

# **ARPA-E GEMINA Portfolio and Digital Twins**

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# ARPA-E Mission

**Goal 1:** To enhance the economic and energy security of the United States through the development of energy technologies that—



- ▶ ARPA-E is investing ~\$40 M in innovative digital technologies R&D aimed at enabling advanced reactor development
- ▶ Near-term timeline for commercial deployment of these digital technologies

# ARPA-E Advanced Nuclear Portfolio

## ► Fission

### – MEITNER

- Can we greatly reduce AR CapEx?

### – GEMINA

- Can we greatly reduce AR OpEx?

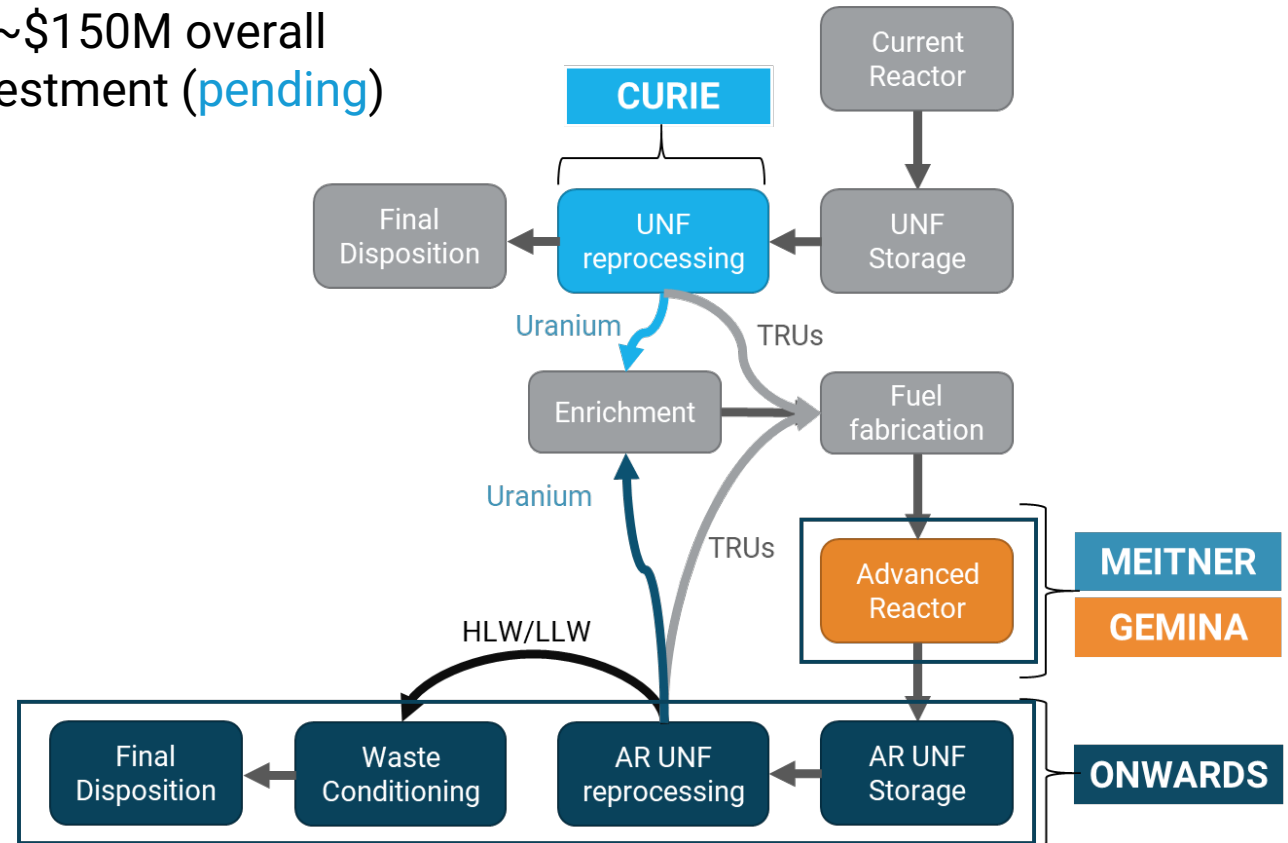
### – ONWARDS

- Can we greatly minimize the disposal impact of AR wastes?

