

# Optimal Operations of Advanced Reactors:

How Do We Get There?

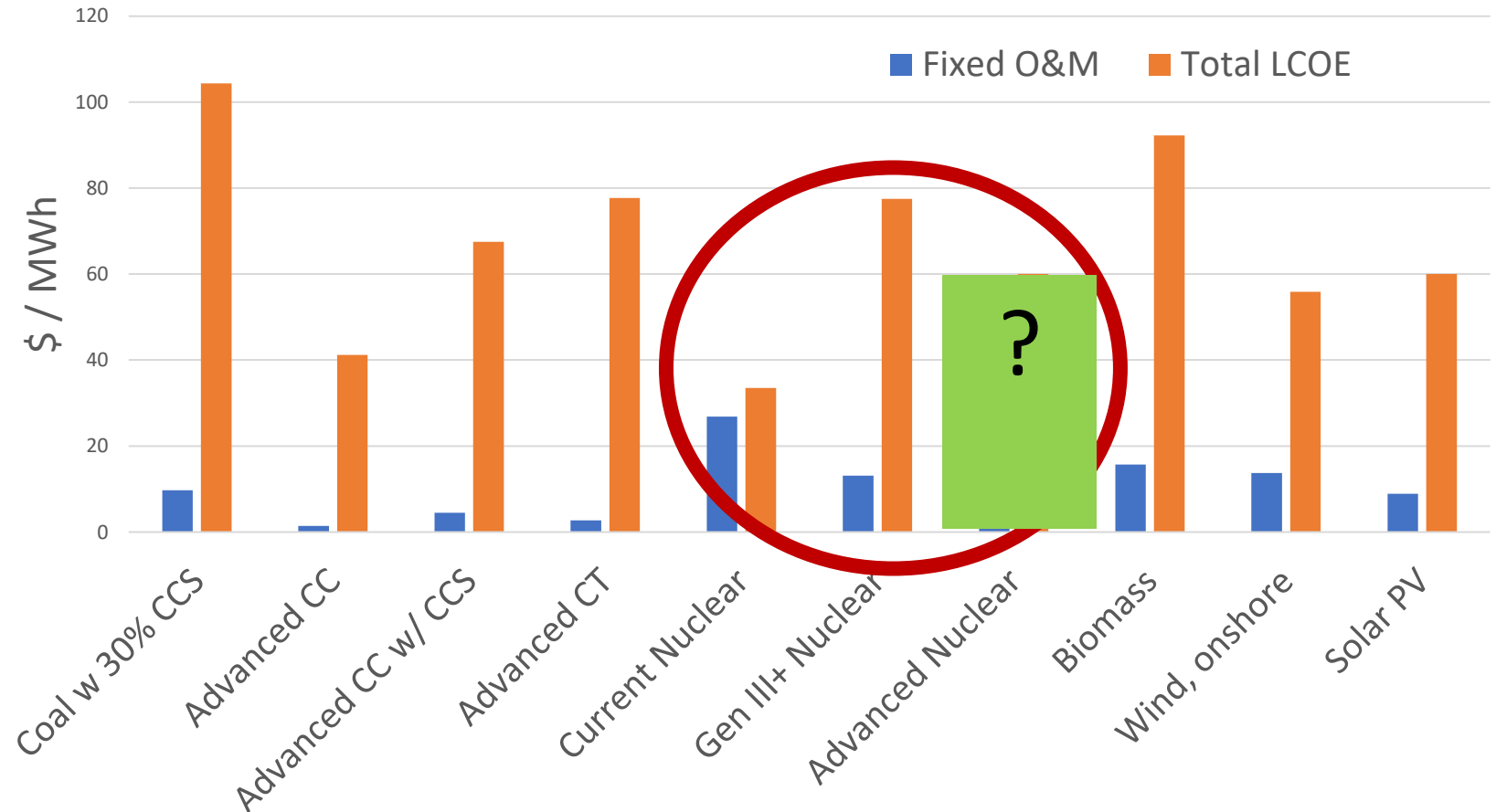
Rachel Slaybaugh  
June 14, 2021  
MCD Roundtable

