United Technologies

Climate | Controls | Security

An Industrial Model Based Development Systems Engineering Strategy

American Modelica Conference 2018, October 9-10 2018, Cambridge,MA

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Version 9

AGENDA

- Team
- Key Points
- Drivers
- Tools chain
- Application examples
- Summary

TEAM

Modelon
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Carrier
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External
John Cassidy (UTC, retired), Larry Biegler (CMU), Karl Åström (LTH), Carl Laird (Sandia), Kevin Otto (RSS)

KEY POINTS

Modelica is a modeling language that (1) captures physics and is useful for modeling at the (2) system level and for modeling (3) heterogeneous systems:

- Need for system models of different scope, complexity and domains
- One modelling language

The use of Modelica is on simulation but goes beyond in "systems engineering" the (re)use of models for variability and robustness analysis, optimization and analysis of design freedom, and control design and analysis:

- Started with control design
- Goal: Unification of model development to Modelica

CCS is using Modelica for system level modeling and the Modelon tool chain to capture system level modeling and to deploy widely using library architectures, GUI and Python infrastructure:

- Support for a tools set that allows unification of models
- Steady-state/Dynamic/Cluster execution/Optimization/Variability

DRIVERS

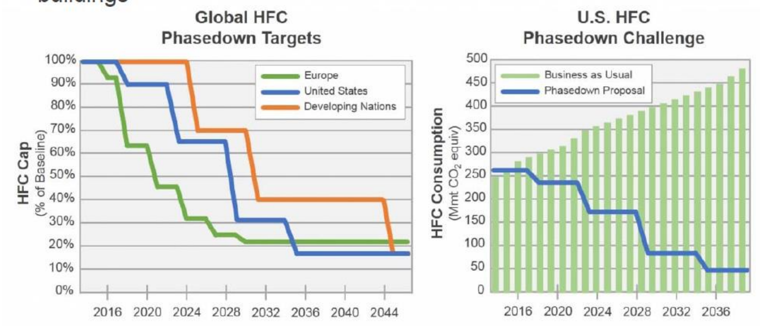
Systems Engineering Needs

Engineering effectiveness – ***drive designs by models*** – validate requirements and drive efficient testing

Need to ***deal with increased system integration complexity*** – Components > Chiller > Chiller plant > Building

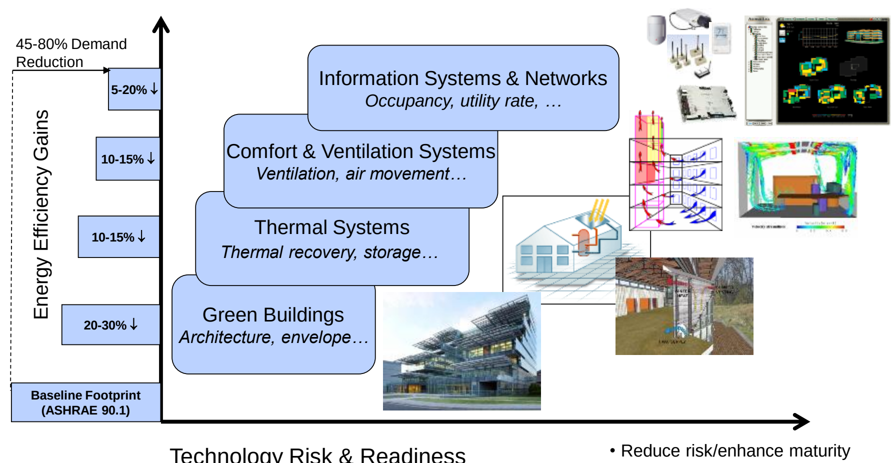
Regulatory environment demands design efficiencies (new technologies, refrigerant changes) and energy efficiency (whole building level)

- Action to phase down HFCs can avoid up to 0.5 °C of warming by 2100
- HVACR uses 50% of all energy in U.S. commercial and residential buildings



