

IBPSA Project 1

Modeling for “conventional” controls including verification.
(MPC dealt with in other discussions.)

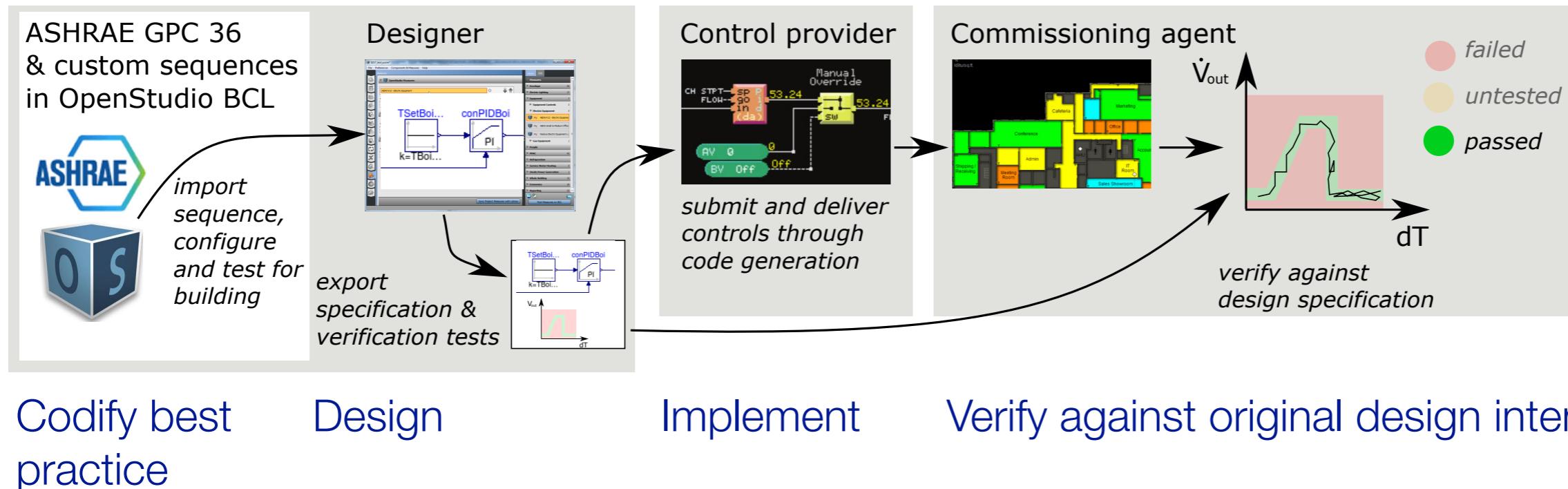
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February 27, 2018



Lawrence Berkeley National Laboratory

OpenBuildingControl: Design and implement control sequences error-free and at lower cost to owner



BACnet standardizes communication.

OpenBuildingControl will standardize

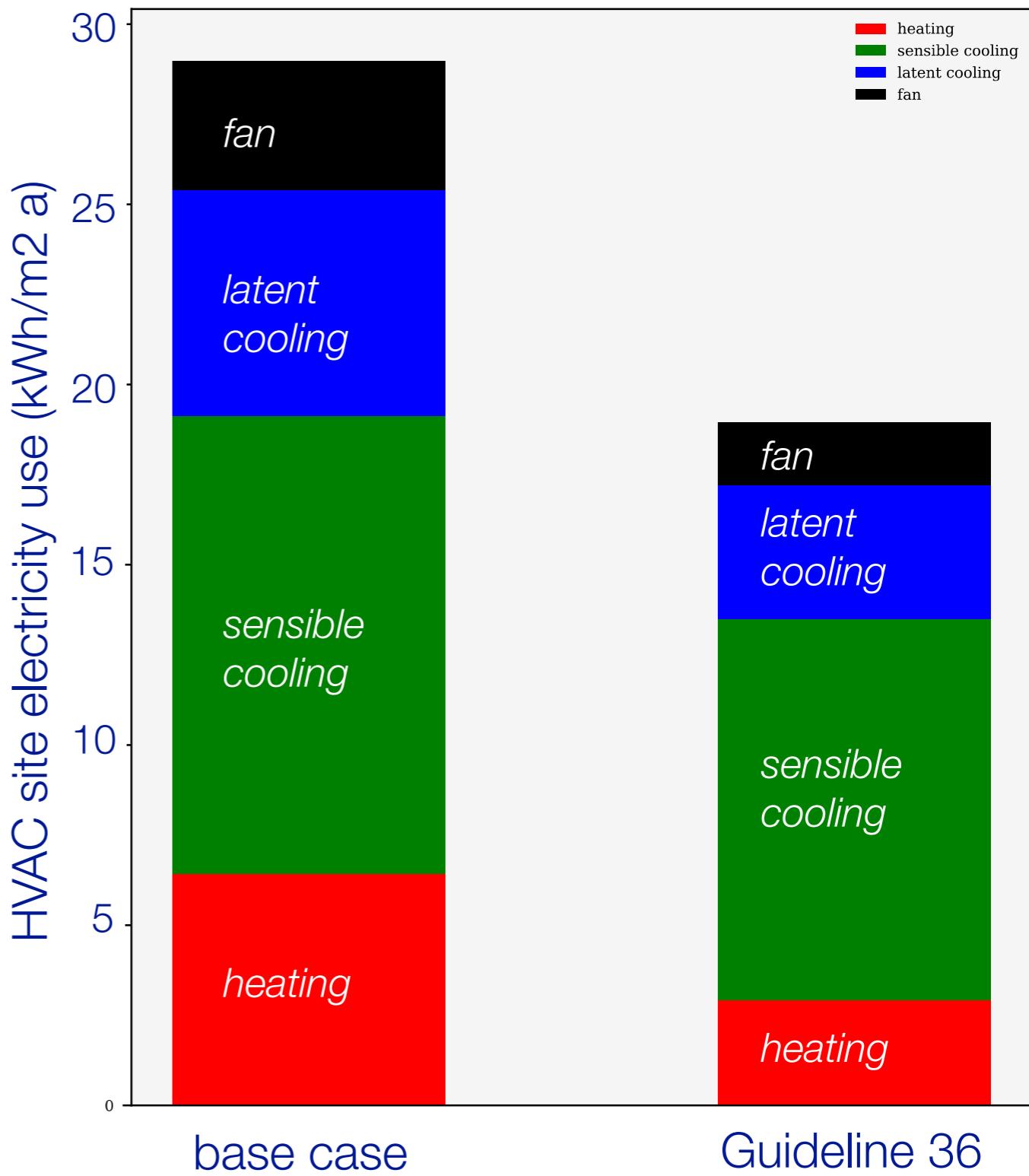
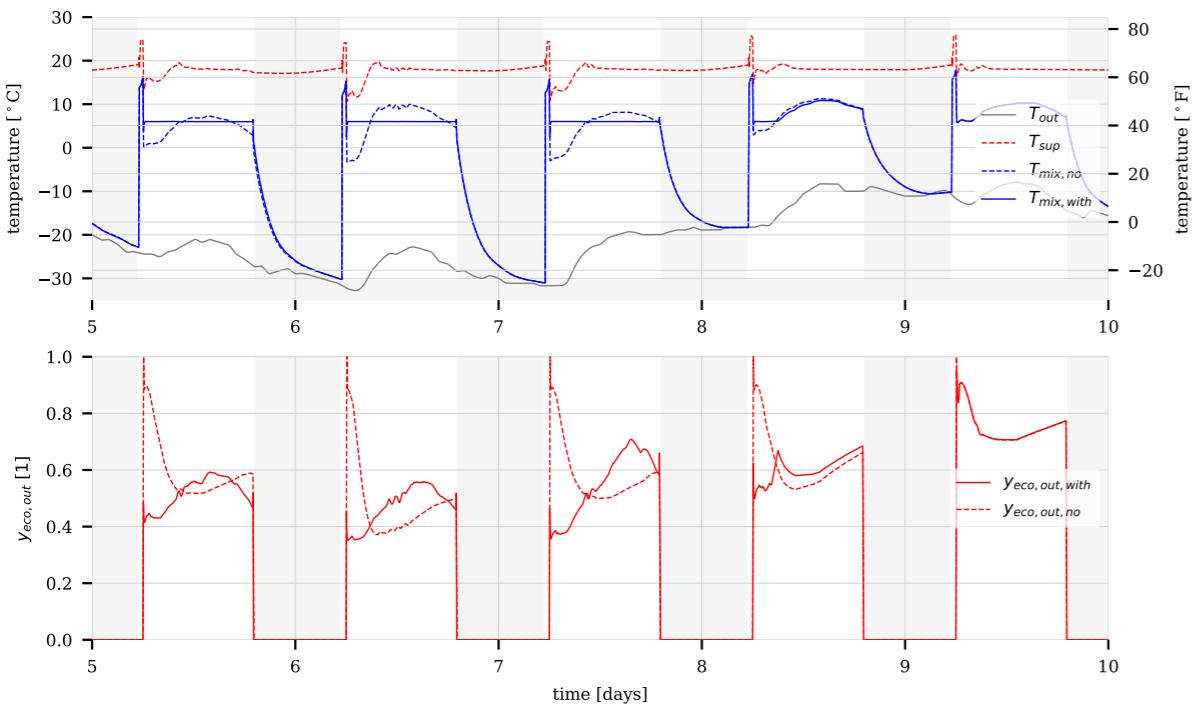
- basic functional building blocks that are used to compose sequences and tests,
 - expressing control sequences,
 - expressing functional verification tests,
- for bidding, automatic implementation and automated functional testing.

