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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

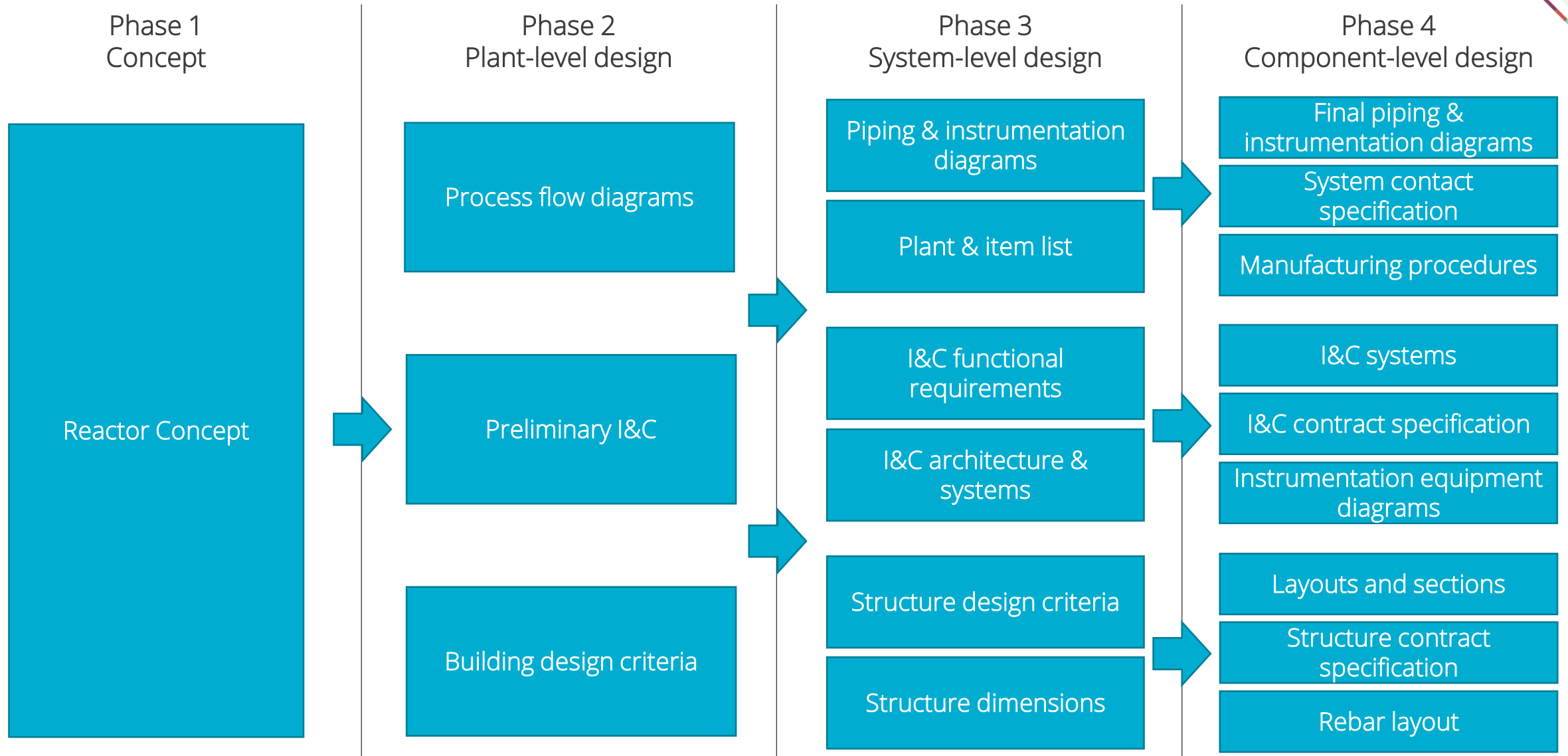
**University of Pittsburgh Coauthors:**  
Abhimanyu Kapuria, Yifan Zhang, Daniel G. Cole