### – CURIE

- Can we improve the cost and monitoring of UNF reprocessing?

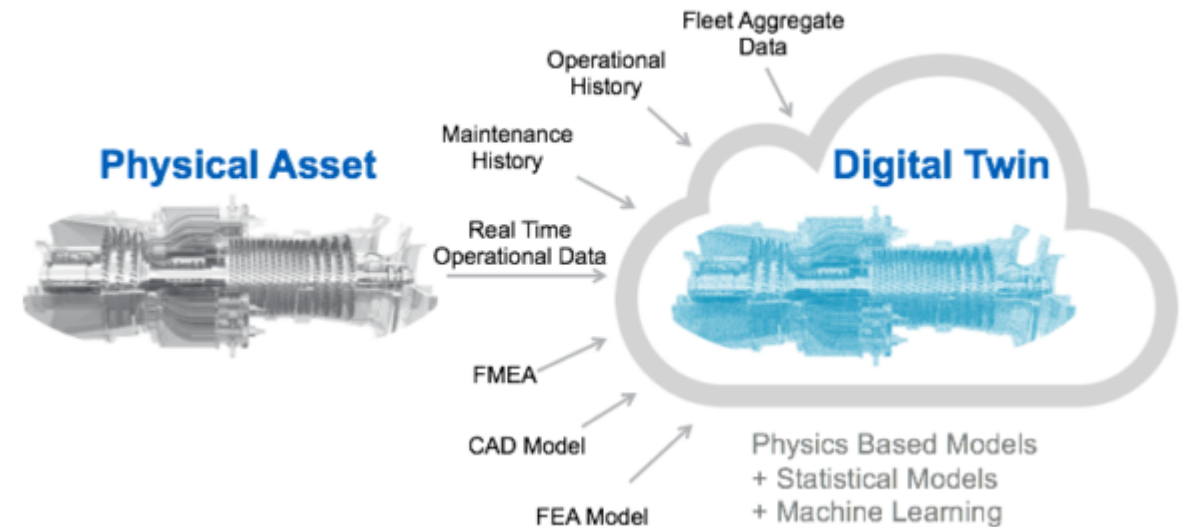
~\$150M overall investment (**pending**)



Attentive to commercialization & deployment

# Defining Digital Twins

- ▶ Mapping of physical asset models in a digital platform where a virtual digital replica is created
- ▶ Consists of three basic building blocks:
  1. 3D models
  2. Simulators
  3. Product Lifecycle Management (PLM) platform to centralize, organize, and manage data
- ▶ Continuous updating (sensors) and real-time data analysis to model physical asset