Key take-aways of 1st case study

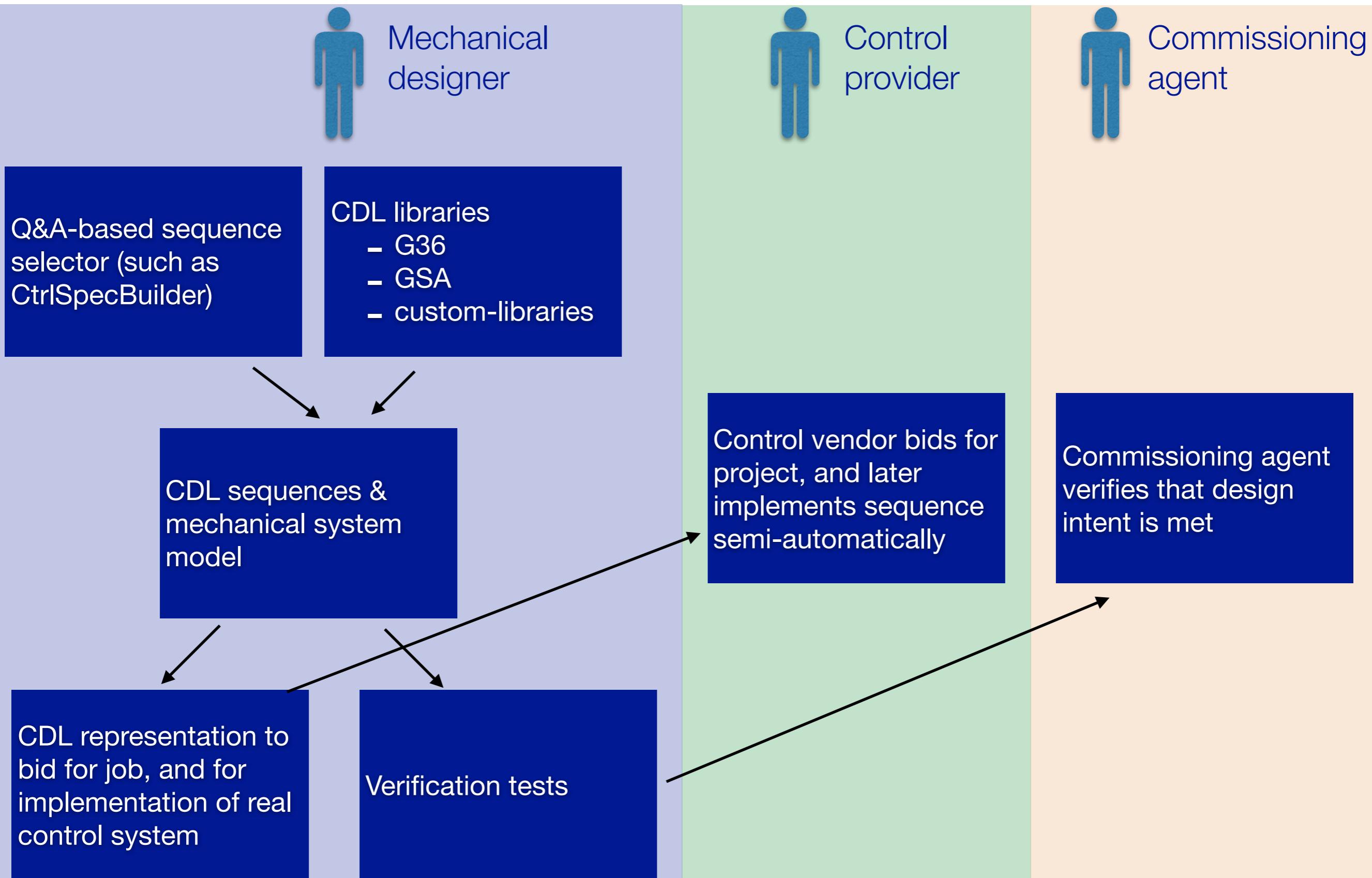
~30% annual site HVAC energy savings for Chicago, solely due to controls.

Can simulate actual control sequences, with dynamic response.

Packaging of sequences is important, because interpretation and implementation of the sequences was more time-consuming and error-prone than anticipated.



Process flow



CDL library

Developed CDL library based on review of industrial control libraries.

