OpenBuildingControl

ASHRAE Standard 231P
—
Control Description Language

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ASHRAE Proposed Standard 231 “A Control Description Language for Building Environmental Control Systems”

- Started in September 2020.
- Approximately 35 members on the committee including system designers, control suppliers, and others.
- Proposed Structure:
  - Title, Purpose, Scope
  - Definitions and introduction
  - **Definition of control function blocks**
  - **Semantics and Structure**
  - **Definition of CDL**
  - Definition of a Controls Exchange Format (CXF)

Why Are We Doing This?

Properly applied commercial building controls can reduce energy use by 20 - 30% and also help improve comfort, safety, and protect occupant health.

But the current process for control design, delivery, operation, and maintenance is problematic.

To ensure that installed control sequences are high performing, OpenBuildingControl

1. Allows performance assessment of controls during design.
2. Digitizes the controls design and delivery.
3. Allows quality control at each step.
4. Allows high performance sequences to be shared — controls becomes a digital asset.

To aid deployment, project

5. Creates an ASHRAE Standard to provide industry with robust technology.
6. Integrates with DOE's BEM program
7. Creates tools for designers, control providers and commissioning agents.

Challenges of today's process

Designer

- Producing specifications are tedious and error-prone.
- Controls is a skill many designers do not have.
- No tools to judge how good a sequence is.
- Controls is not tested, let alone co-designed or optimized.

Controls Contractor

- Interpreting verbose sequence is tedious and error-prone.
- Often very tight schedule and budget.
- Often old sequences are adapted to make them work on next building.
- Errors and callbacks are expensive.

Commissioning agent & operator

- Verification is slow, tedious, and often done only for a limited set of conditions.
- Control intent is poorly documented.
- Lack of semantic knowledge complicates FDD and analytics.

What is new?

Specification

Provide tools for system designers to select and customize control sequences using a reference library including ASHRAE Guideline 36.

Performance testing

Provide tools for the designer to validate and test the sequence during design.

Support Spawn of Energy Plus to do accurate energy modeling of control sequences.

Deployment

Communicate logic to the contractor in a digital format.
This means that the control contractor no longer needs to interpret the sequence and develop the logic - saving time and money and reducing errors.

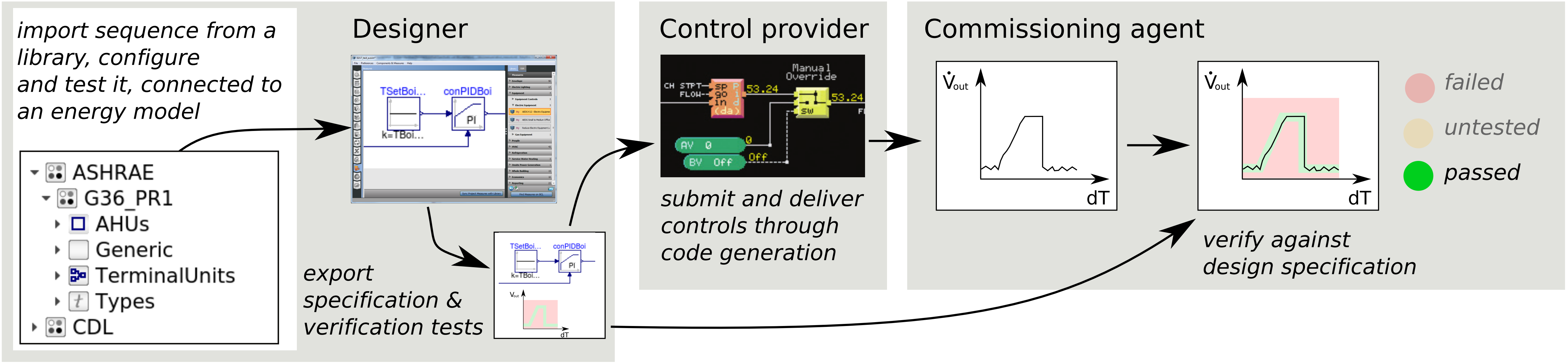
Standard documentation of control logic for commissioning agents and owners.