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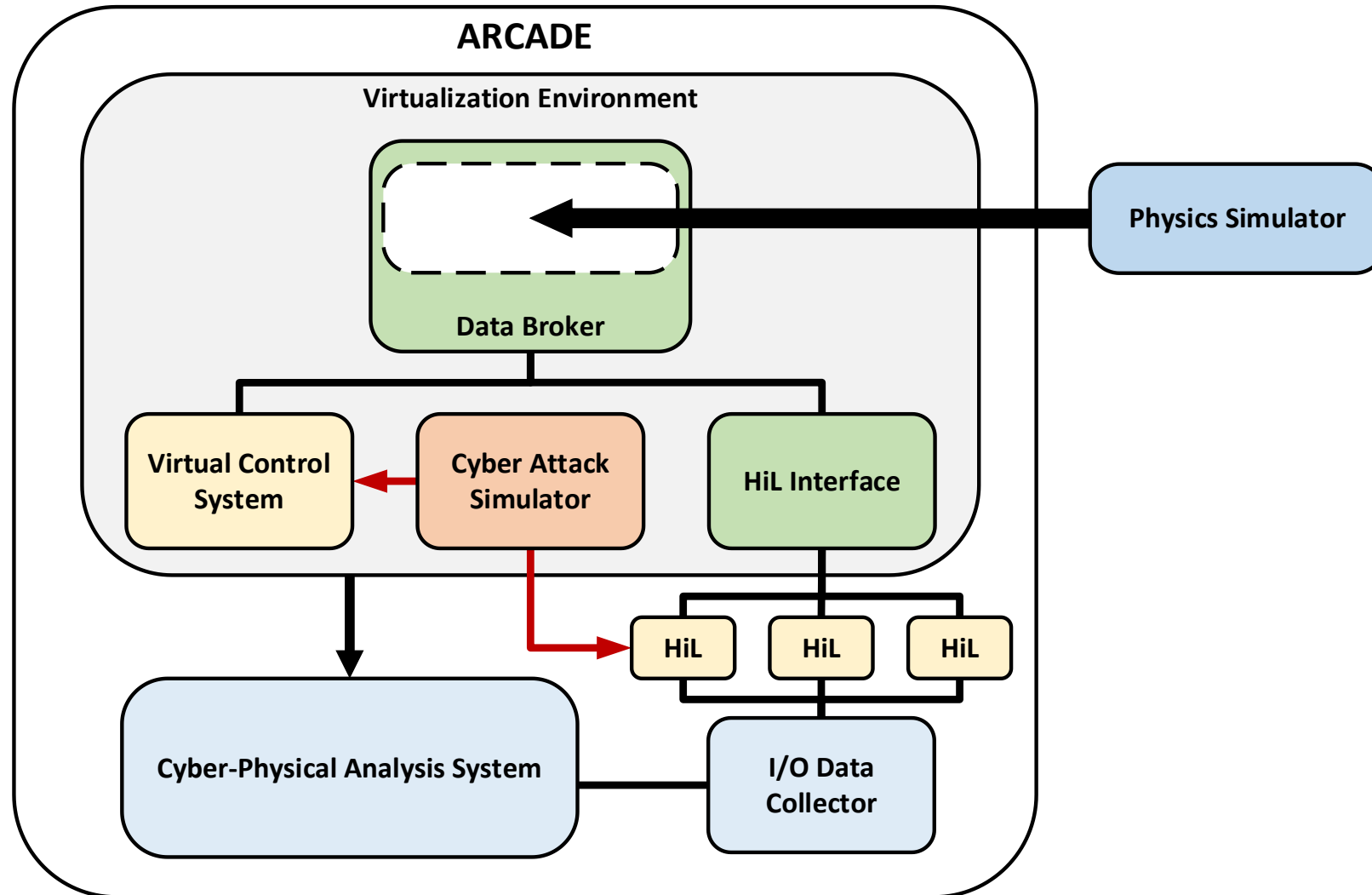
## Why use physics models for cybersecurity?