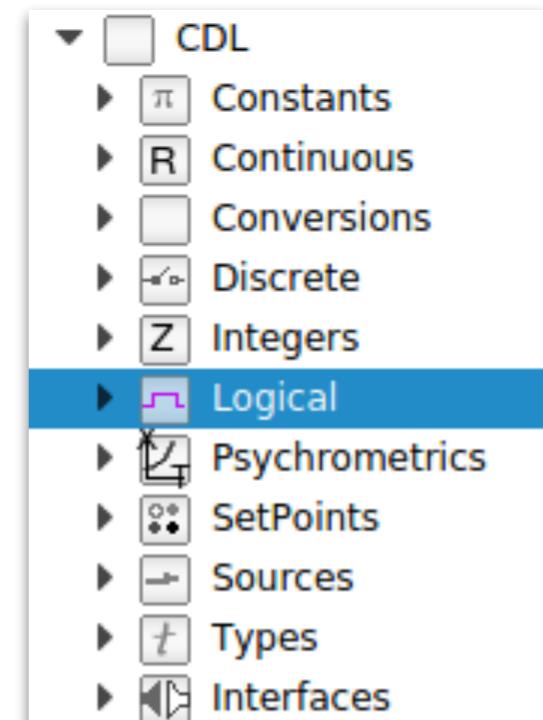
Validated blocks to ensure expected functionalities

- against known results
- across two independent simulators (Dymola and JModelica)

In CDL library:

- 11 packages
- 134 basic blocks

Package name	Description
Constants	Library of constants
Continuous	Library with elementary mathematical functions for continuous variables
Conversions	Library with blocks for type conversion
Discrete	Library of discrete input/output blocks with fixed sample period
Integers	Library with elementary mathematical functions for integer variables
Logical	Library with logical blocks
Psychrometrics	Library with psychrometric blocks
Routing	Package of blocks to combine and extract signals
SetPoints	Package with models for control set points
Types	Package with type definitions
Interfaces	Library with connectors for input and output signals



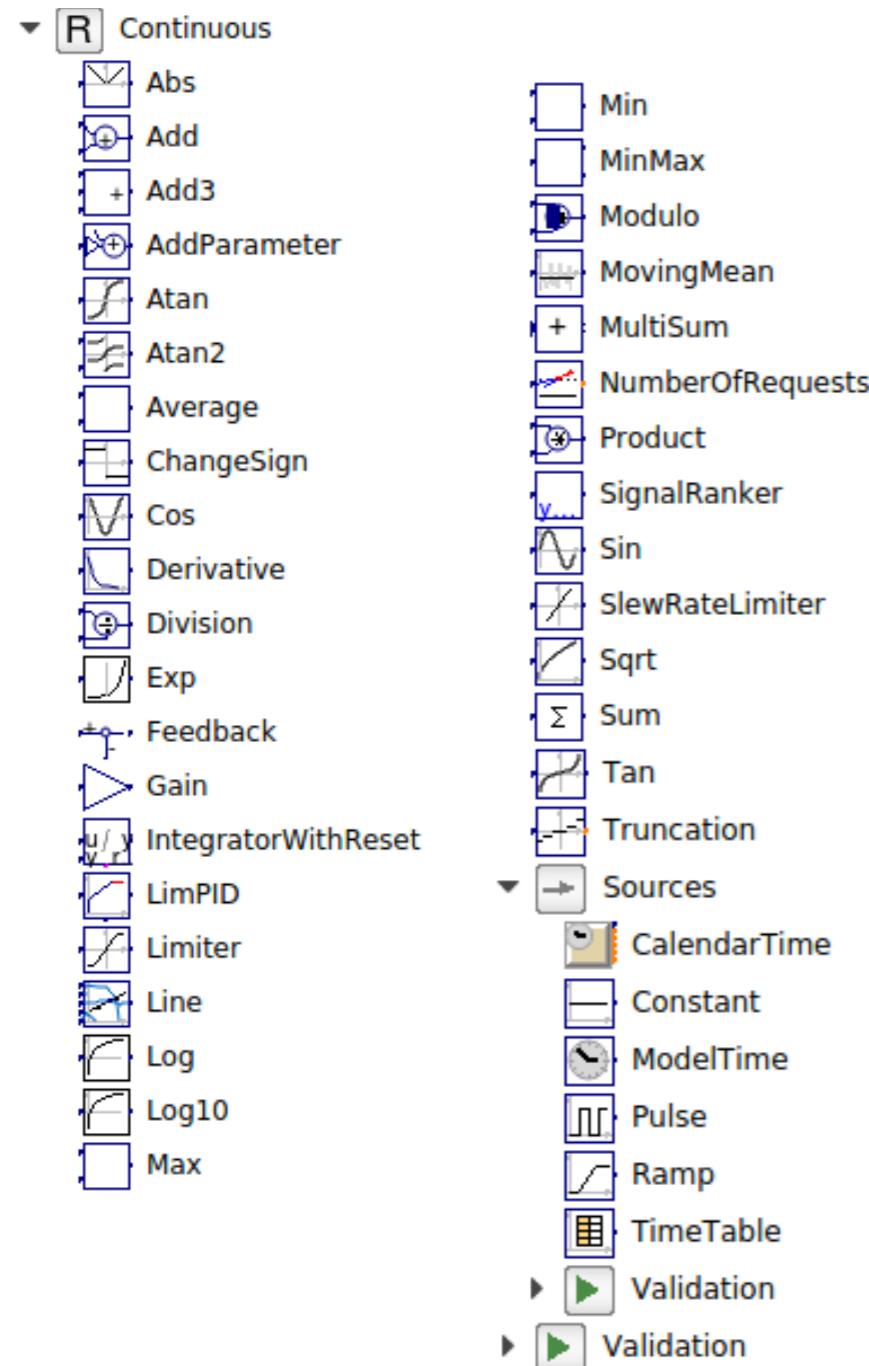
Browse CDL library at

http://simulationresearch.lbl.gov/modelica/releases/v5.0.0/help/Buildings_Controls_OBC_CDL.html

CDL library: Packages

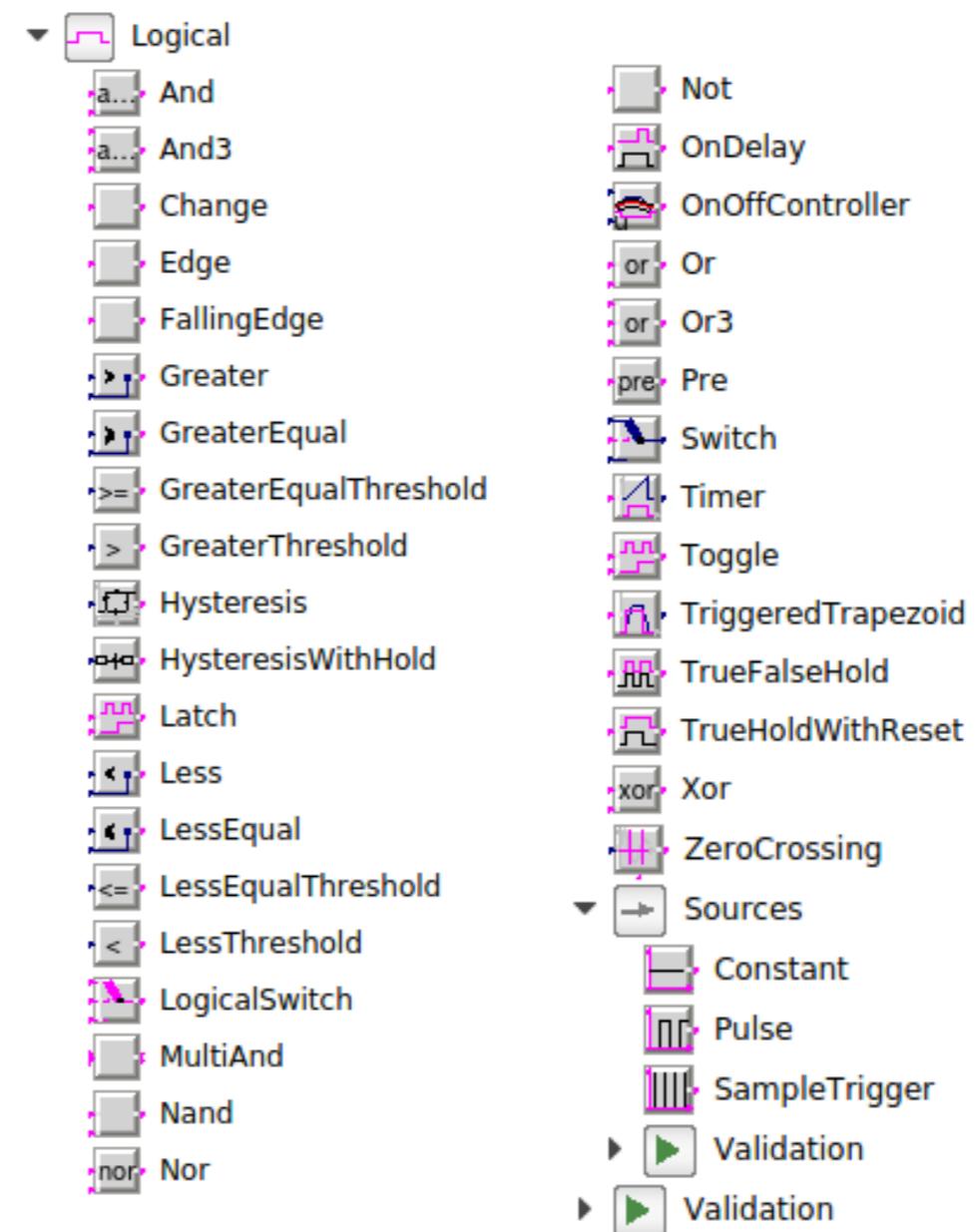
CDL.Continuous:

elementary mathematical functions for continuous variables



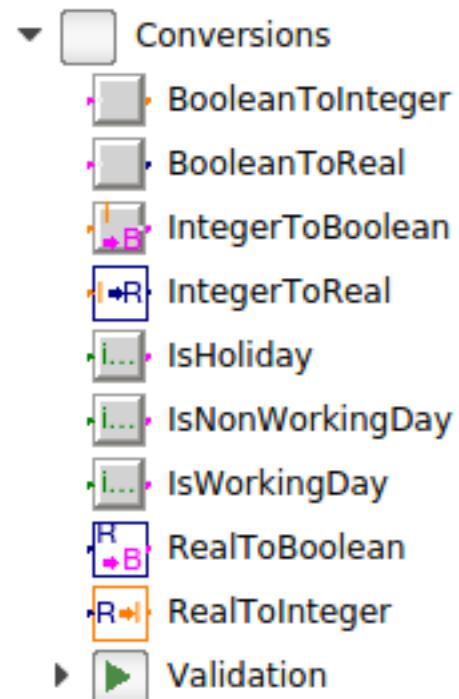
CDL.Logical:

elementary mathematical functions for boolean variables

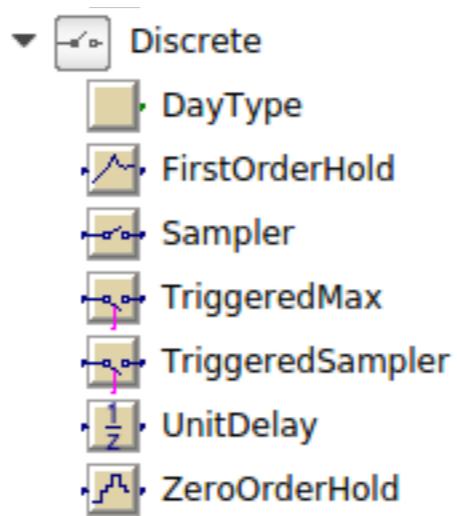


CDL library: Packages

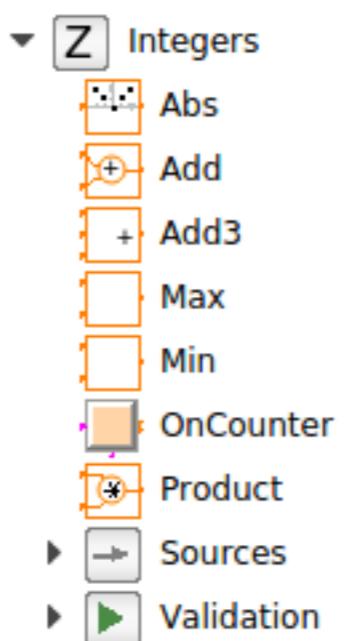
CDL.Conversions:
type conversions



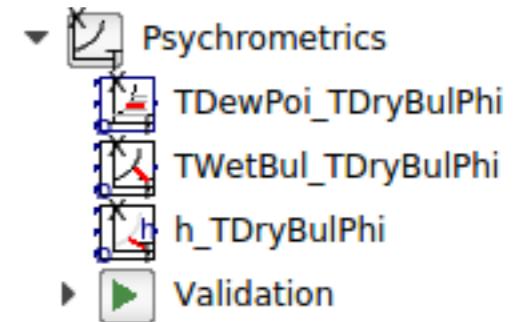
CDL.Discrete:
daytype, sample, delay, hold



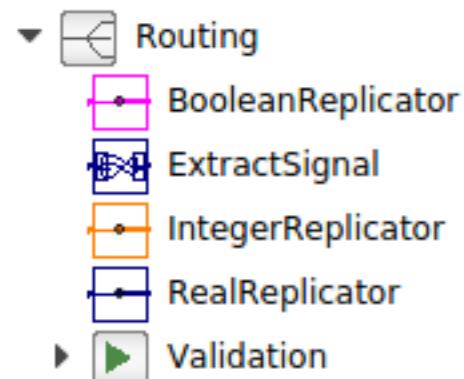
CDL.Integers:
mathematical functions for integer variables



CDL.Psychrometrics:
psychrometric calculations



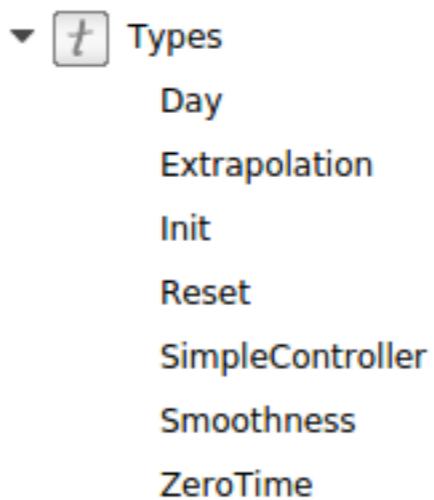
CDL.Routing:
combine and extract signals



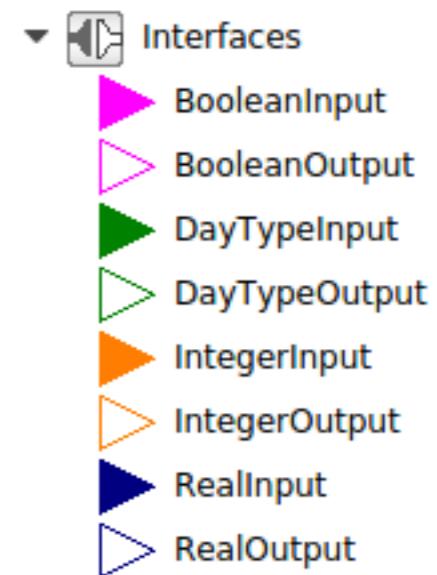
CDL.Setpoints:
setpoints for control systems