# Nuclear Reactors Can't Compete on Ops and Maintenance

## LCOE and Fixed O&M

We've lost **7**  
reactors in the last  
5 years

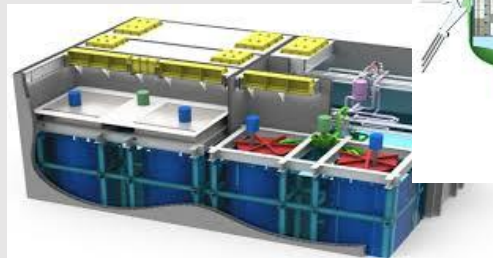
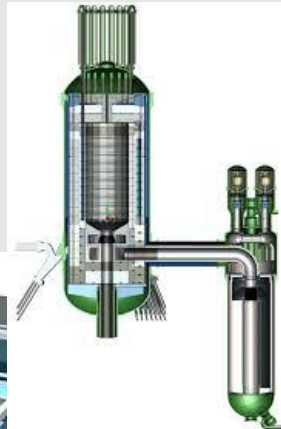
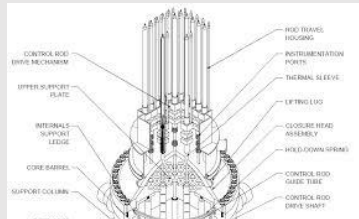
**14** more scheduled  
to close by 2025



# The Future We Are Trying to Create

## Current state

**Multitude of design concepts,  
optimizing for getting built**



**DIGITAL  
SIMULATORS**

+

**Low-Staff  
Maintenance**

*Enable*

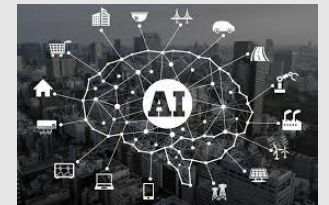
New regulatory  
paradigms

Design  
improvements

Operating cost  
reduction

## Future state

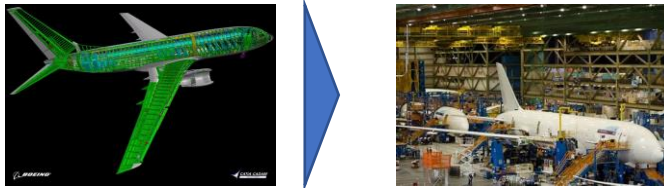
**Software-enhanced, lean  
operating advanced nuclear**



# Take Inspiration From Aerospace Success

## Design

*Digital design accelerated the 777 development process*



Boeing 777: First new Boeing aircraft in 10 years:

- First jetliner 100% digitally designed
- Pre-assembly done digitally, eliminating need for costly pre-production mock-ups
- Five years from project launch to production, and eight years from launch to commercial flight

