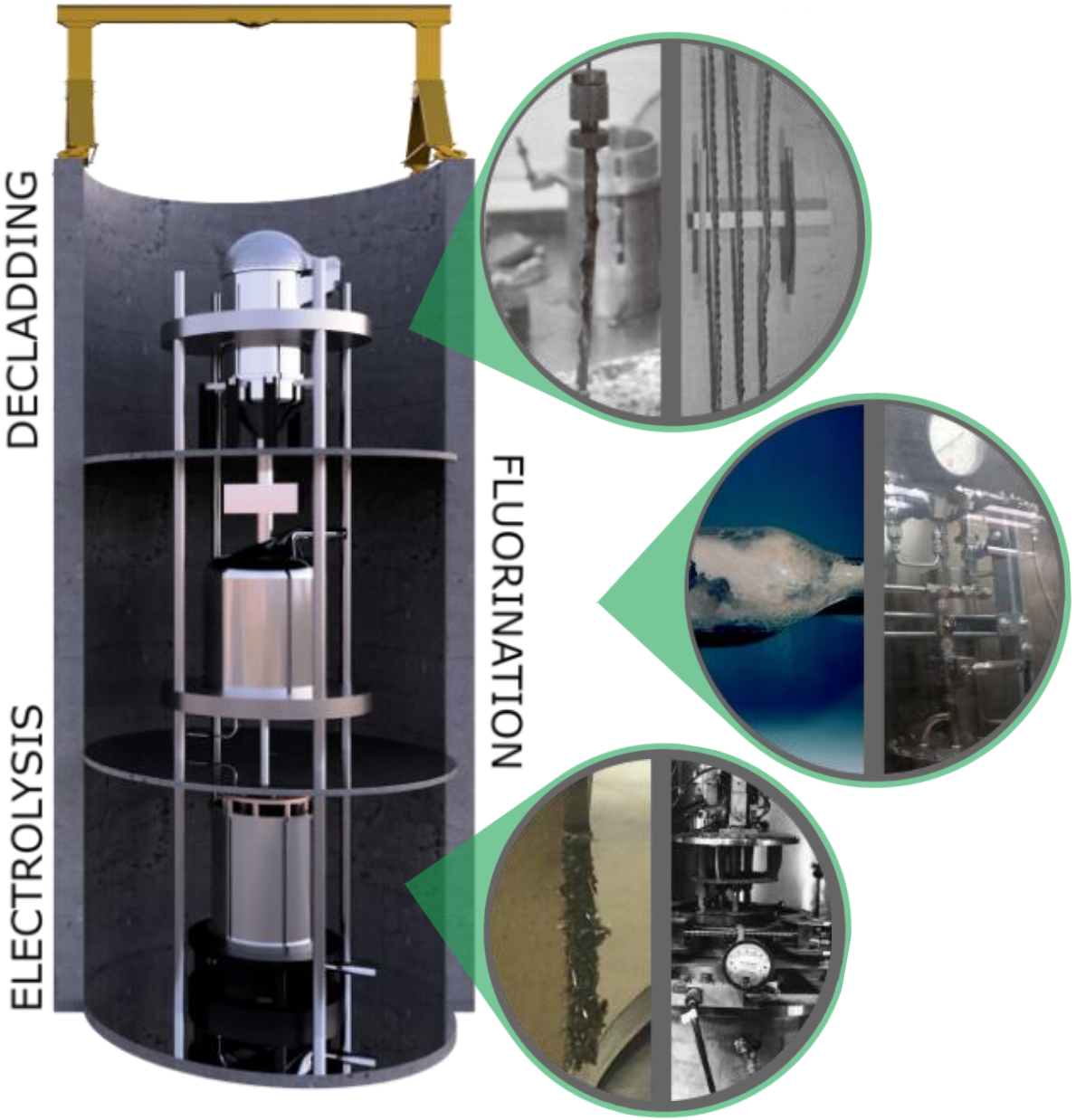
- Development of a modular, integrated, compact, and versatile process
- Recover fissile material agnostic to reactor type
- Recover valuable isotopes

IMPACT:

- Enrichment-ready uranium extraction
- Efficiencies gained in head-end processing
- Integrated process enables semi-autonomy and safeguards-by-design

PERFORMANCE METRICS:

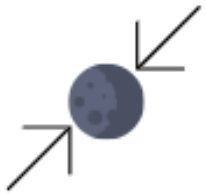
- No pure Plutonium streams, Pu and MAs left w/ FPs after fluorination
- >99% recovery of U greatly reduces HLW relative to direct disposal
- Provide ~0.9 wt.% U at market-competitive prices
- Design MC&A for accounting SNM to within1% uncertainty