CDL.Types:
type definitions

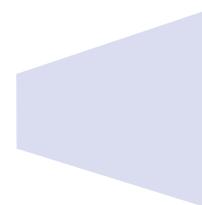


CDL.Interfaces:
connectors for input and output signals



CDL is used to implement open and proprietary sequences

The standard
to be
supported by
vendors



CDL

ASHRAE

G36

GSA

ARUP

ALC

Custom
implementations
that are built
using the CDL
language, and
CDL blocks

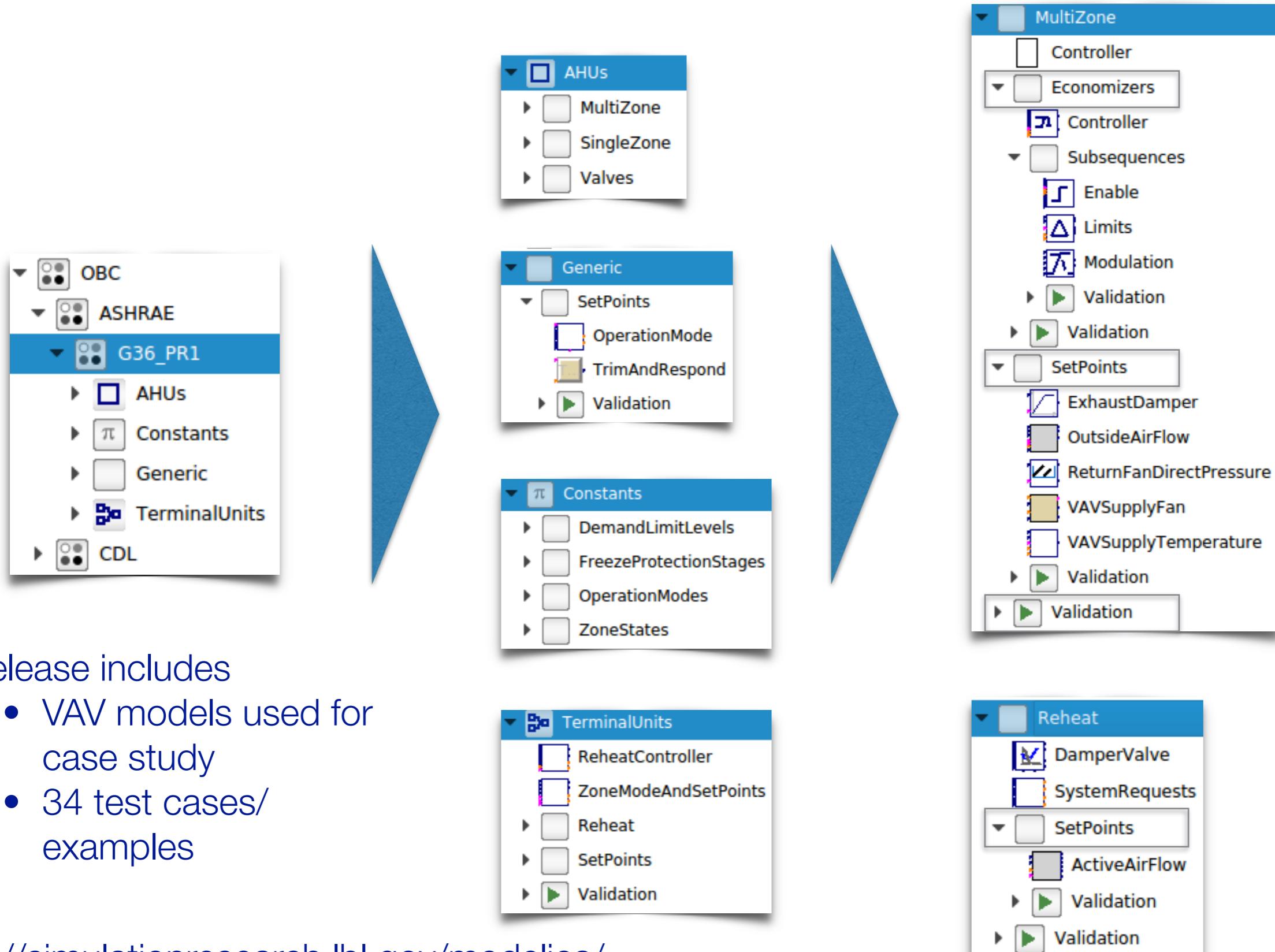
Sequences that come out of
ASHRAE projects and can be
shared with community.

GSA preferred sequences,
made available through a CDL-
complaint implementation.

Design firms can share their own
(proprietary) implementation
across their offices.

Control vendors can provide their
own specialized sequences, either
as open-source, or as compiled
(proprietary) I/O blocks.