- 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






# Advanced Reactor Cyber Analysis and Development Environment (ARCADE)

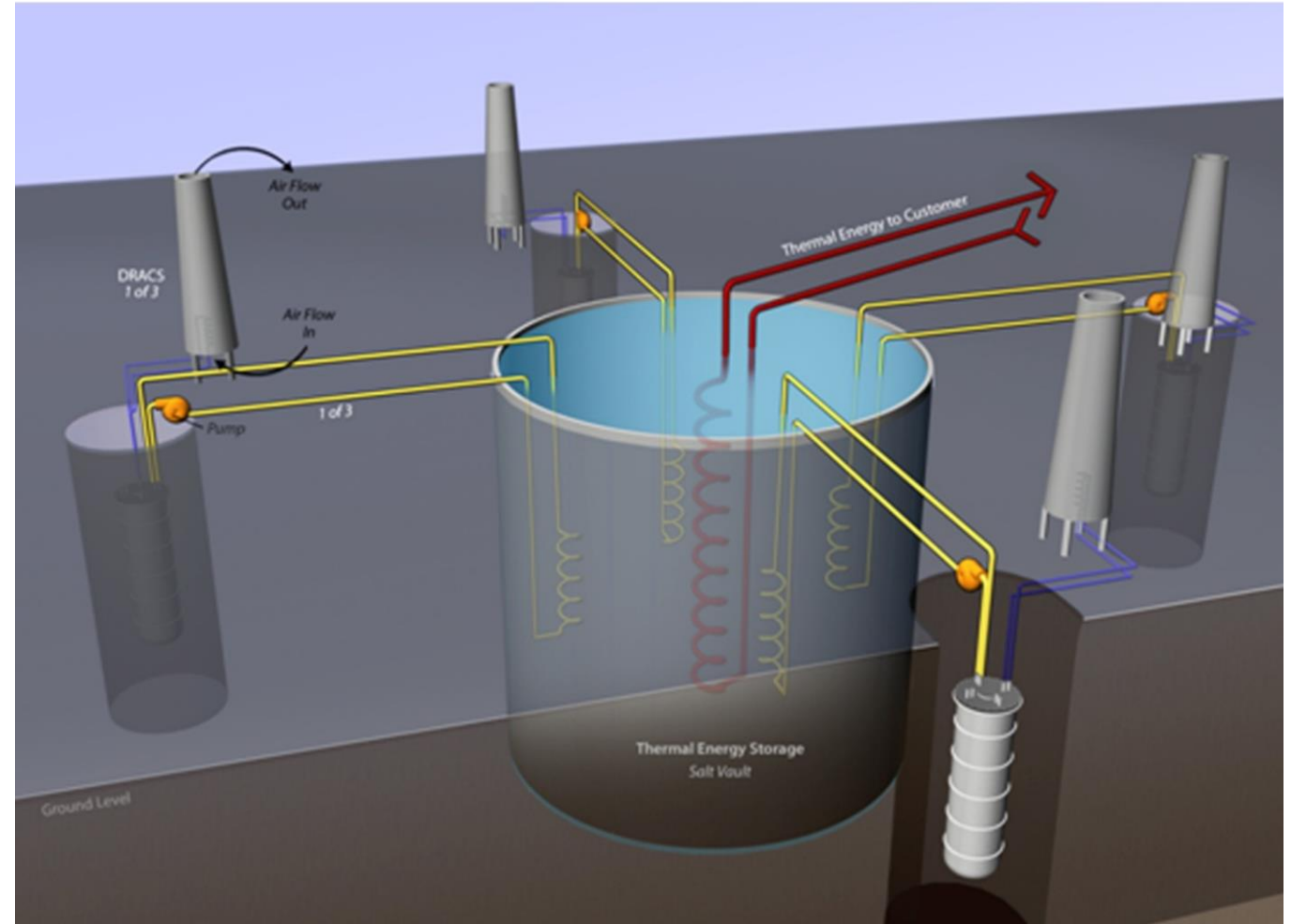
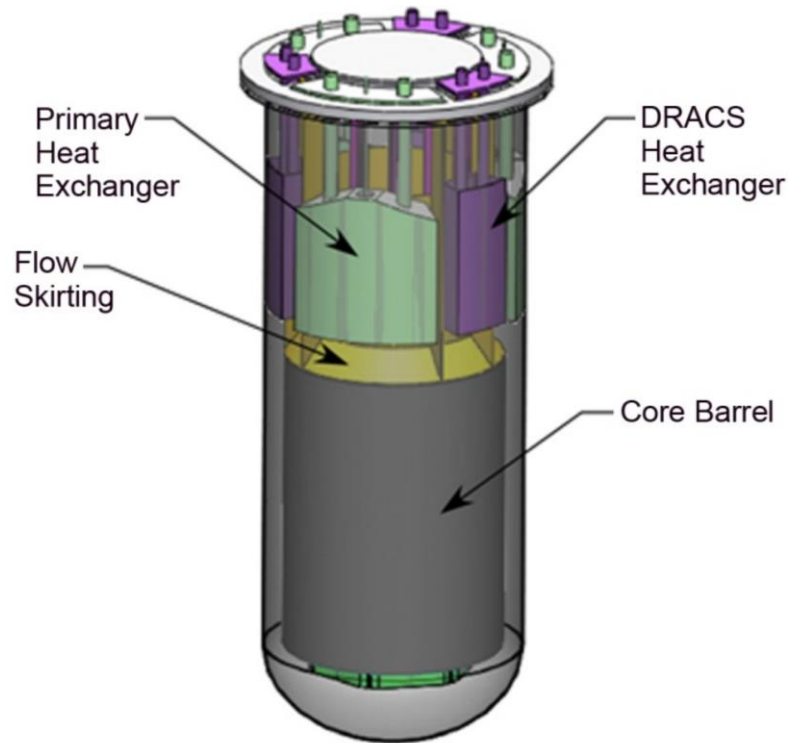