Verification

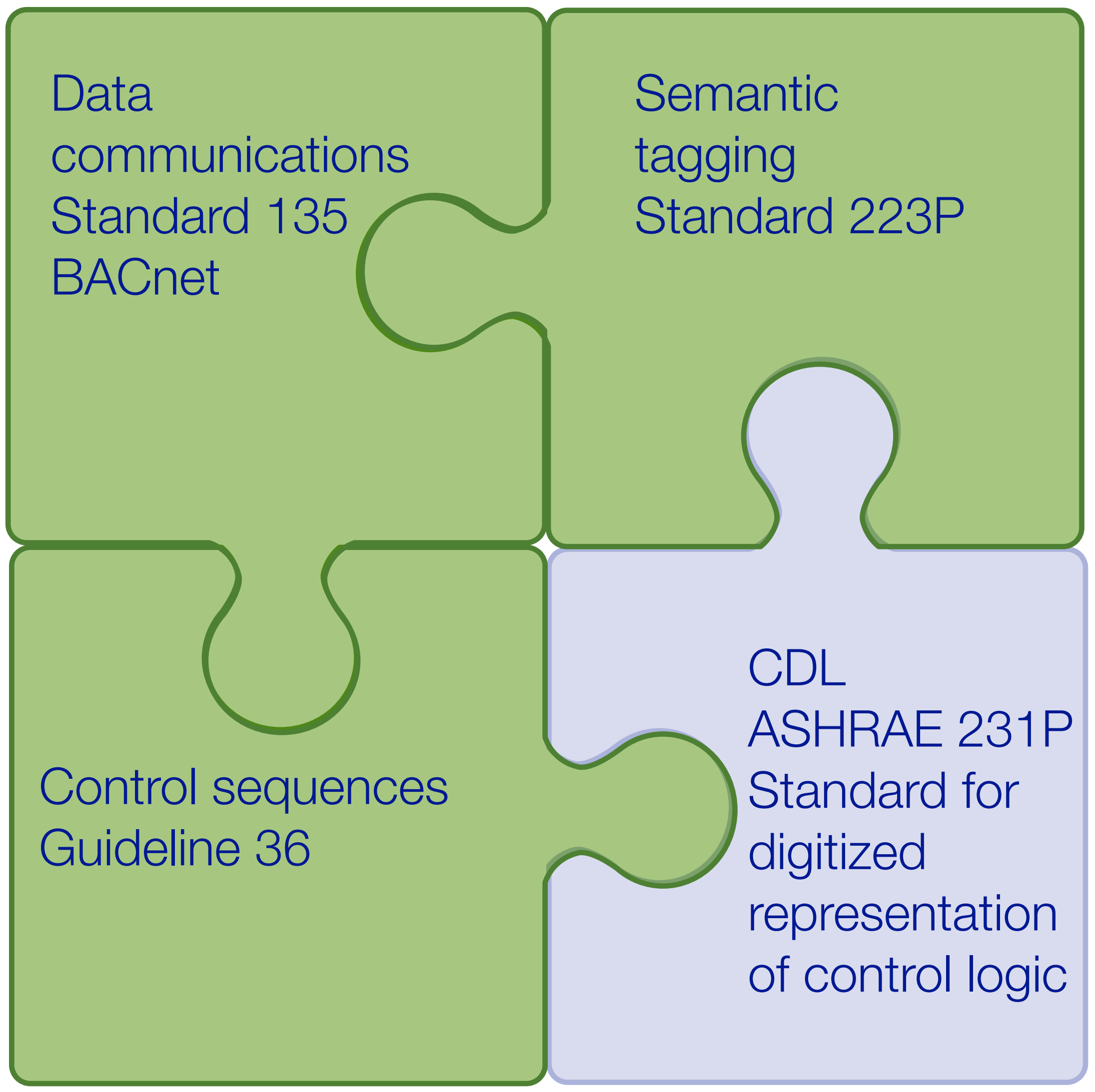
Tools to validate the logic in an installed system relative to design specification.

Standardized through a vendor-independent language

Digital control delivery process that links repository of control sequences with tools for design, deployment and verification

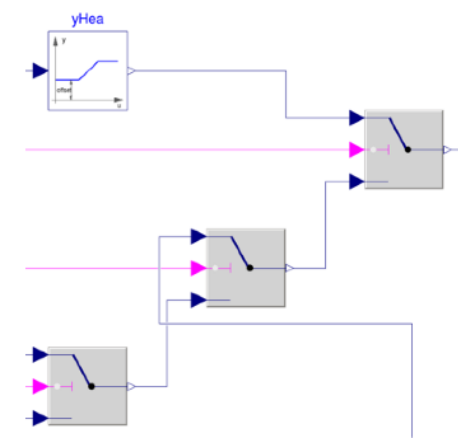


What gap does CDL address?



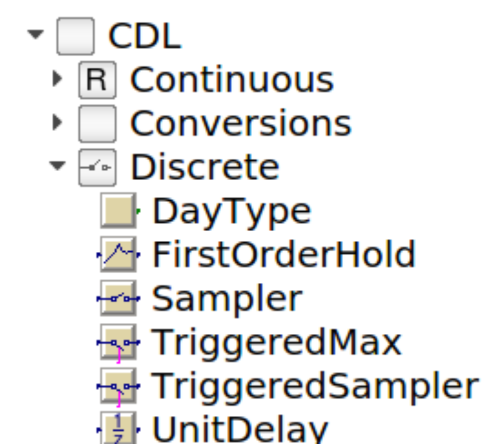
What is the Control Description Language?

A declarative **block diagram language**.

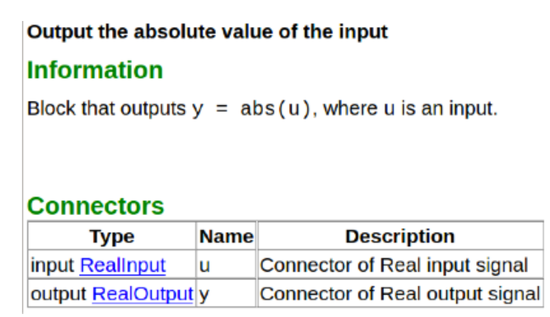


A **library** with elementary input/output blocks that should be supported, through a translator, by control providers.

