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Advanced Reactor Cyber Analysis and Development Environment (ARCADE) for University Research

Presenter: Lee T. Maccarone

Sandia National Laboratories Coauthors:
Andrew S. Hahn, Romuald Valme, Michael T. Rowland

University of Pittsburgh Coauthors:
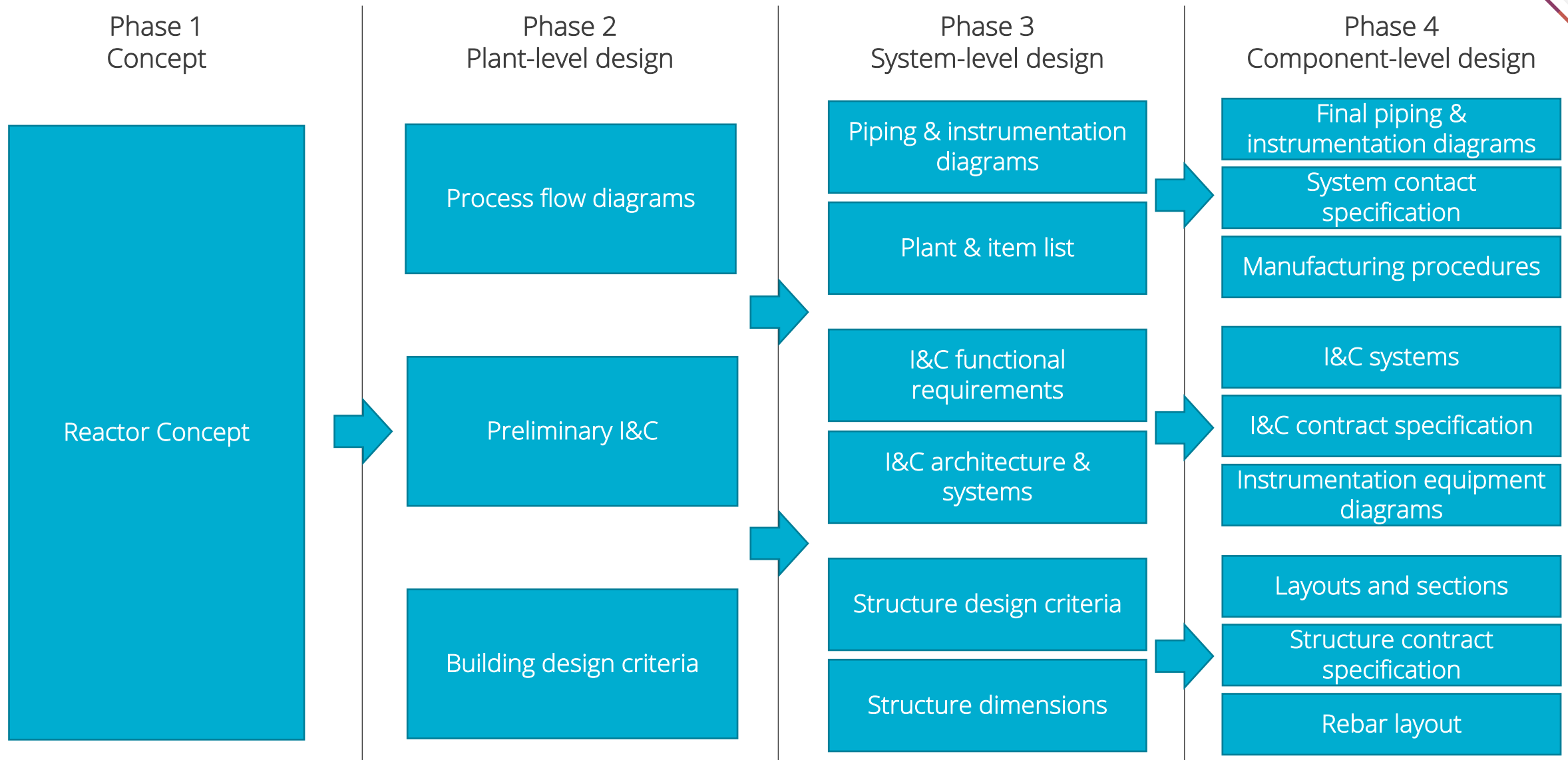Abhimanyu Kapuria, Yifan Zhang, Daniel G. Cole
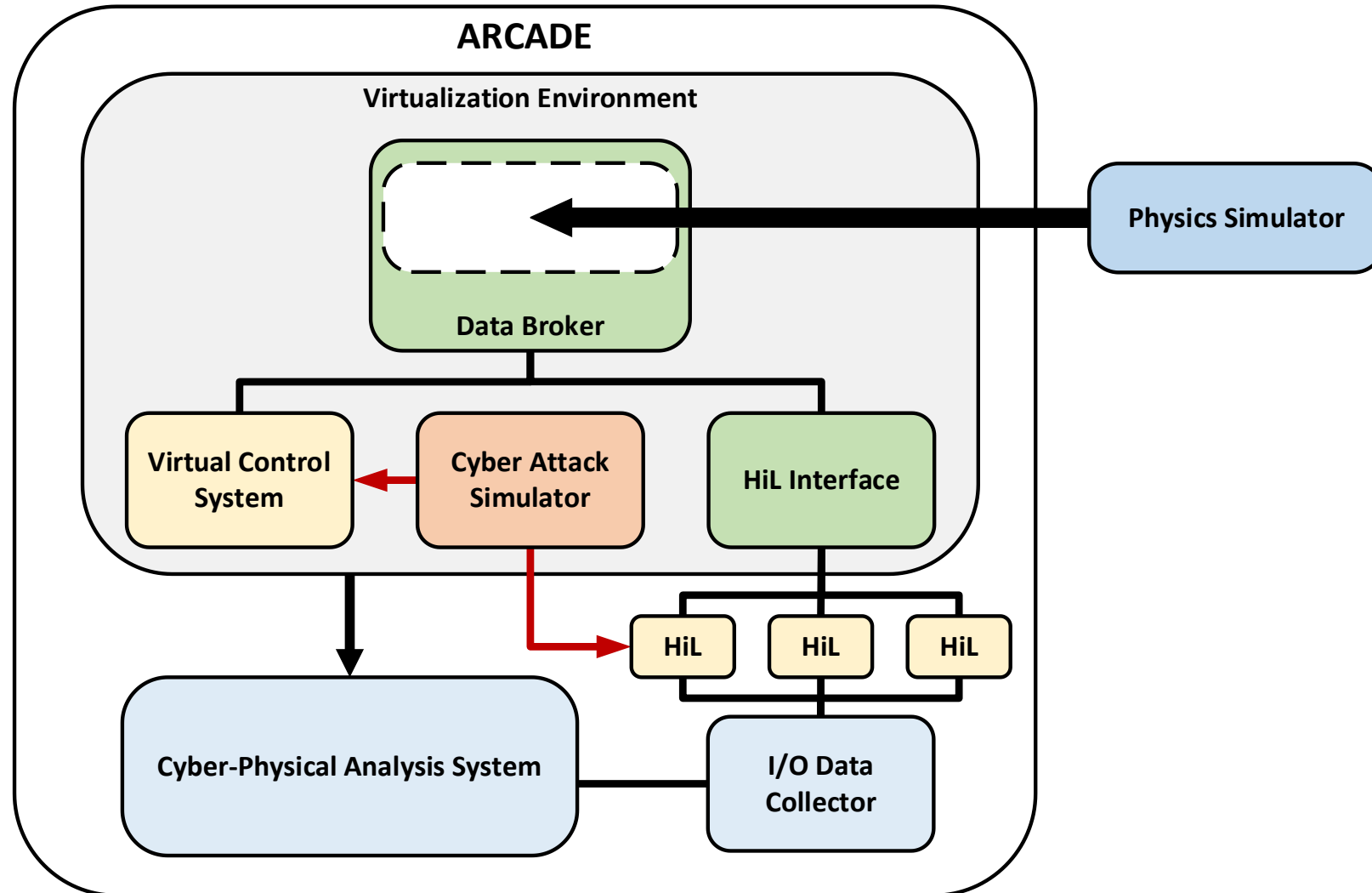
2023 TRTR-IGORR, College Park, MD

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U.S. DEPARTMENT OF ENERGY

NISA
National Nuclear Security Administration

Why use physics models for cybersecurity?