# ARCADE Open-Source Software Stack

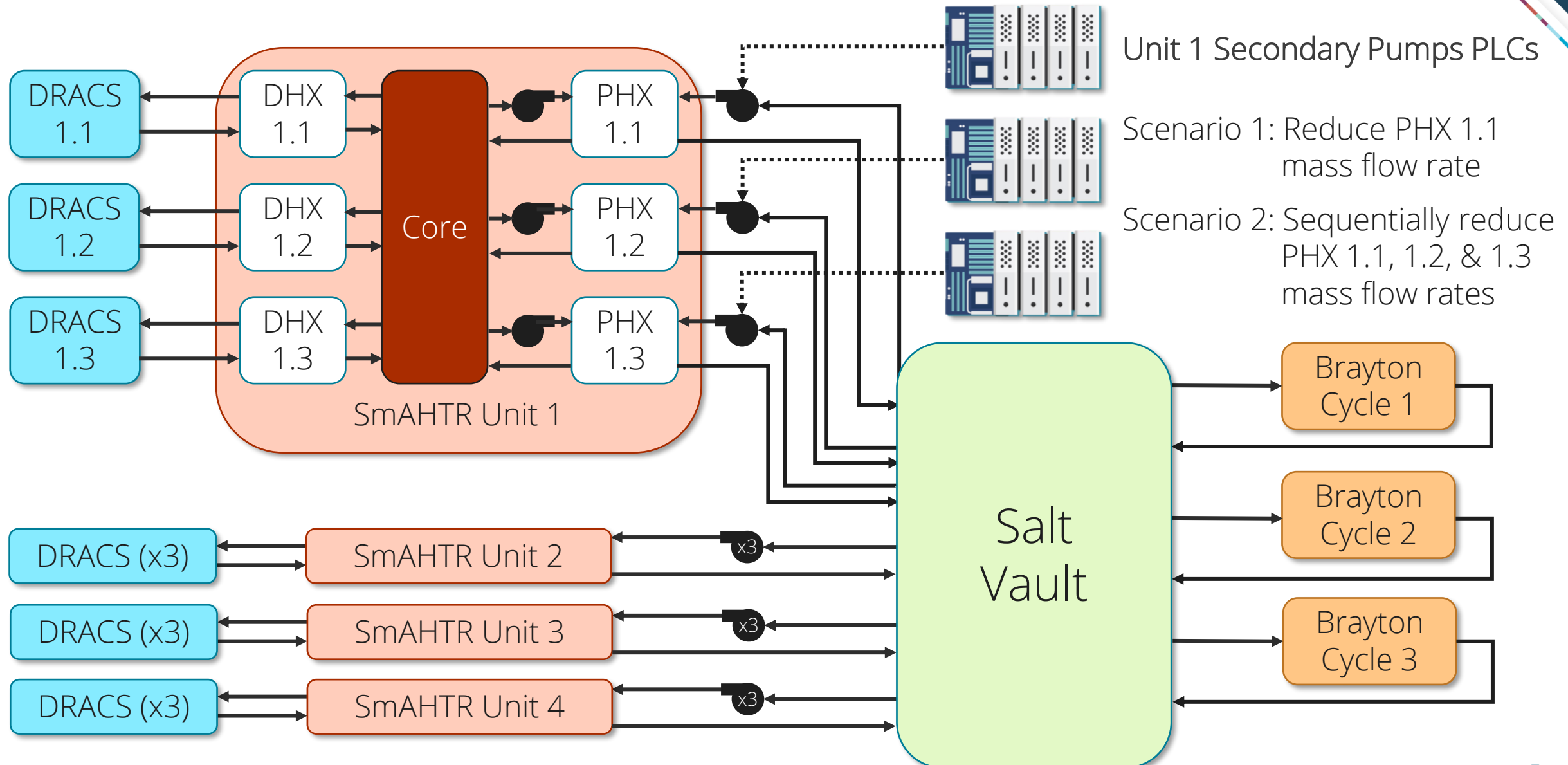
Components	Technology
Virtualization Environment	 minimega
Physics Integrator	Sandia DataBroker
Cyber Attack Simulator	ManiPIO &  Kali Linux
PLC Runtime Environment	 OpenPLC
SCADA Interface	SCaDa-LTS
Physics Simulation	Not Included