Released Guideline 36 sequences with Buildings library 5.0.0

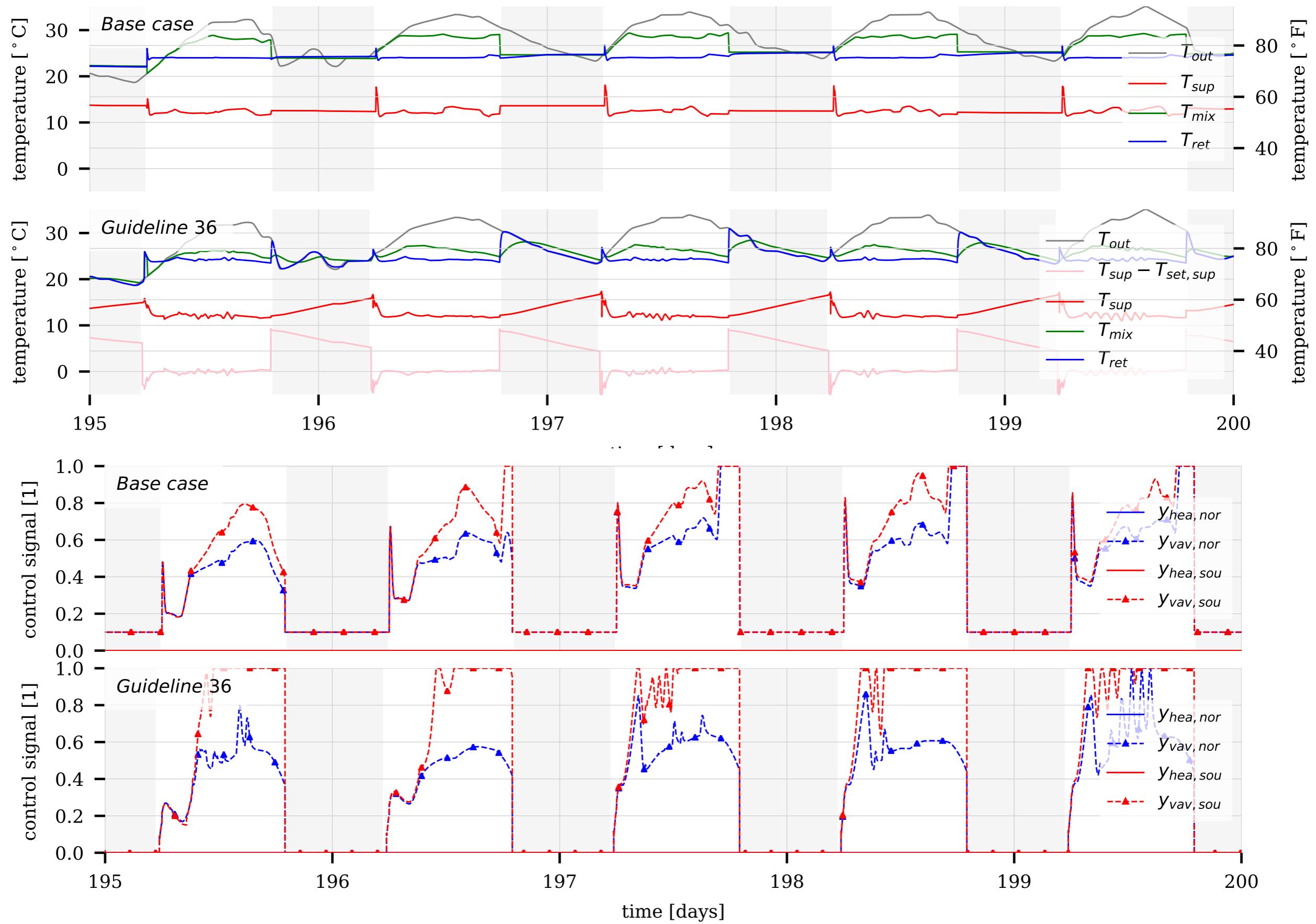


Release includes

- VAV models used for case study
- 34 test cases/examples

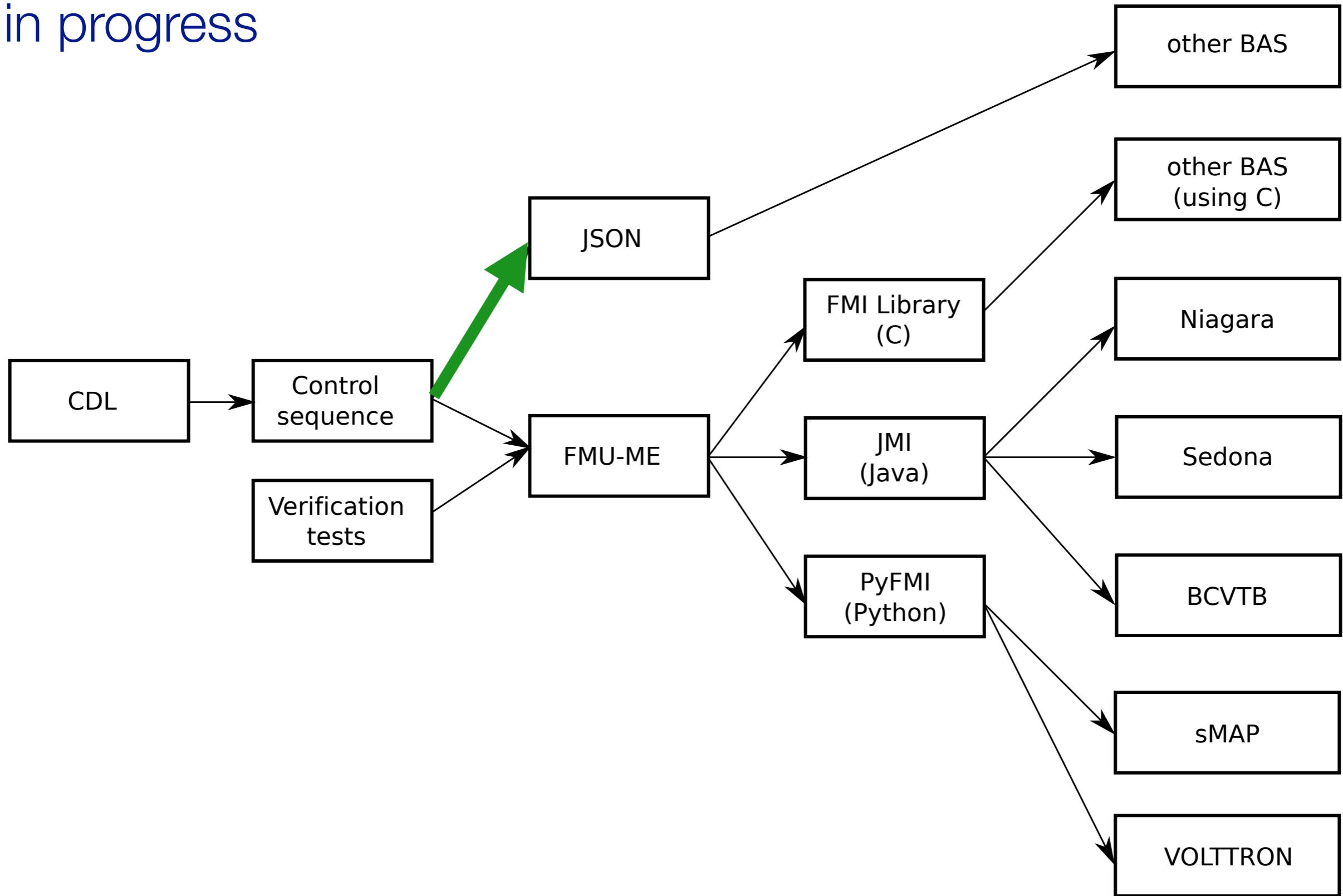
Example output

See <http://obc.lbl.gov/specification/example.html>
for more trajectories and discussion



CDL export

Development of parser from CDL to JSON, and JSON to html in progress



Repository

Control sequences &
verification test
declarations

Executable
format

Import
libraries

Runtime
environment

Development of parser from CDL to JSON, and JSON to html in progress

Software developer

modelica.g4

antlr

*.java (antlr generated)

*.java
(for antlr)