Principal Technical Project Objectives

- Declad UNF fuel rodlets >12-inch
  - <1% UNF residue remaining
  - <100-micron pulverized product
- Use temperature-based reactivity of NF_3 to separate FPs with volatile fluorides and uranium
  - Determine parameters to maximize separation of volatile transition metal FPs and U from TRU
- Use SIMFUEL studies to develop kinetics models
- Incorporate safeguards and security by design
  - Conduct MC&A of NuCycle flowsheet

Tech Goals



<50-µm particle size

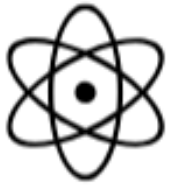
Homogeneous prod for input accountancy

<0.1% UNF residue

Recycle Hf-free zirconium

Kr-85 and tritium recovery

Temp-based separation of FPs from U



>99% U recovery

UF6 meeting ASTM standards

Pu and MA left with FPs

Co-extract U/TRU

>99.9% actinide recovery

Precious metals recoverable

Sr-90 & Cs-137 recovery

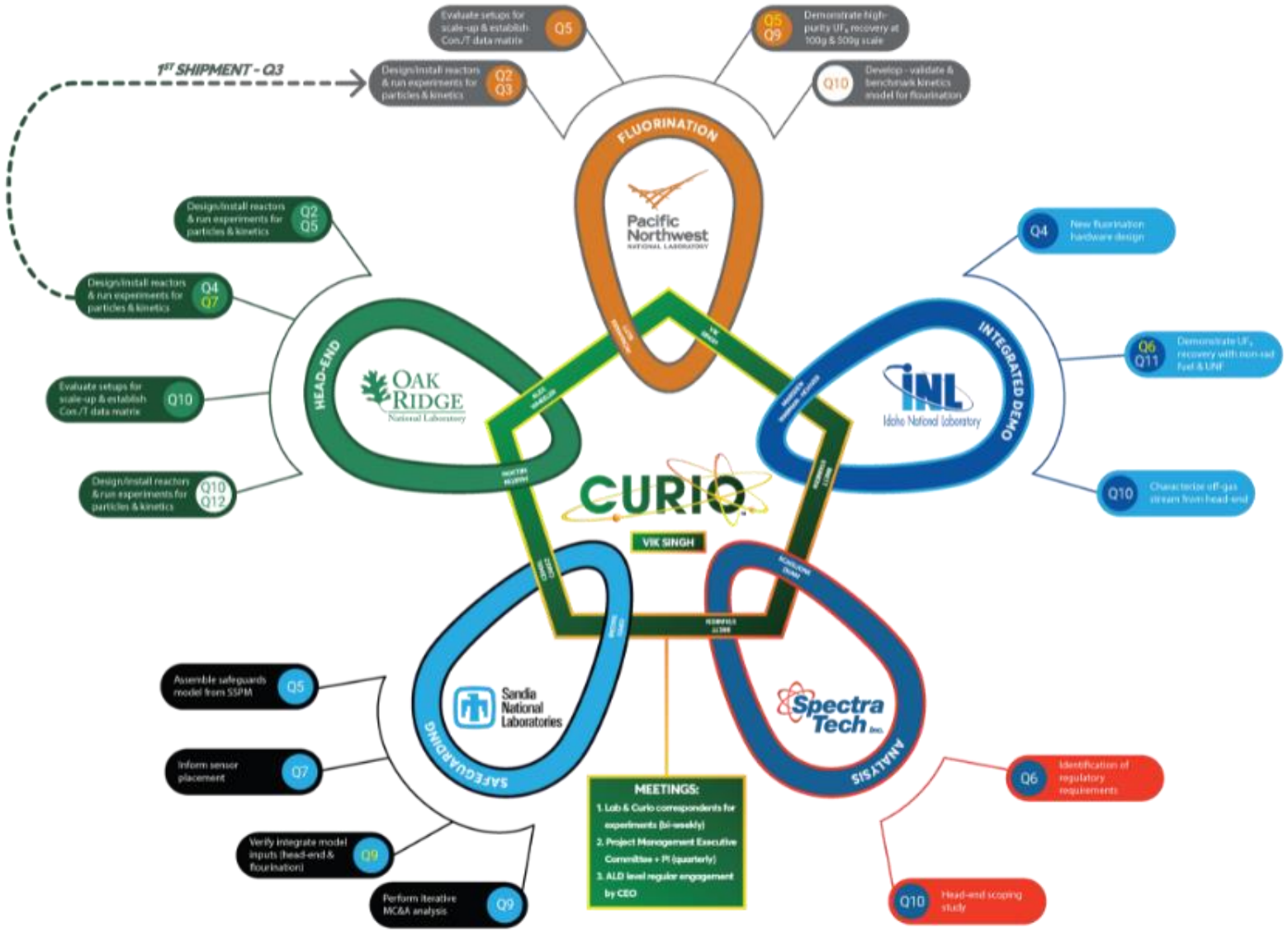
Near-complete salt recycle

DEOX → FLUORINATION → ELECTROWINNING

CLOSING THE CYCLE WITH NUCYCLE®

NuCycle

ARPA-E PROJECT MANAGEMENT



SYMBIOTIC NATIONAL LAB PARTNERSHIPS

Recent Accomplishments

- **All go/no-go milestones completed**

- **VOLOXIDATION:**
  - Experiments with 3, 6, 8, and12-in. SIMFUEL rodlets
  - Modeled chemical kinetics and mechanics of the process
  - Reproducibly demonstrated scalable process for large-scale decladding