- Models and experimentation allow the evaluation of cyber consequences to systems

- Demonstration of plant robustness factors to mitigate cyber-attacks

- Integrate systems hazards analysis techniques (e.g., STPA) with cybersecurity

- Rapidly test diverse cyber mitigation strategies

- Parallel and automated system testing for experimental efficiency

- Training, exercises, and education of operators

ARCADE can support cybersecurity analysis throughout the design process

Phase 1 Concept	Phase 2 Plant-level design	Phase 3 System-level design	Phase 4 Component-level design
Reactor Concept	Process flow diagrams	Piping & instrumentation diagrams	Final piping & instrumentation diagrams
		Plant & item list	System contact specification
			Manufacturing procedures
	Preliminary I&C	I&C functional requirements	I&C systems
		I&C architecture & systems	I&C contract specification
			Instrumentation equipment diagrams
	Building design criteria	Structure design criteria	Layouts and sections
		Structure dimensions	Structure contract specification
			Rebar layout

Citation: World Nuclear Association, "Design Maturity and Regulatory Expectations for Small Modular Reactors", 2021

# Advanced Reactor Cyber Analysis and Development Environment (ARCADE)

ARCADE Open-Source Software Stack

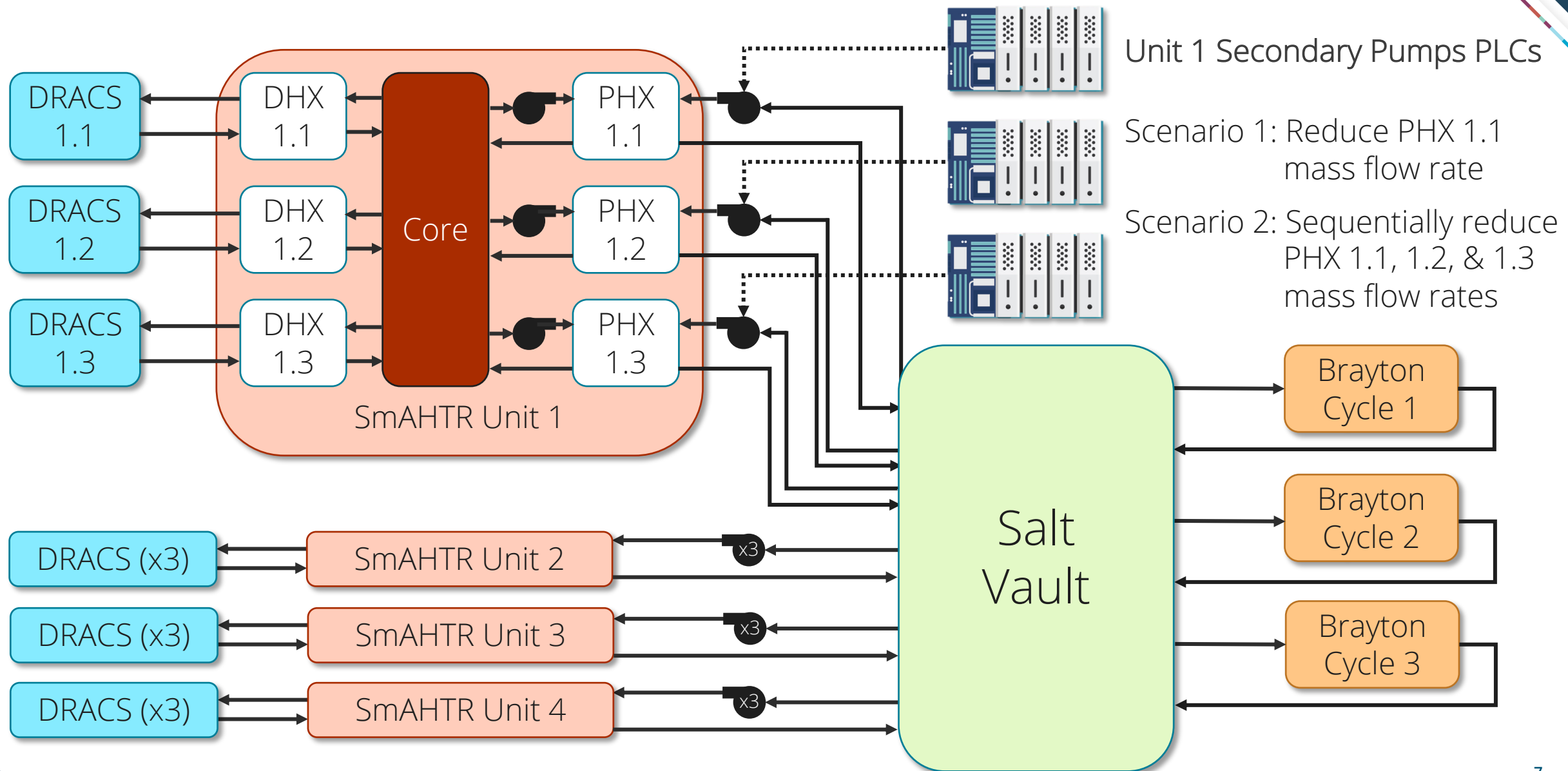| Components	Technology
Virtualization Environment	minimega
Physics Integrator	Sandia DataBroker
Cyber Attack Simulator	ManiPIO & Kali Linux
PLC Runtime Environment	OpenPLC
SCADA Interface	SCADA-LTS
Physics Simulation	Not Included