javac

moParser.jar

javascript

jre

User

other modelica libraries

CDL library

modelica block

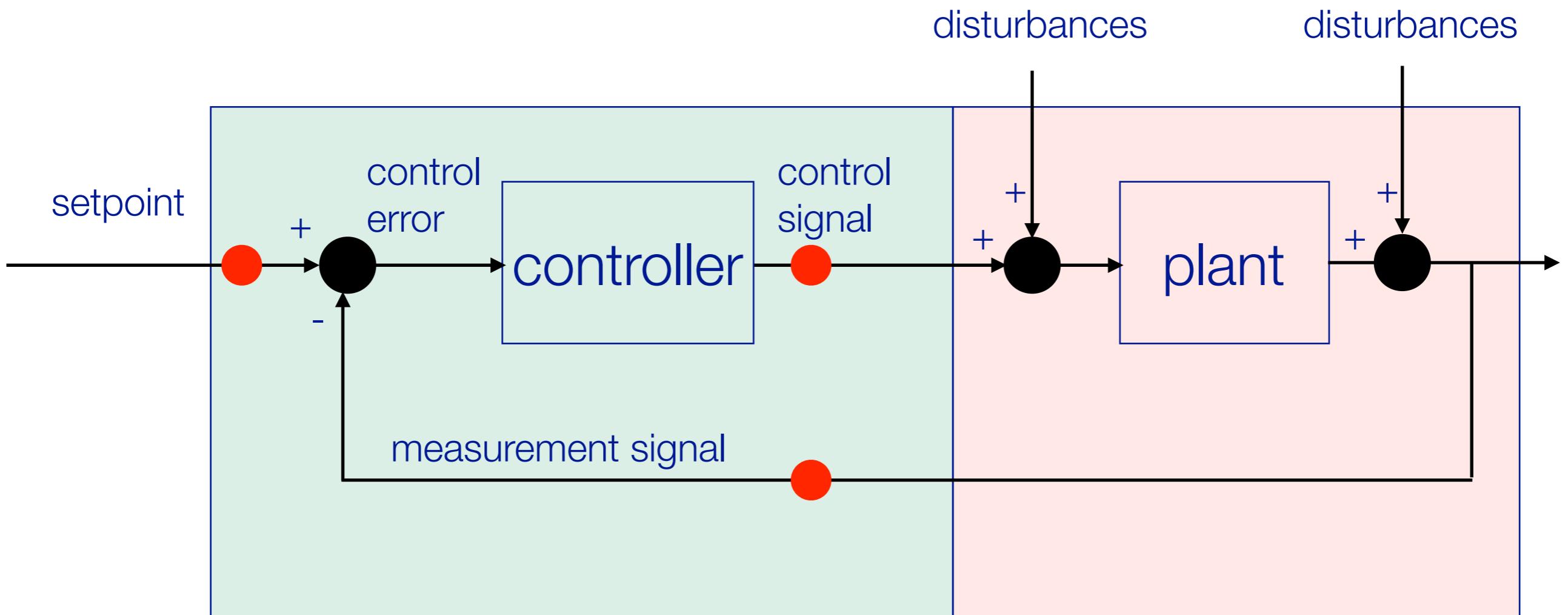
node

json

html

Verification

Verification of control sequence



- Red points indicate which signals to verify against a CDL generated response.

3-valued logic



R

Violated: Test condition is **violated** at least once.



Y

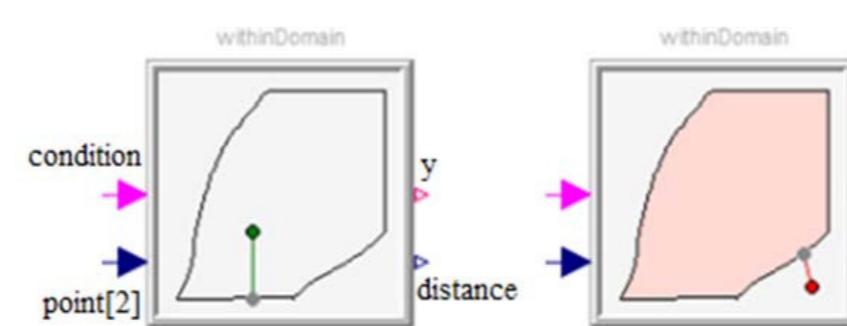
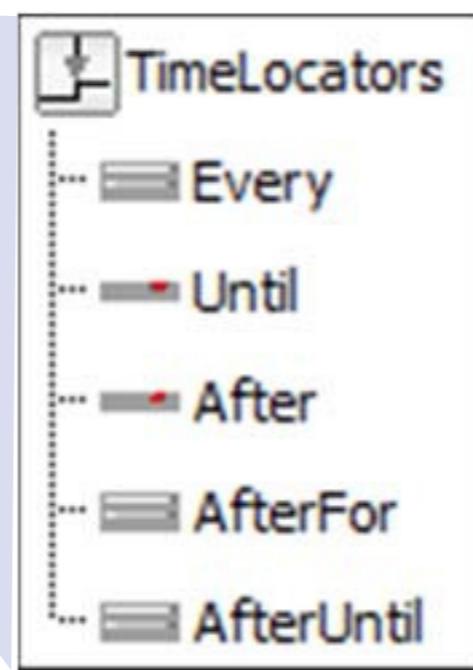
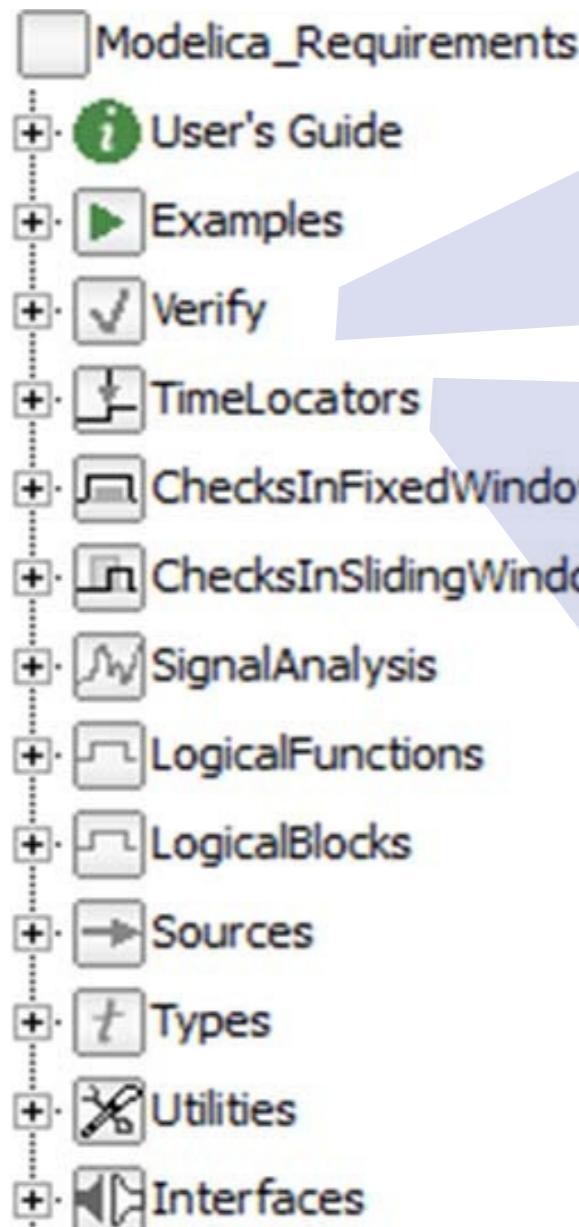
Untested: Test condition is **undecided** for the complete test period.