# Small Modular Advanced High-Temperature Reactor (SmAHTR)



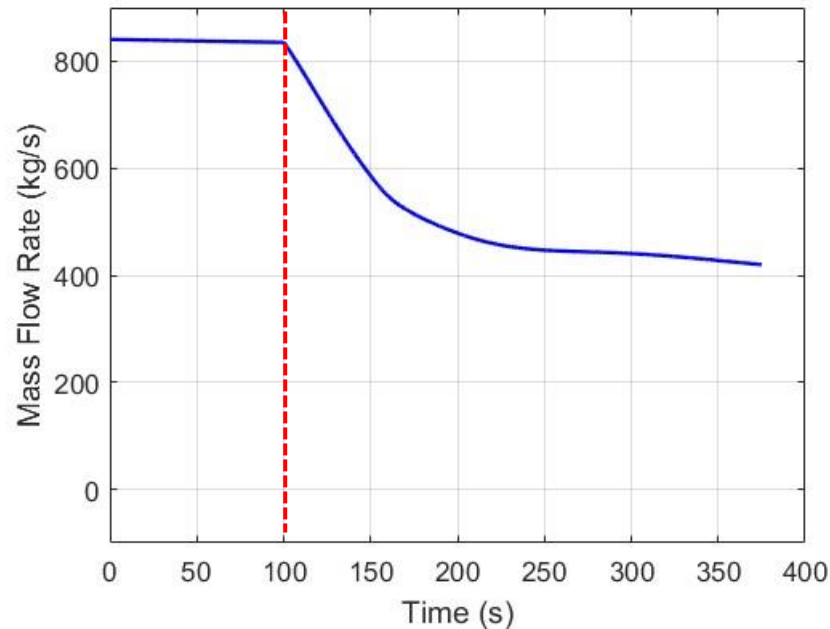
Citation: Oak Ridge National Laboratory, "Pre-Conceptual Design of a Fluoride-Salt-Cooled Small Modular Advanced High-Temperature Reactor (SmAHTR)", 2010