Source: U.S. Department of Energy (http://energy.gov/eere/buildings/road-zero-does-next-generation-heating-and-cooling-rd-strategy)

Energy Savings in Commercial Buildings



- Reduce risk/enhance maturity
- Make solutions scalable & robust
- Drive commercial adoption

NEED TO EXPOSE DIFFERENT VIEWS…

Heterogeneous Modeling, Different Fidelities…

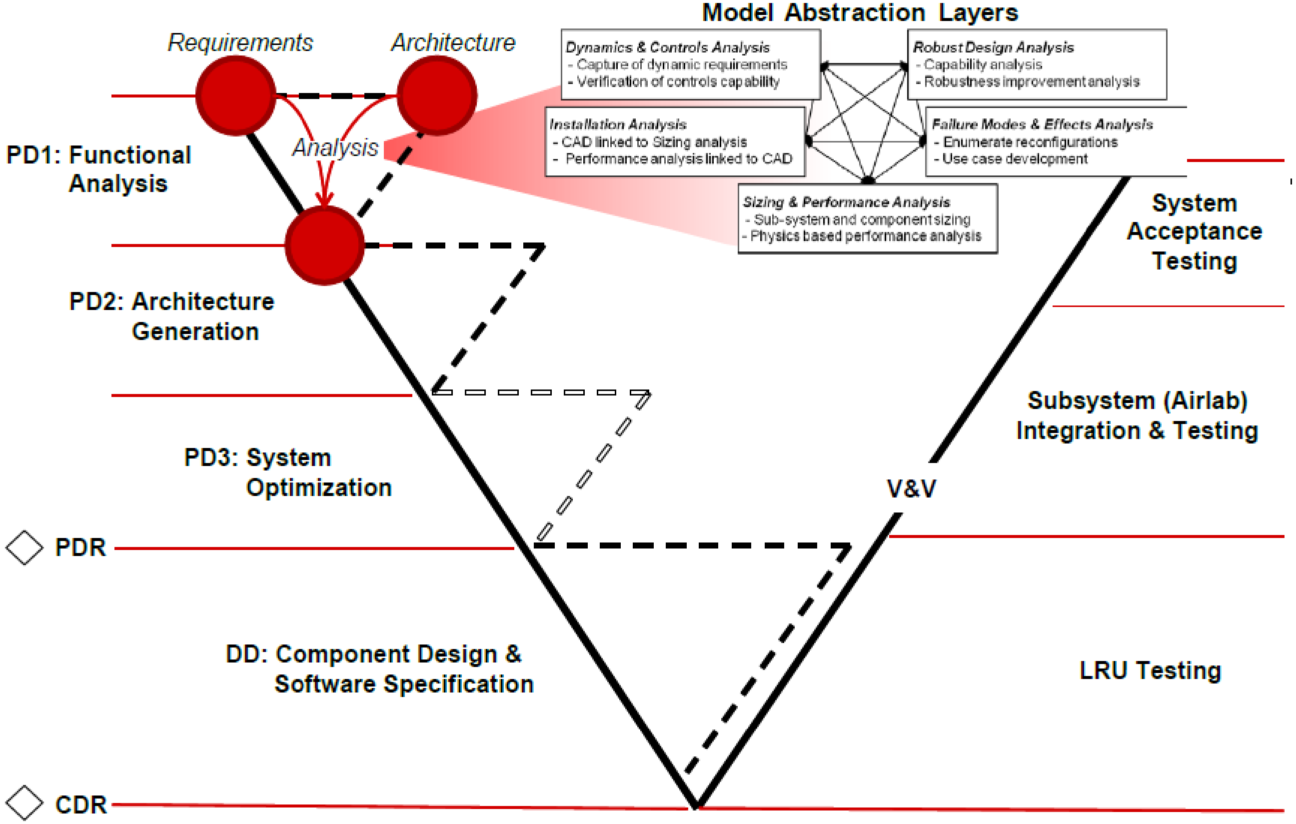
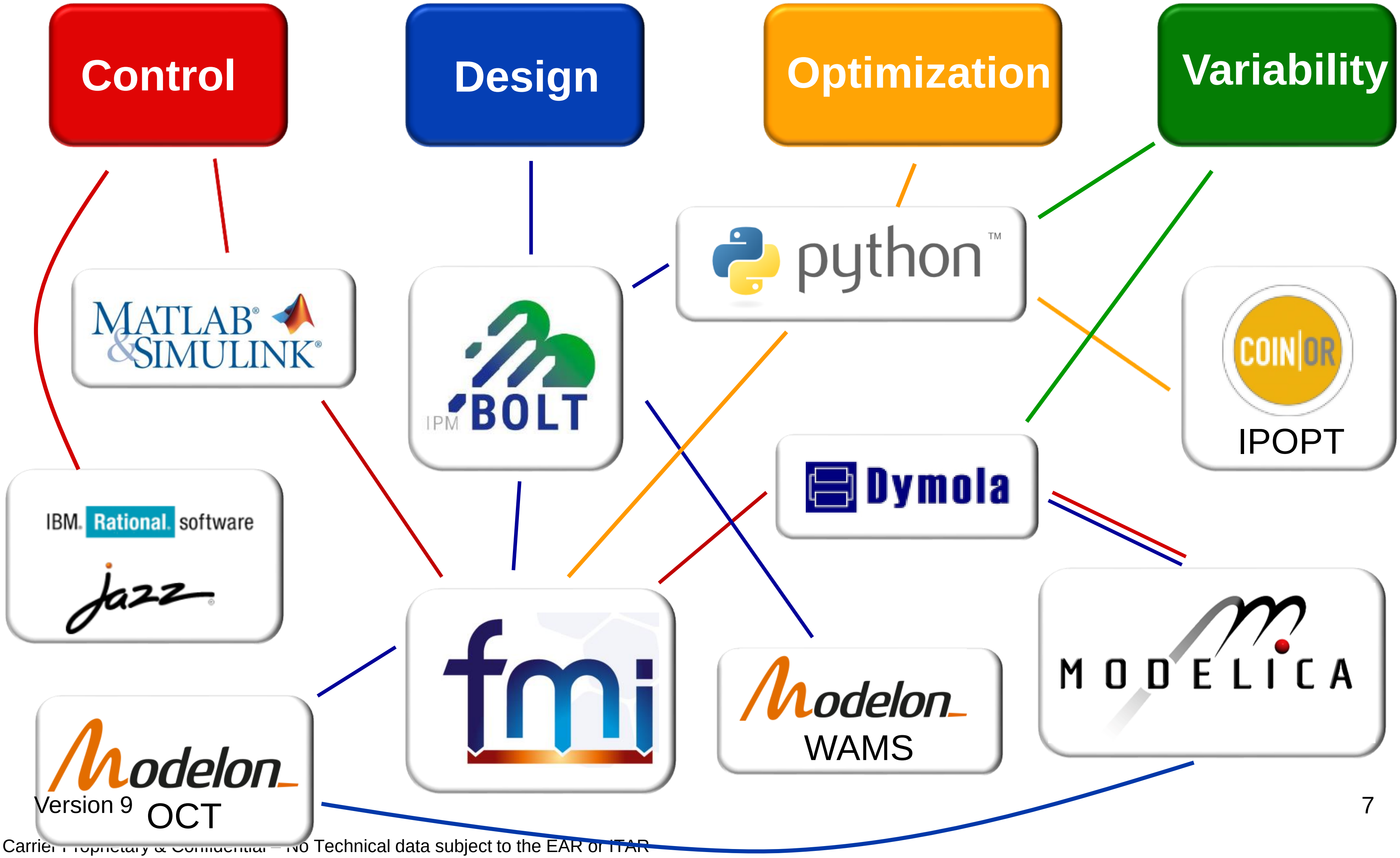
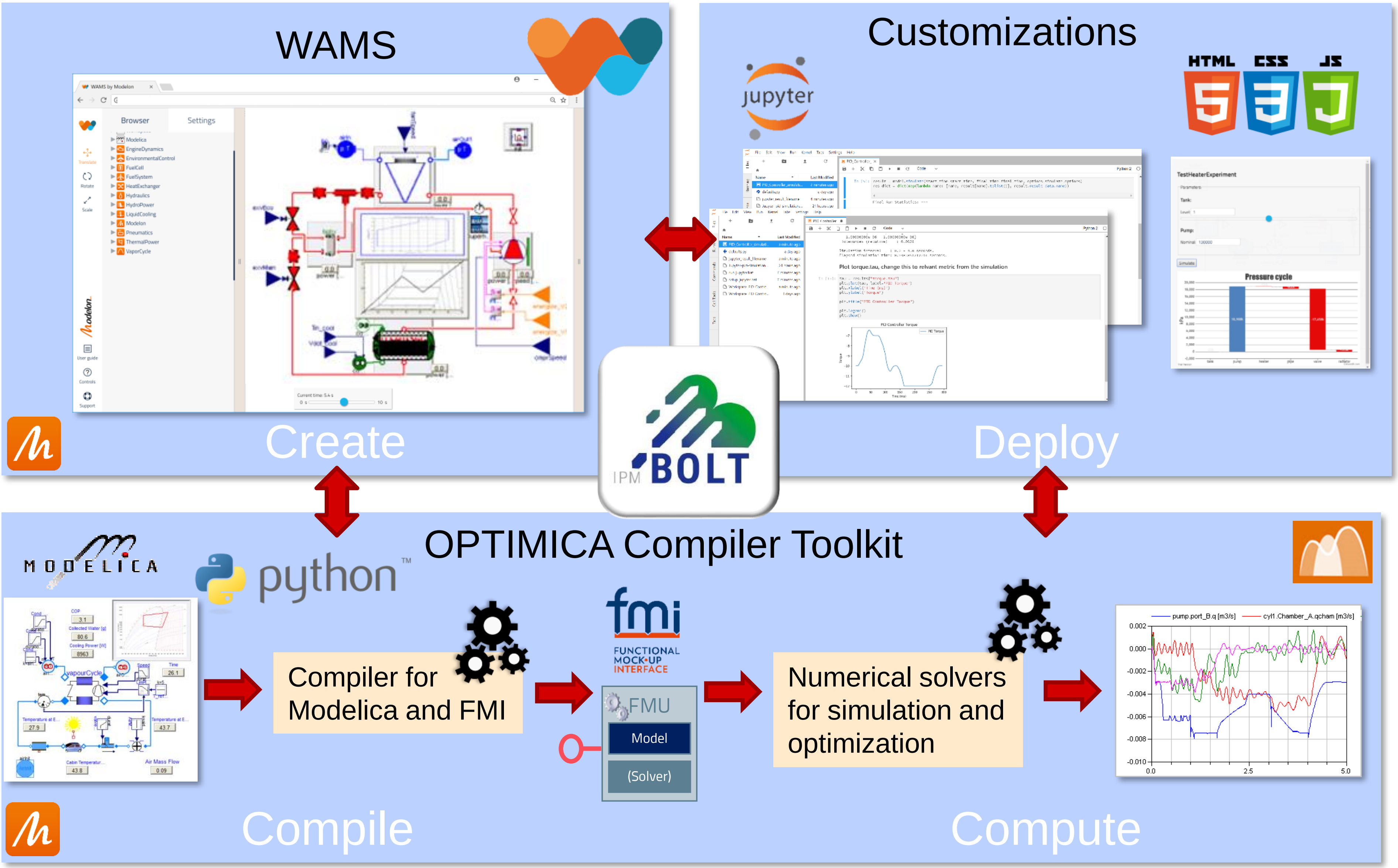