Small Modular Advanced High-Temperature Reactor (SmAHTR)
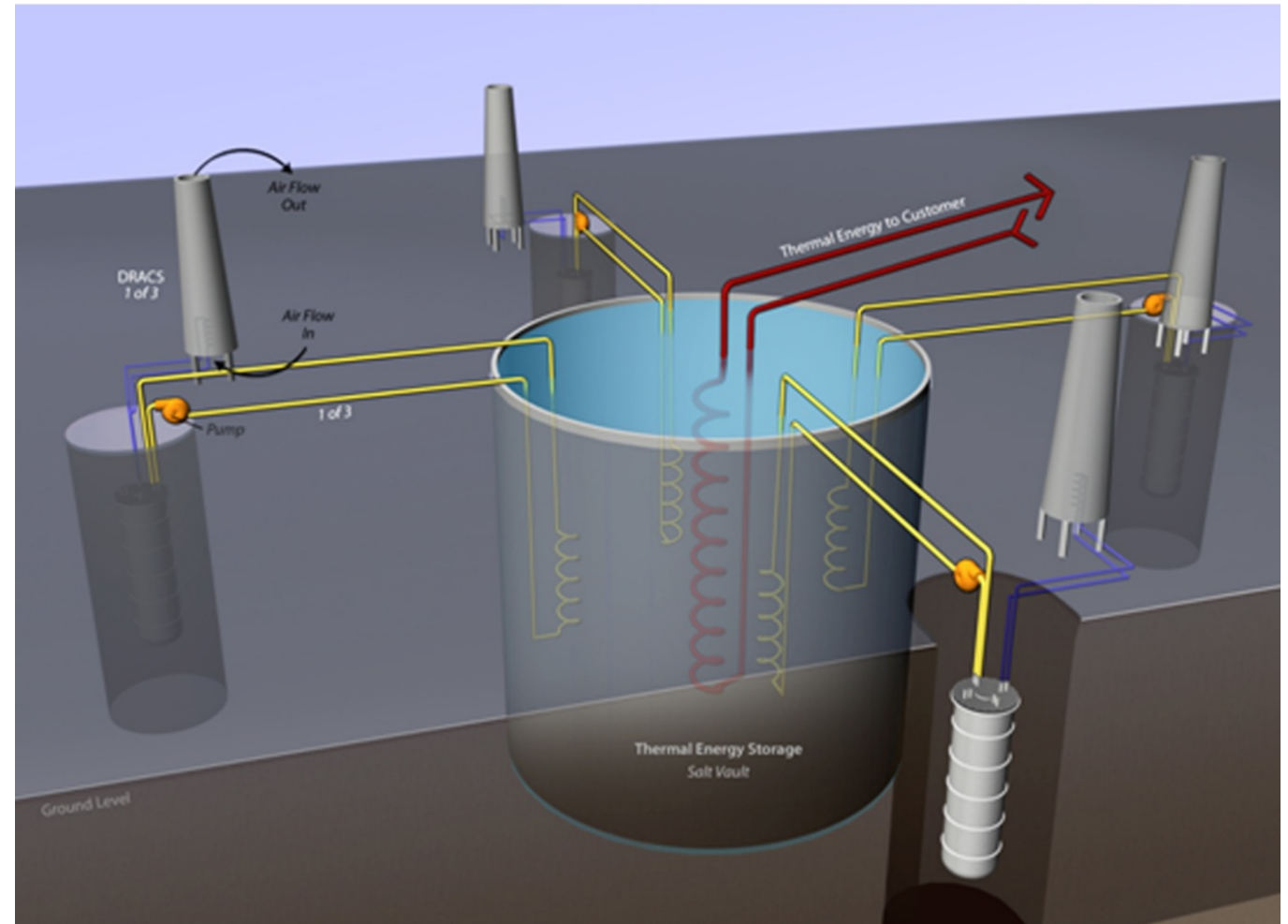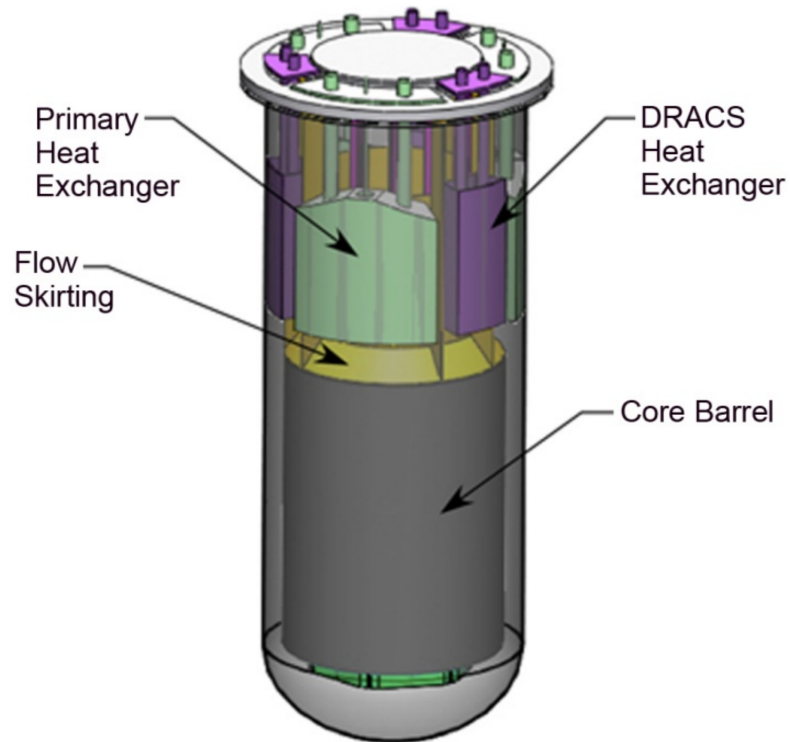
Citation: Oak Ridge National Laboratory, "Pre-Conceptual Design of a