# Where are DTs applied currently?

*Oil & Gas, Gas Turbines (and Combined Cycles), Wind, Hydro, Aviation, etc.*

**SIEMENS**

**AVEVA**

**Bentley®**



# Digital twins provide a range of benefits

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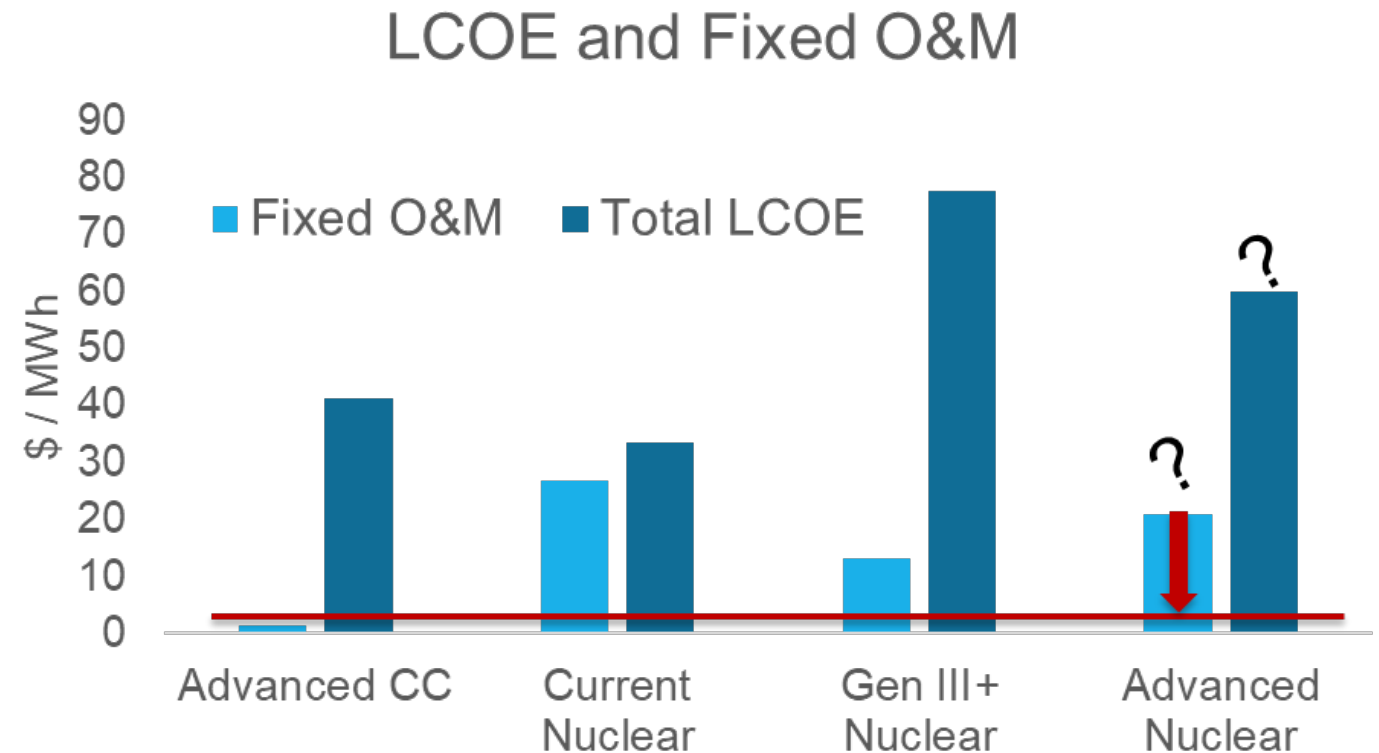
- ▶ Allow for *optimal operations* and condition-based *maintenance*
- ▶ *Time travel*: Allow for manipulation of DT for scenario and what-if analysis without disturbing physical asset (continuously updated data goes beyond static picture)
  - This can also apply during design phase – prior to physical asset launch and for planning possible impacts of proposed plant modifications
- ▶ Enables:
  - Rapid design iterations and optimization
  - Remote operations (future)
  - Autonomous power plants (future)
  - Fleet management
  - Performance improvement

# GEMINA (Generating Electricity Managed by Intelligent Nuclear Assets)

- ▶ **Goal:** Develop the tools and cost basis for ARs to **achieve fixed O&M costs of \$2/MWh** without shifting costs to other parts of LCOE

Awardee teams are developing the following for one or more of the most promising AR designs:

- **Digital twins for advanced reactor systems**
- **Relevant cyber physical systems**
- **O&M approaches for advanced reactors**
- **Cost models and design updates**



[https://www.eia.gov/outlooks/aeo/pdf/electricity\\_generation.pdf](https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf),  
<https://www.innovationreform.org/wp-content/uploads/2018/01/Advanced-Nuclear-Reactors-Cost-Study.pdf>