# The University of Pittsburgh's SmAHTR model was integrated with ARCADE for cybersecurity R&D



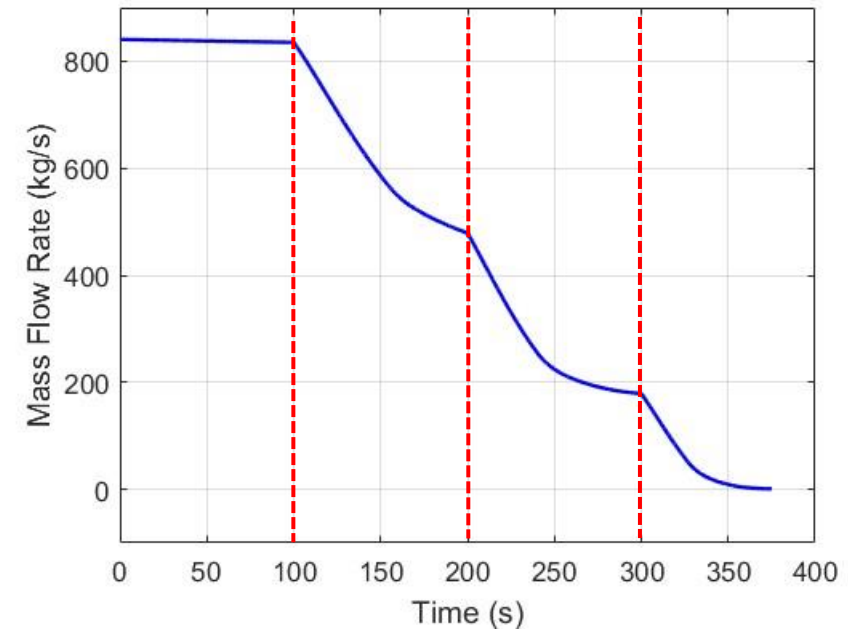
# Unit 1 PHX secondary coolant mass flow rate was reduced to examine the effects on plant conditions

Scenario 1:  
Reduce mass flow rate for PHX 1.1



Unit 1

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

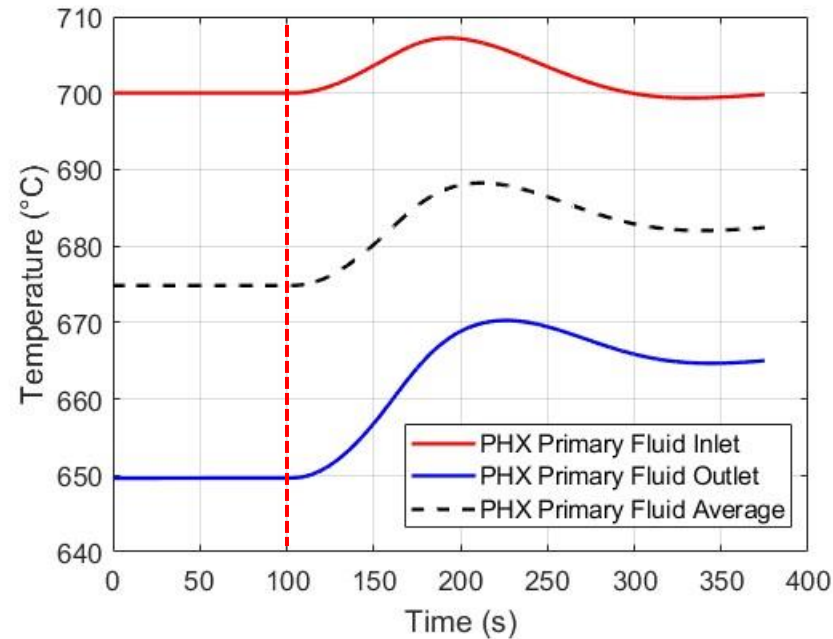


Unit 1



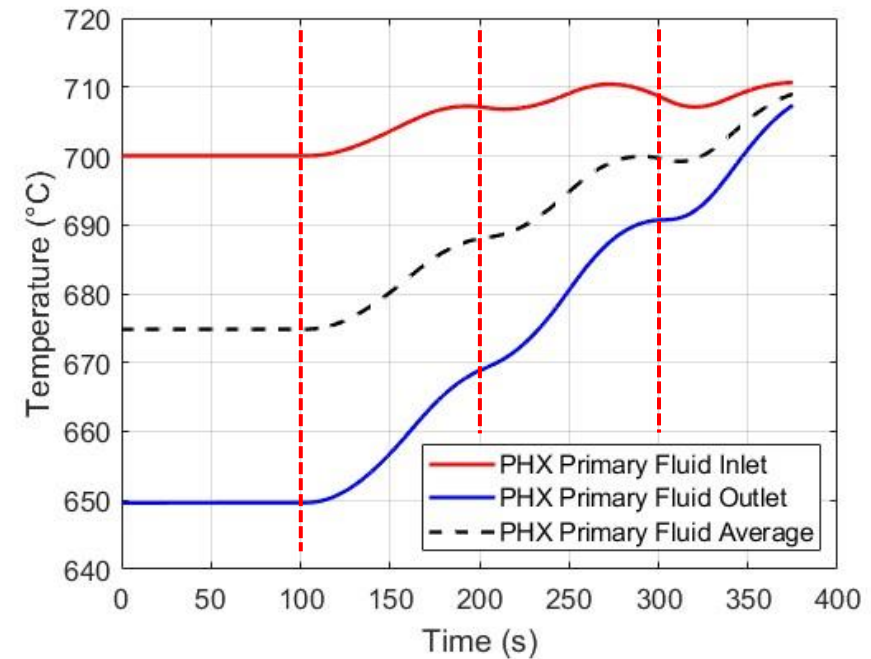
# Primary fluid temperature stabilized for Scenario 1, but grew without bound for Scenario 2