Fluoride-Salt-Cooled Small Modular Advanced High-Temperature Reactor (SmAHTR)", 2010
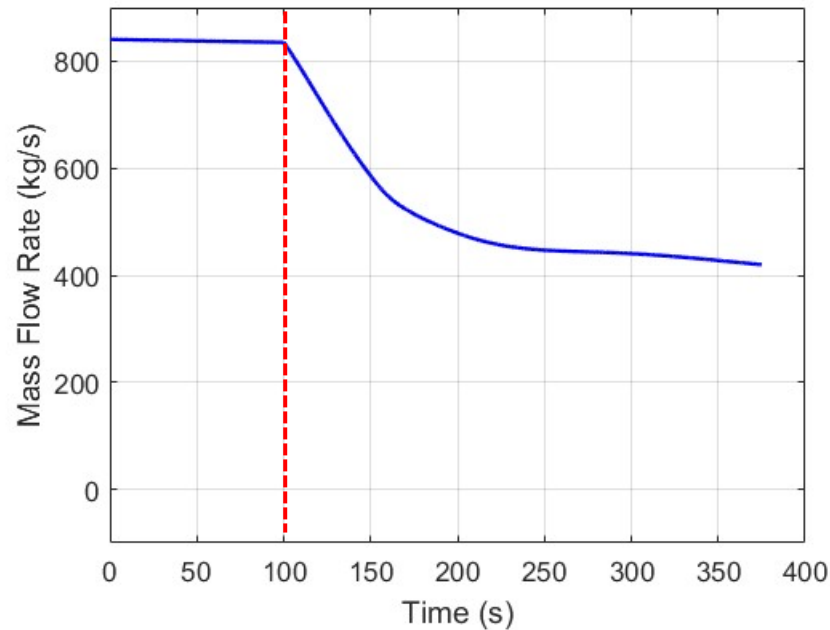
# The University of Pittsburgh's SmAHTR model was integrated with ARCADE for cybersecurity R&D