## Operational Simulation

*Simulators support design of new aircraft + pilot training*



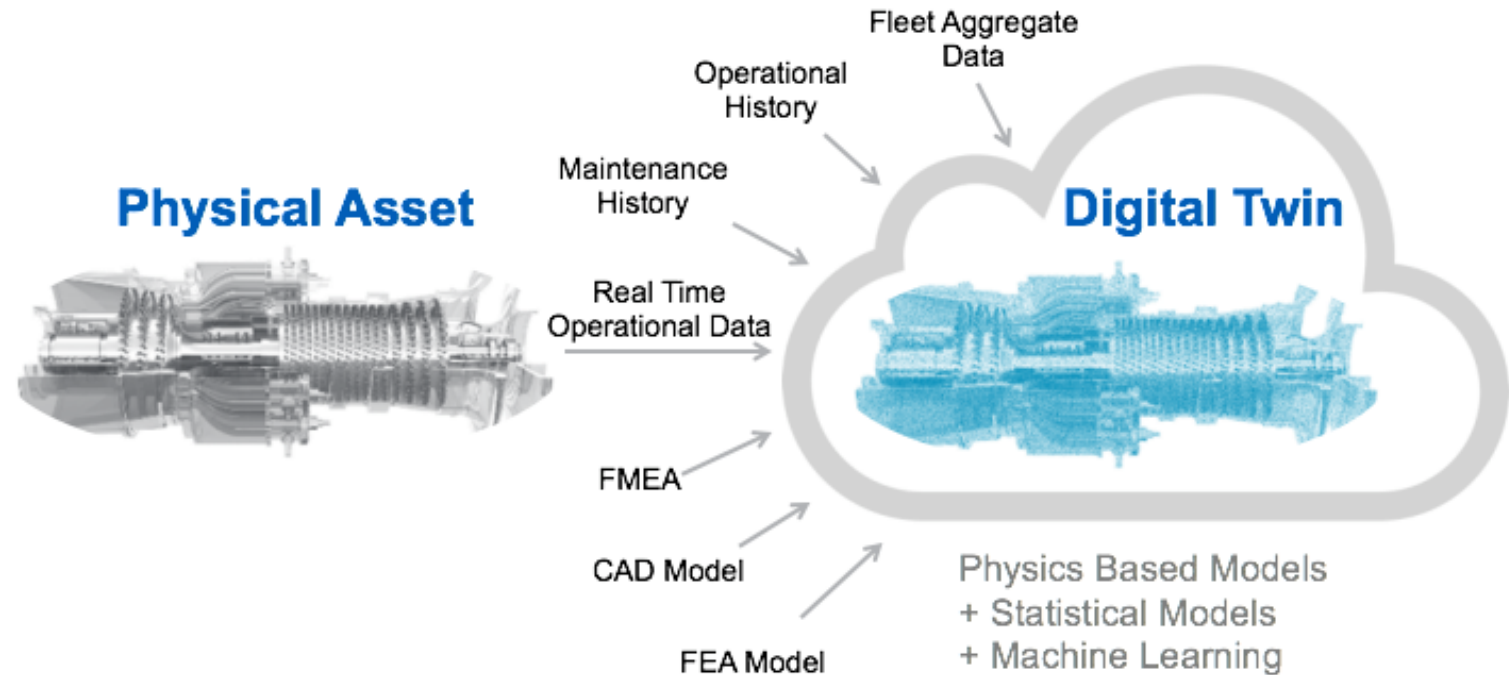
Based on flight equations and matches with physical data, simulators:

- Teach pilots – especially in advanced aircraft – how to assimilate data from new / unique systems (e.g. F22 Raptor)
- Offer “Extended envelope” training; teaches pilots, regulators how systems perform in extreme conditions
- Provide developers with insights into aircraft design trade-offs