Figure 1: Proposed Model Based Development Process

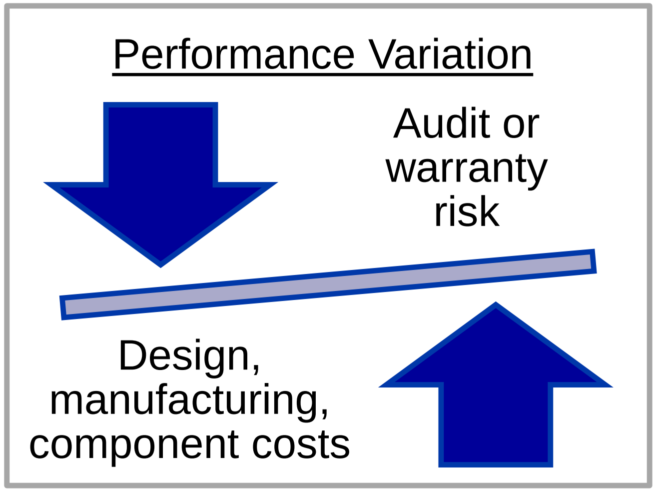
TOOLCHAIN ECO-SYSTEM

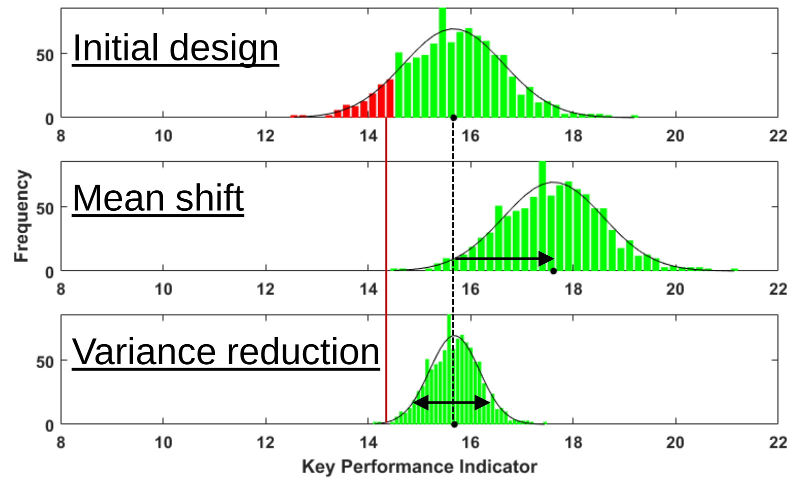


MODELON PLATFORM FOR MBD



VARIABILITY – ENGINEERING METHODS



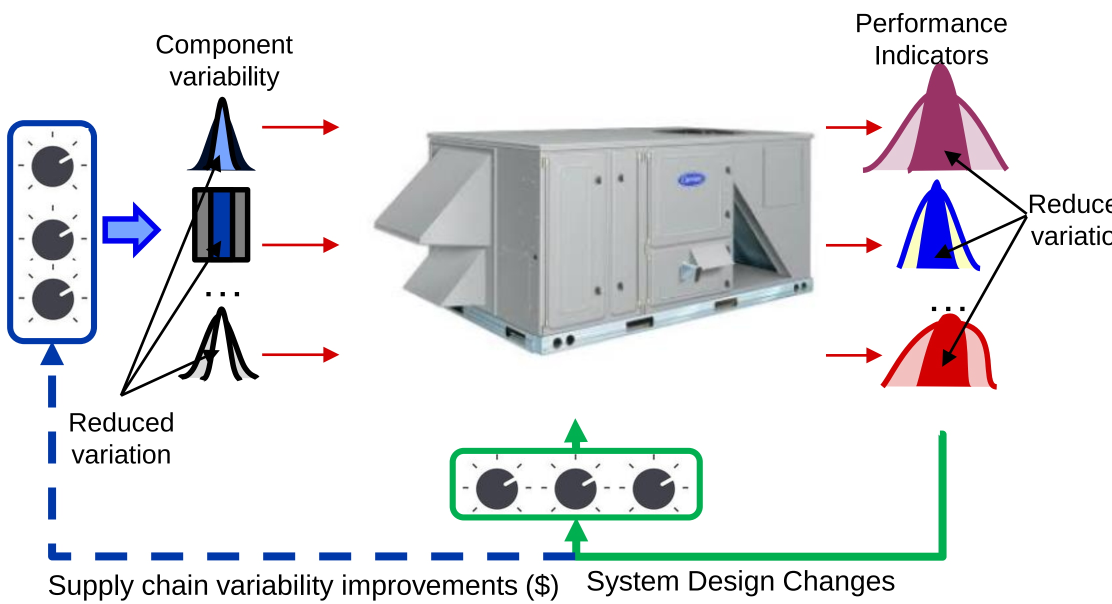


Analysis methods

- Model-based manufacturing analysis
- Test variation: Gage R&R, internal audits, extra testing

Design methods

- Adjust the relationship between mean (designed), deviation, tails of KPI's
- Feasibility analysis
- Sensitivity/variability reduction



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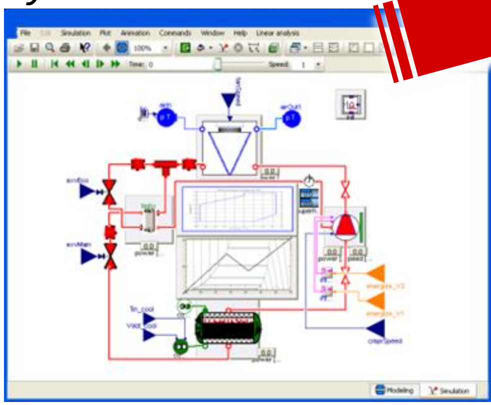
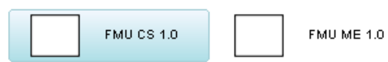
MODEL BASED CONTROL DESIGN