Unit 1 Secondary Pumps PLCs

Scenario 1: Reduce PHX 1.1 mass flow rate

Scenario 2: Sequentially reduce PHX 1.1, 1.2, & 1.3 mass flow rates

Unit 1 PHX secondary coolant mass flow rate was reduced to examine the effects on plant conditions

Scenario 1:
Reduce mass flow rate for PHX 1.1

Scenario 2:
Sequentially reduce mass flow rates
for PHX 1.1, 1.2, & 1.3
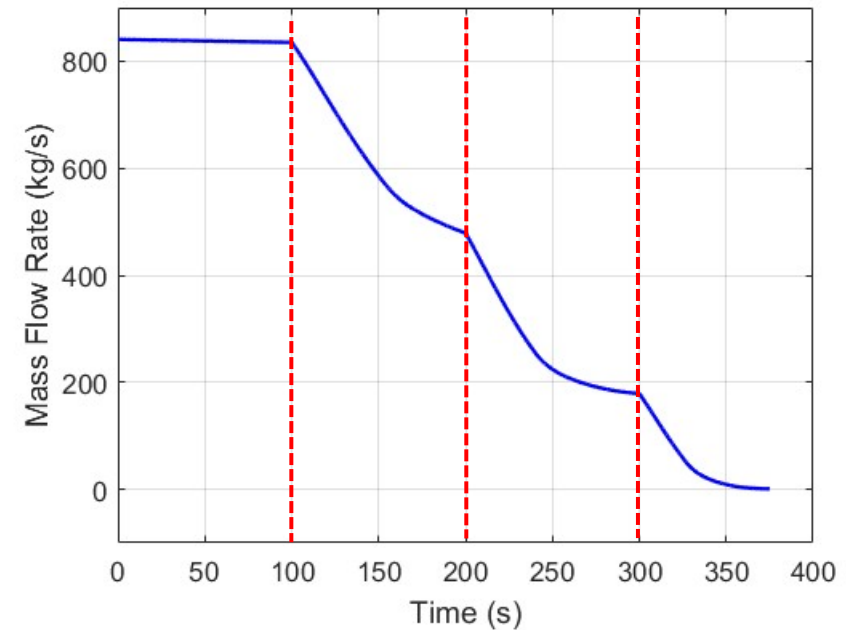
Unit 1
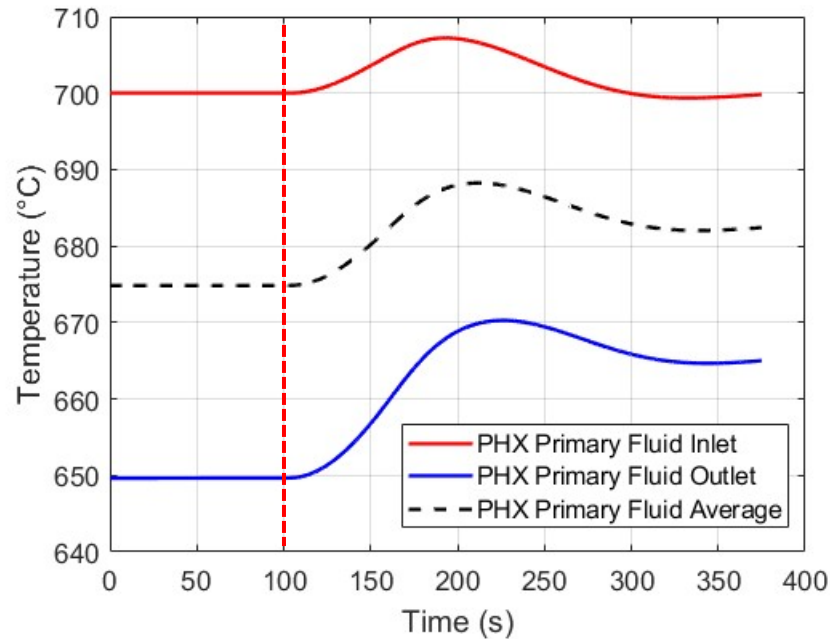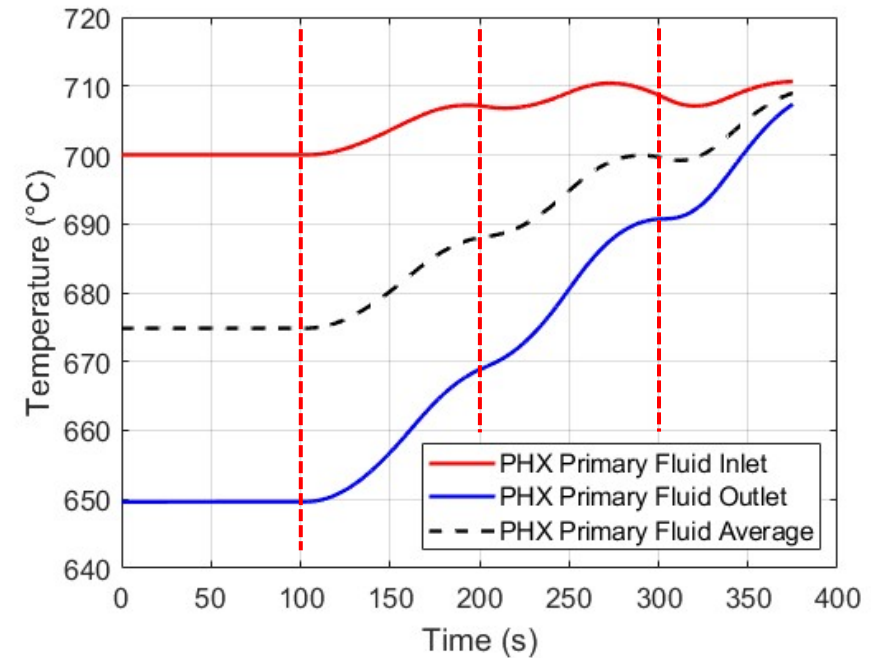