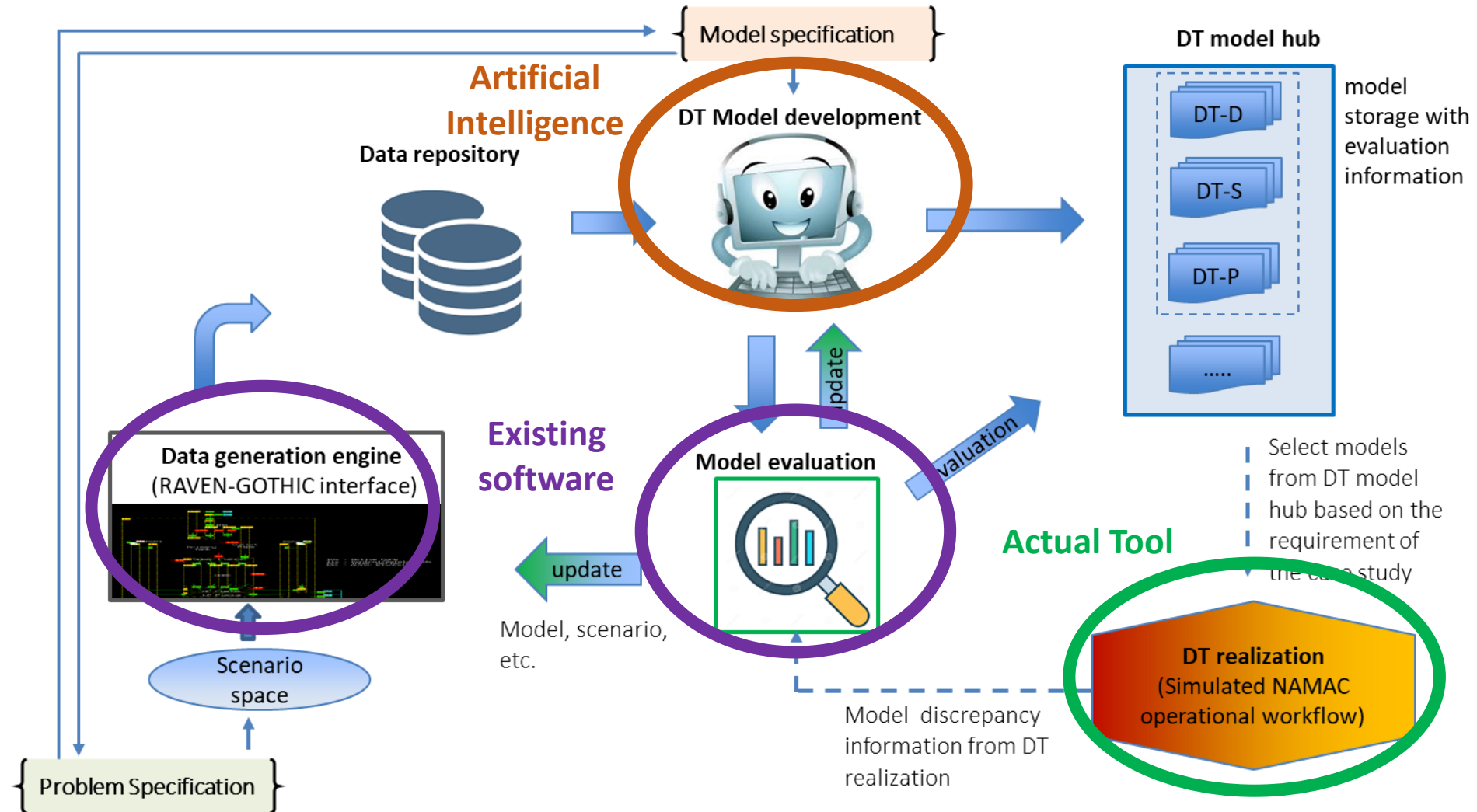
# Digital Twins

Digital Twin:

“A ‘digital twin’ is a physics-based, or data science-based, model of an asset that exists in real life. It should mirror digitally the exact characteristics and operating performance of the real device, so that operators can understand the...asset”