# ARPA-E teams are building digital tools for ARs and building blocks for DTs

## Advanced Reactor Digital Twins



## Sensors and Data Generation



## Construction



## O&M TEA



## Autonomous Maintenance

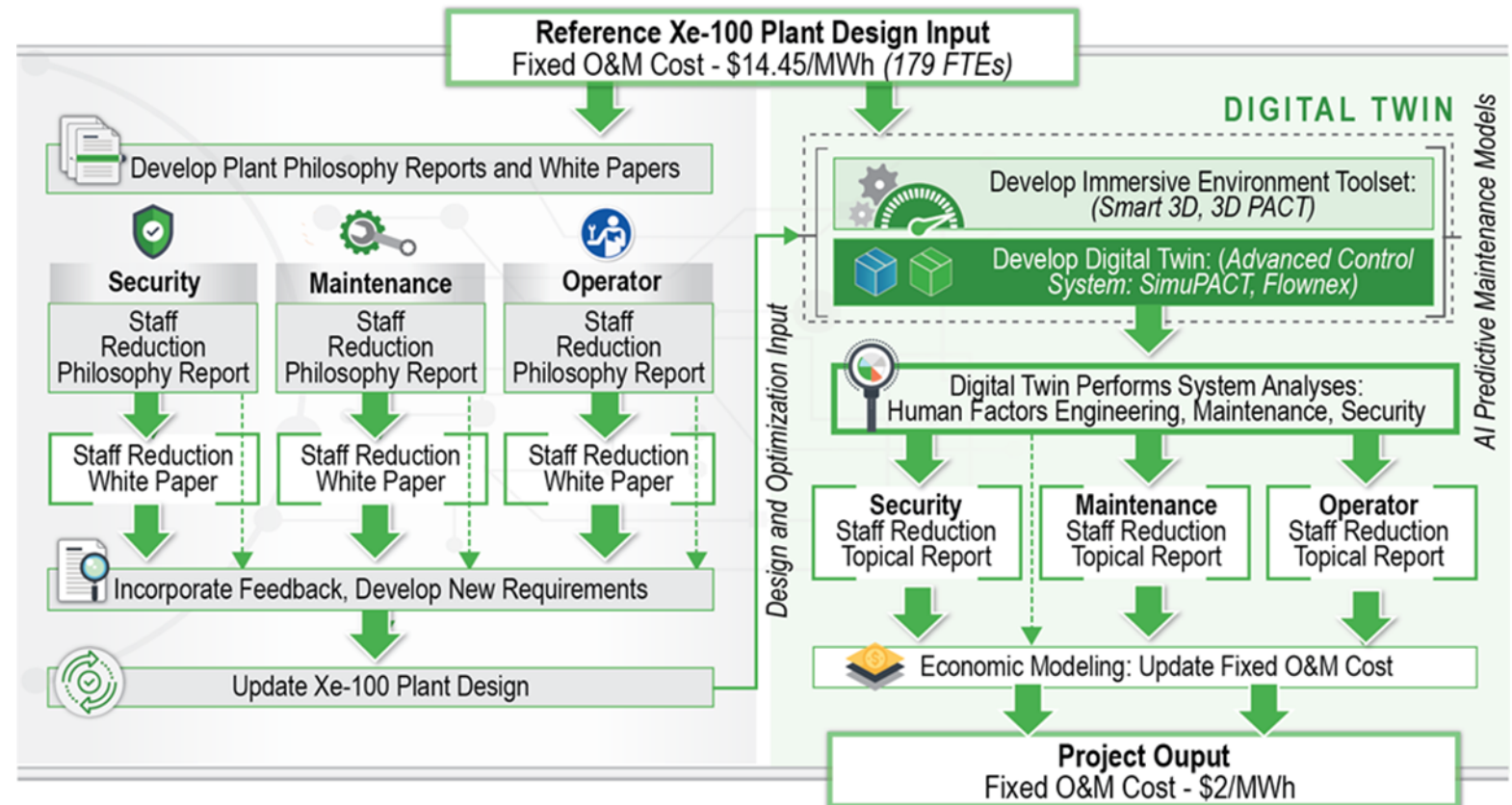




# X-energy: Advanced Operation & Maintenance Techniques Implemented in the Xe-100 Plant Digital Twin to Reduce Fixed O&M Cost