Unit 1

Primary fluid temperature stabilized for Scenario 1, but grew without bound for Scenario 2

Scenario 1:
Reduce mass flow rate for PHX 1.1

Scenario 2:
Sequentially reduce mass flow rates for PHX 1.1, 1.2, & 1.3

Unit 1

Unit 1

ARCADE can be used by universities for workforce development for the security of advanced reactors

- Nuclear power plant cybersecurity R&D

- Development of interdisciplinary coursework in cyber-physical systems
  - ARCADE can also be used with non-nuclear physics models

- Raise research reactor operators' awareness of cybersecurity and its effects

- Fundamental cyber-physical systems R&D

Control Systems Engineering

Nuclear Engineering

Computer Science

Advanced Reactor Cybersecurity
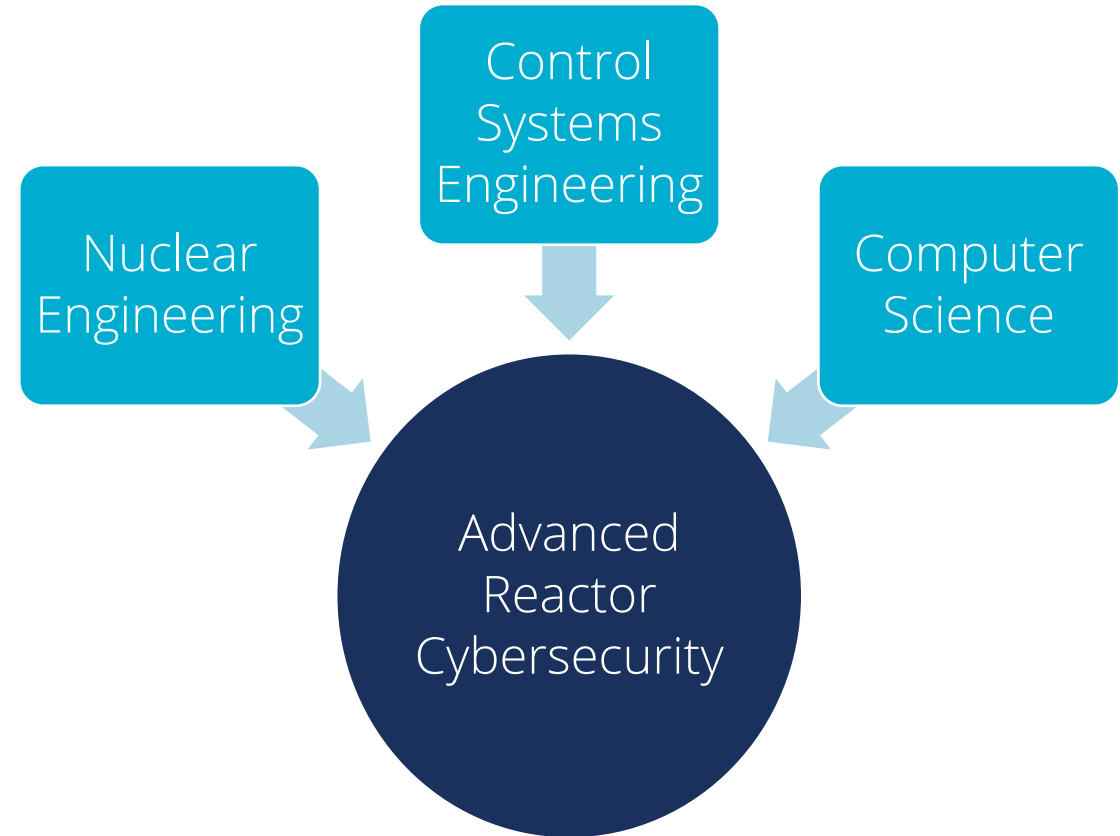
Thank you for your time and attention

Contact Information:
Lee T. Maccarone
lmaccar@sandia.gov