- **SELECTIVE FLUORIDE VOLATILITY (SFV):**
  - Fluidized bed reactor development
  - Scaled up SFV from 500mg to 100g
  - Demonstrated recovery of clean UF_6 from SIMFUEL w/ TRU at 100-g scale

- **ELECTROWINNING:**
  - Acquired world-first dataset on fundamental redox chemistry of transuranic- and lanthanide-fluoride species of interest
  - Cyclic voltammograms covering multiple temperatures and concentrations acquired for each species

(Clockwise from upper left) Rodlet containing UO2 pellets undergoing voloxidation. Fluidized bed. Electrowinning experiments. Lab-scale electrowinning. (Center) Sample of pulverized U3O8 from voloxidation.

T2M Approach - Development Path

Proof-of-concept demonstrated through ARPA-E & GAIN Vouchers

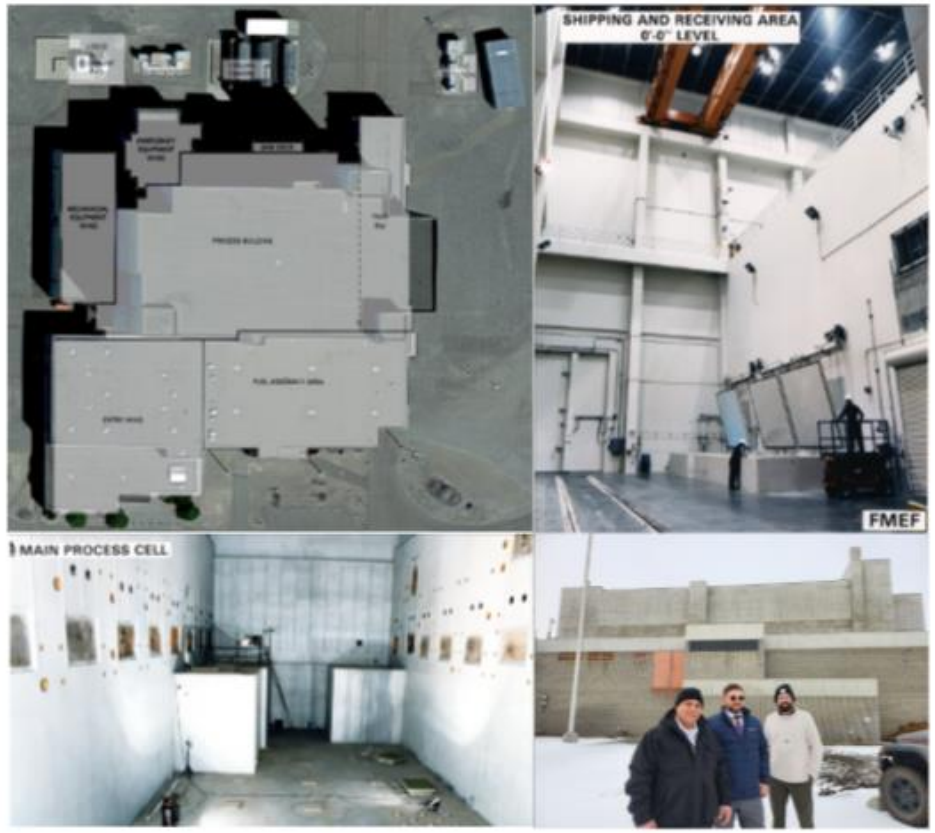
- 100-g scale using actual UNF
- Determined key chemical and thermophysical parameters
- Demonstrated recovery of uranium and TRU
- Developed MC&A design

Engineering Scale

- 100x scale-up in batch size
- Secure CRADA
- Secure Cooperative Agreements
  - With National Laboratories for technology development
- Demonstrate key control, data acquisition, and auxiliary systems
- Demonstrate waste form fabrication
- Deploy safeguards sensors and instrumentation

Commercial Scale

- Demonstrate commercial-scale equipment
- Provide TRUfuel for advanced reactor demonstrations
- Expanded supply of isotopes
- Implement nation's first safeguards- and security-by-design facility



Questions