G

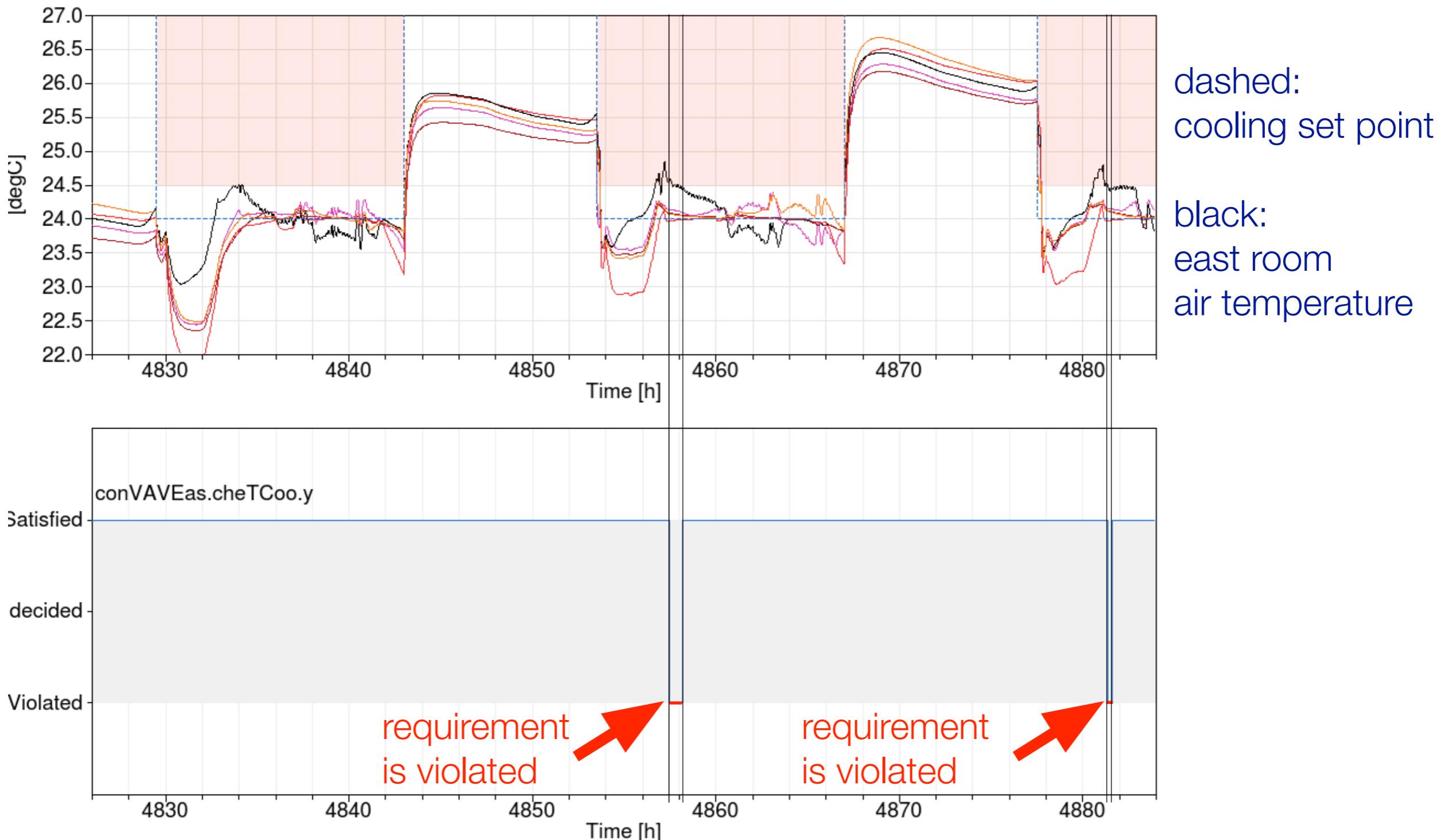
Satisfied: Test condition is **satisfied** at least once, and is never violated.

Implementation based on Modelica_Requirements



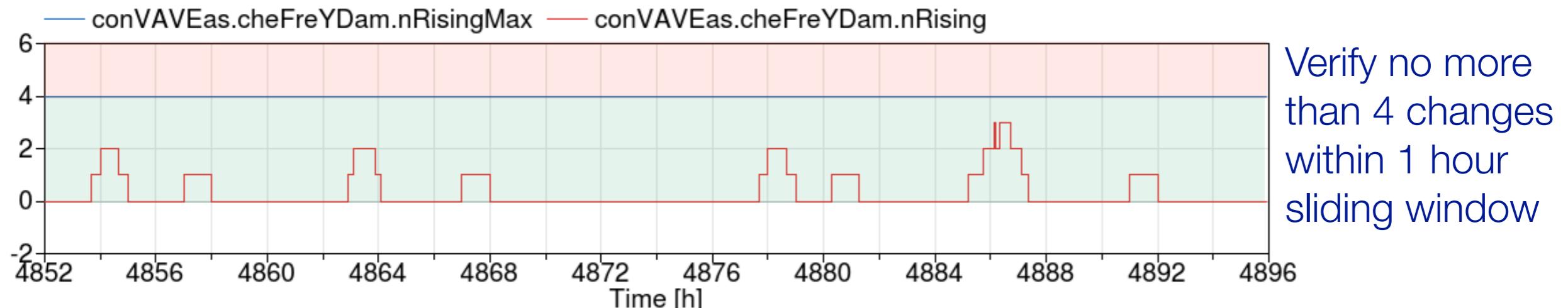
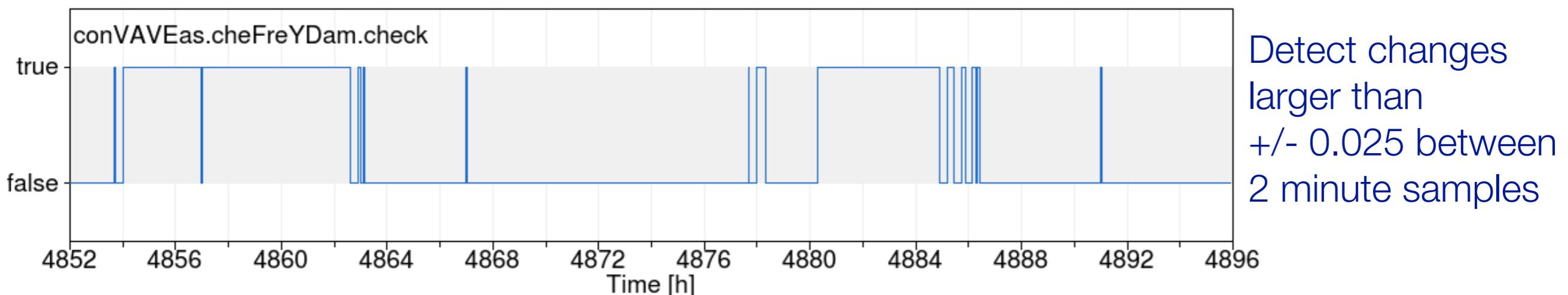
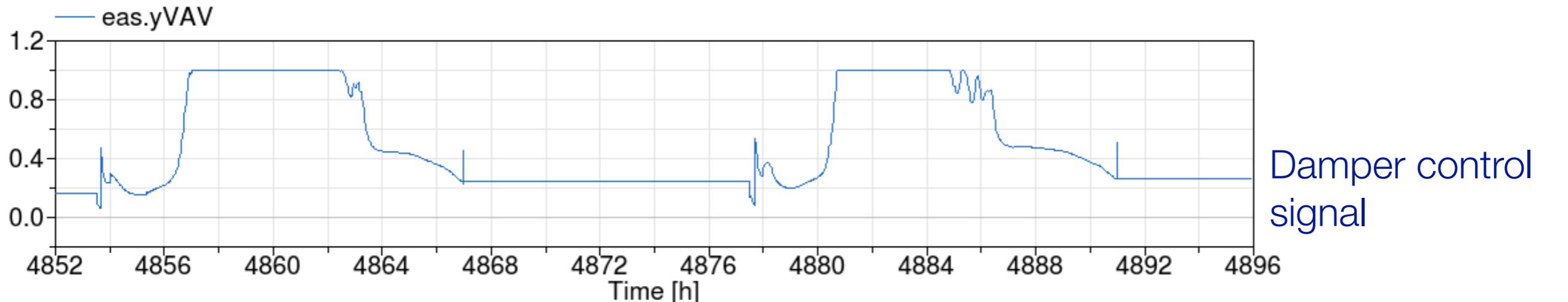
Verification of room air temperature of east zone

Requirement: Room air temperature shall be within $(T_{Set} + 0.5 \text{ K})$ for at least 45 min within each 60 min window.



Verification of east zone damper signal

Requirement: Damper signal shall not oscillate more than 4 times per hour between +/- 0.025 (for a 2 minute sample period)



Discussions