Software tools to support automatic code generation and testing

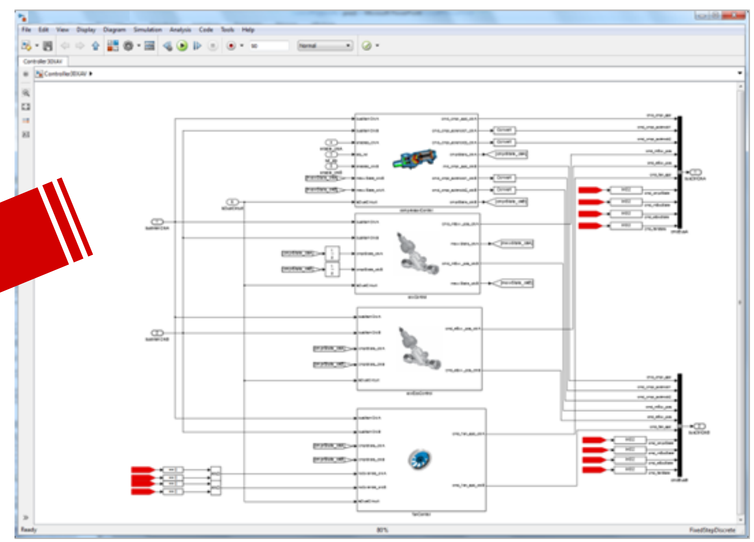
Dymola
Dynamic model



FMI Toolbox
Run model in Simulink

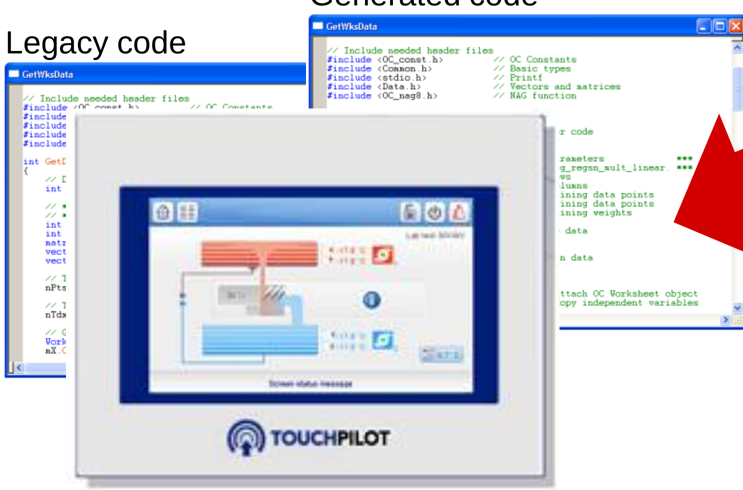


Matlab/Simulink/Stateflow
Create controller
Automatic code generation
***Tool boxes:** EmbeddedCoder*



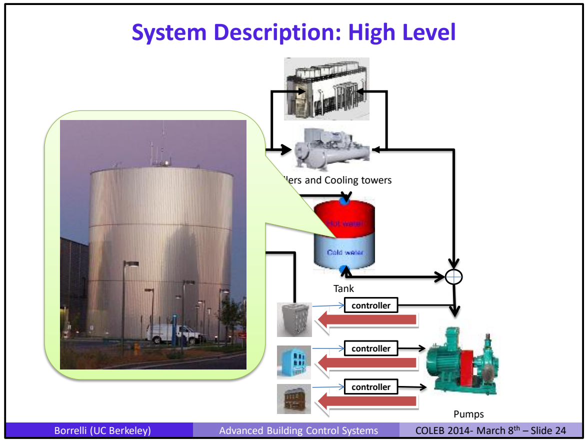
Generated code

Legacy code



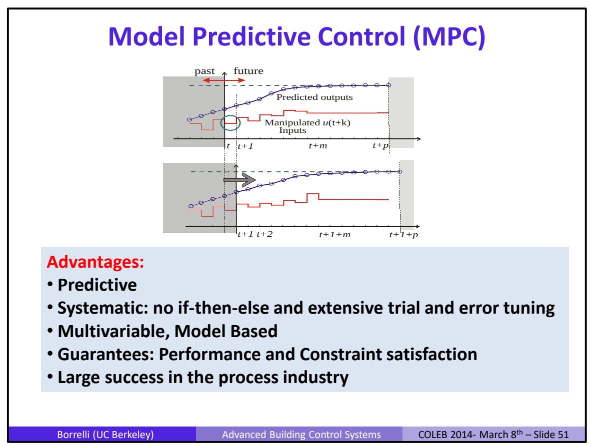
ENERGY EFFICIENCY @ SYSTEM LEVEL

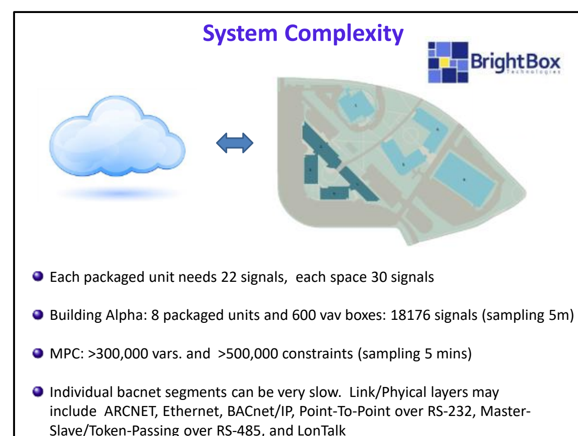
MPC Used For Achievable Performance



System level considerations…heterogeneous system…

Examine limits of performance using MPC control design…





Implementation done in cloud environment…

Thanks to F. Borrelli (Berkeley) – joint work with UTRC

KEY POINTS

Modelica is a modeling language that captures physics and is useful for modeling at the system level and for modeling heterogeneous systems (and both steady state & dynamics).

CCS is using Modelica for system level modeling and the Modelon tool chain to capture system level models and to deploy widely using library architectures, GUI and Python infrastructure.

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