Scenario 1:  
Reduce mass flow rate for PHX 1.1



Unit 1

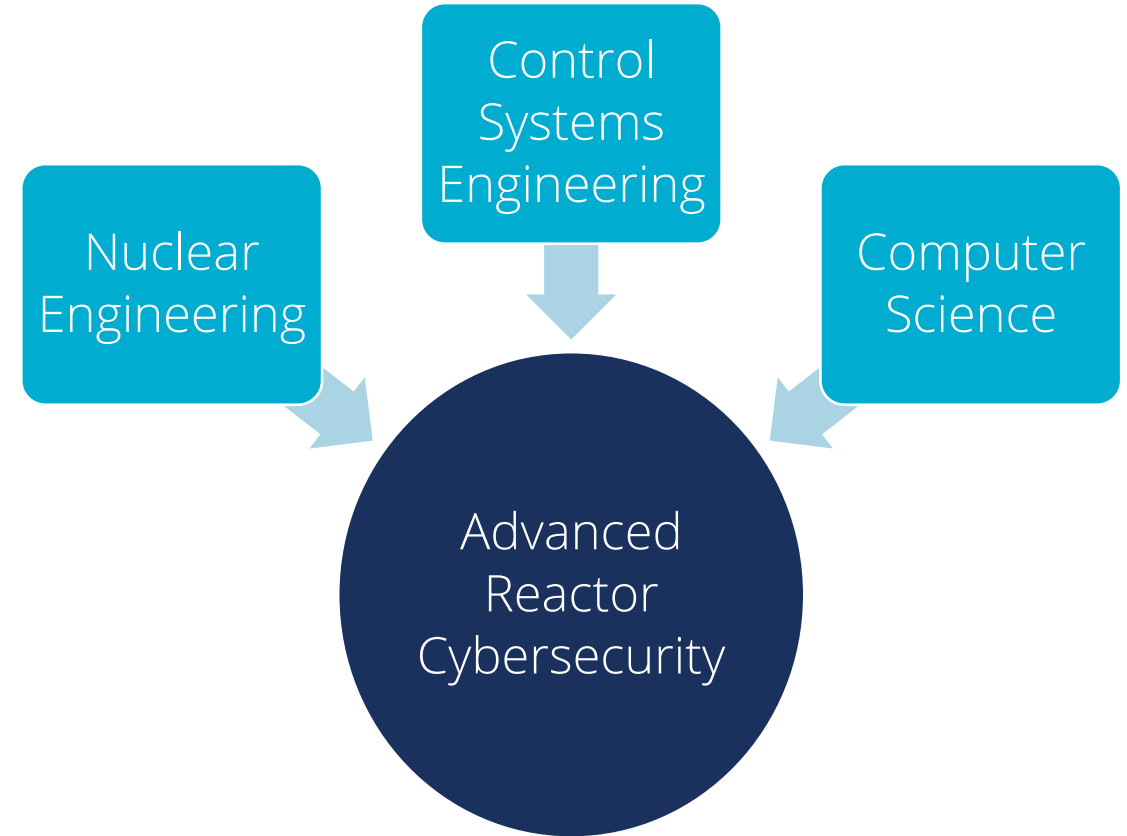
Scenario 2:  
Sequentially reduce mass flow rates  
for PHX 1.1, 1.2, & 1.3



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



**Thank you for your  
time and attention**

**Contact Information:  
Lee T. Maccarone  
[lmaccar@sandia.gov](mailto:lmaccar@sandia.gov)**