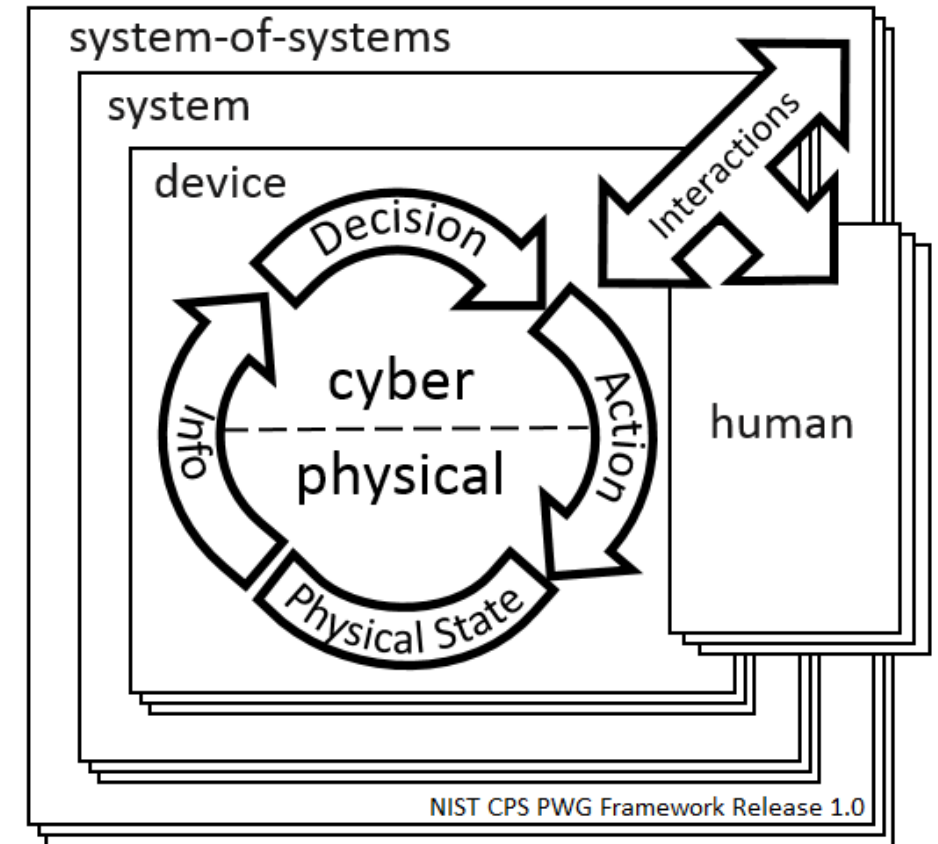
# Digital Twin Developmental Workflow



# Cyber-Physical Systems

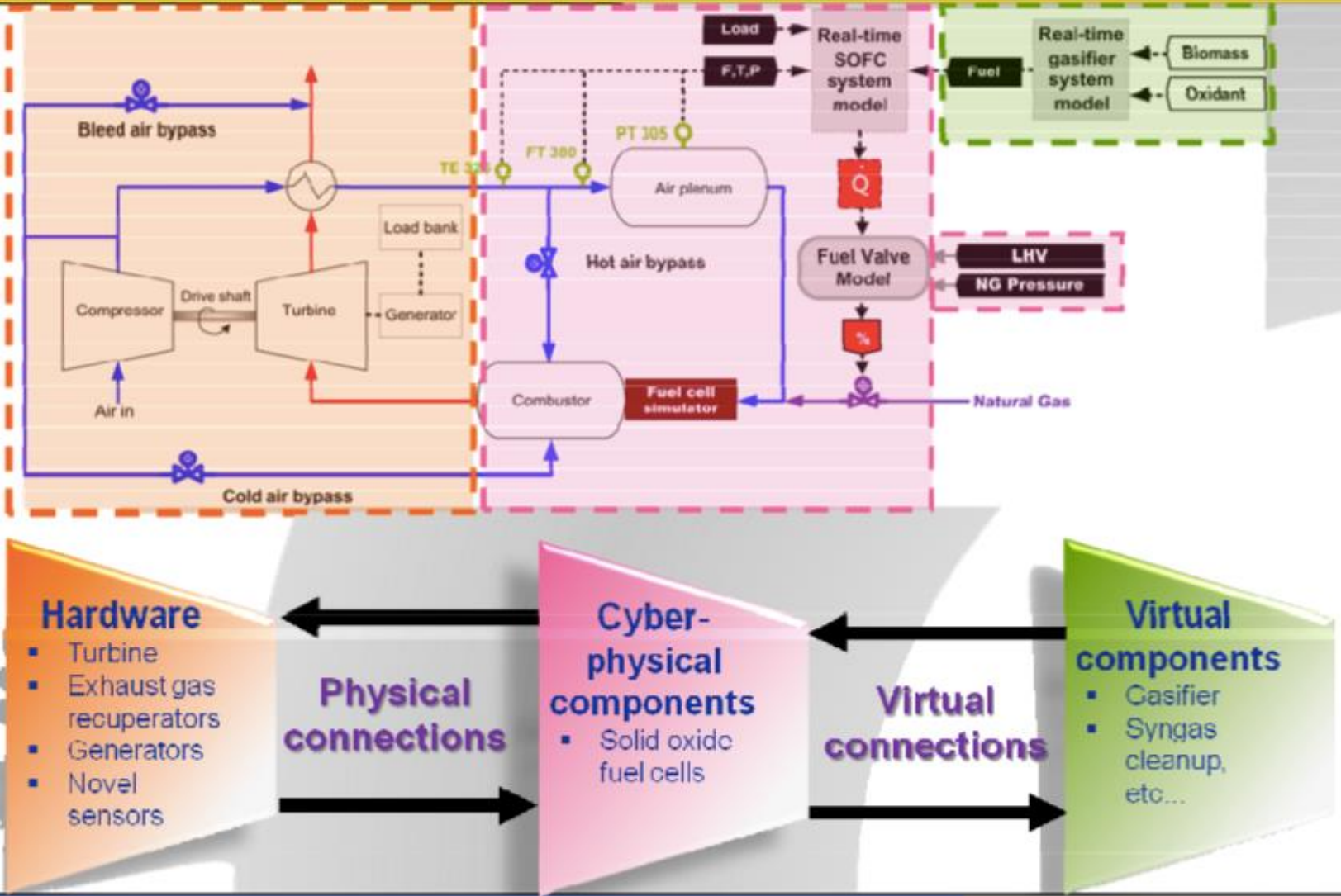
## Cyber-physical system:

- “integrations of computation, networking, and physical processes...with feedback loops where physical processes affect computations and vice versa...”
- CPS integrates the dynamics of the physical processes with those of the software and networking...”





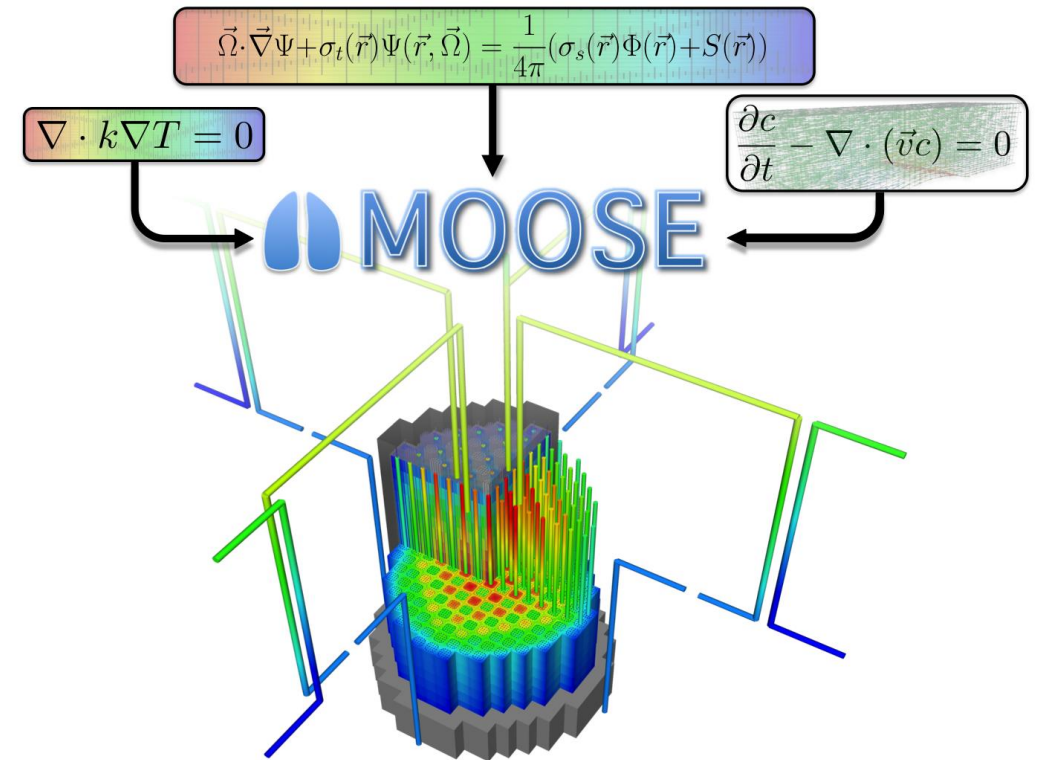
# Cyber Physical System Example: Hyper





# Technical Challenges to AR Modeling

- We can make very pretty pictures, but a lot of the software has not been fully validated: can have large uncertainties
- DOE codes need supercomputers not desktops = problem
- Do not have dynamic resolution
- DOE and NRC codes have been developed for different purposes
  - DOE: normal operation, very high detail
  - NRC: accident scenarios, peak power regions
- Some (vital) data are non-existent
  - Molten salt thermophysical properties
  - High temperature material behavior



# Leverage New Ideas and Sort it out NOW

- Lots of industries are developing better controls, better models, better data, better algorithms
- Focus on autonomy and machine learning (ML) is getting many questions answered
- Answer those questions specific for nuclear and prove out ideas in our systems and with our software; aid in code validation
- Have tools the industry and the regulator can use