First Xe-100 plant would have 40,000 sensors to integrate with digital twin

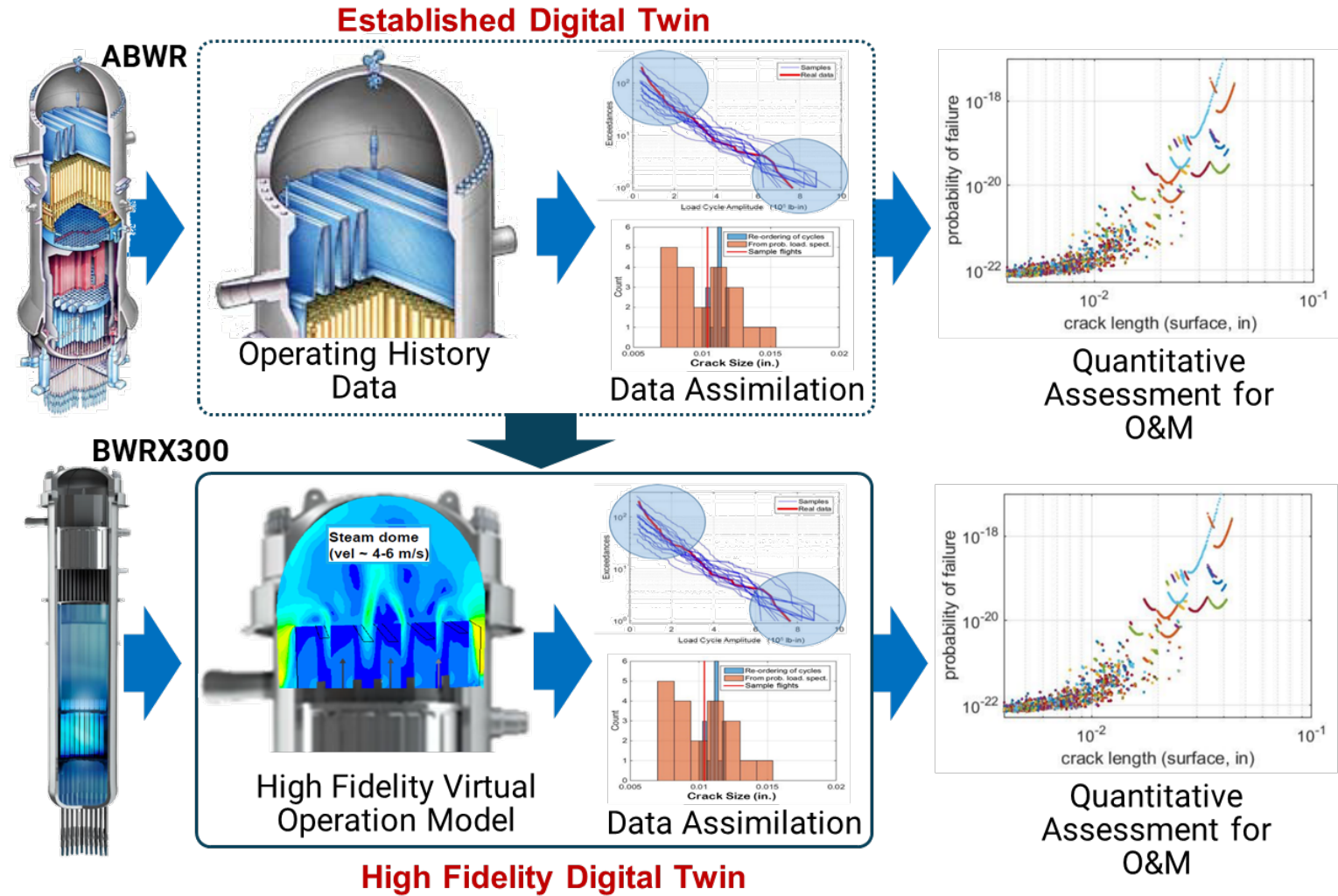
- ▶ Main goal is to target cost-reductions via **security**, **maintenance**, and **operating** staff reductions
- ▶ Targeting digital representations of the plant for physical security



Has submitted topical papers to NRC

# MIT & GE: High Fidelity Digital Twins for BWRX-300 Critical Systems

- Advancement and demonstration of *high-fidelity simulations-based maintenance approaches* and model-based fault system detection techniques.
- *Address mechanical and thermal fatigue* failure modes which drive O&M activities of BWRX-300



Are extendable to all advanced reactors (ARs) where a flowing fluid is present