Example:
CDL has a gain with input **u**, gain **k**, and output **y = k∗u**.



A **documentation syntax** for control blocks and sequences.



Output the absolute value of the input

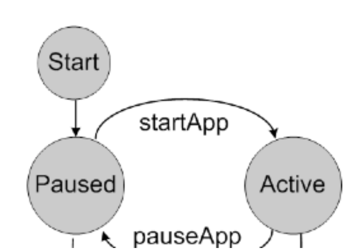
Information

Block that outputs `y = abs(u)`, where u is an input.

Connectors

Type	Name	Description
input RealInput	u	Connector of Real input signal
output RealOutput	y	Connector of Real output signal

A **model of computation** that describes when to update signals.



A language fully compatible with the open Modelica standard, enabling **simulation** and **code generation**.

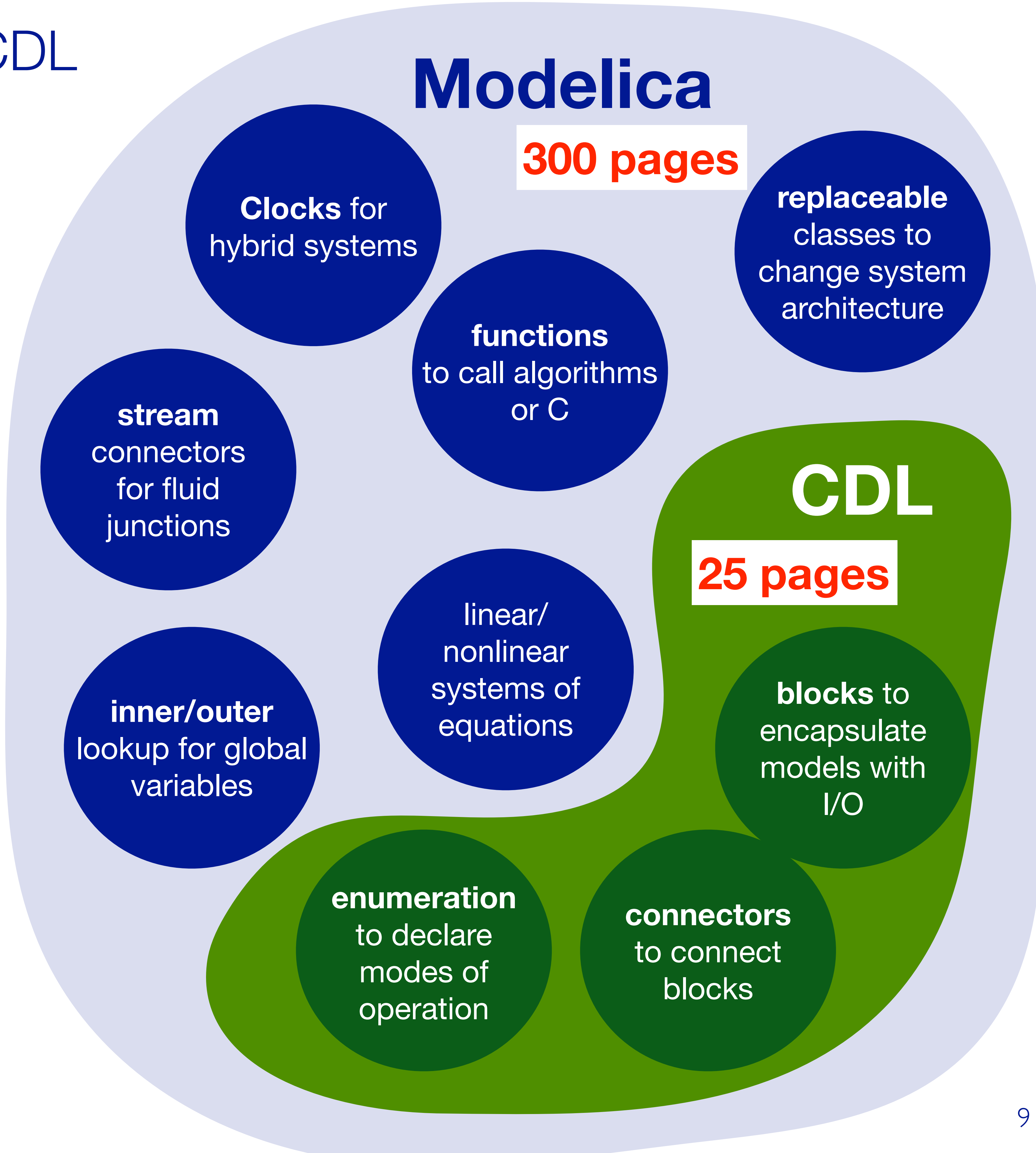
How we specified CDL

Conform to the Modelica Standard 3.3, ***but*** remove everything that is not needed to practically declare control logic and their English language documentation.

Keep it simple & easy to parse.

… and allow reuse of technology from the Modelica ecosystem.

Reviewed by advisory panel, through peer-review process, and used by various project partners from industry.

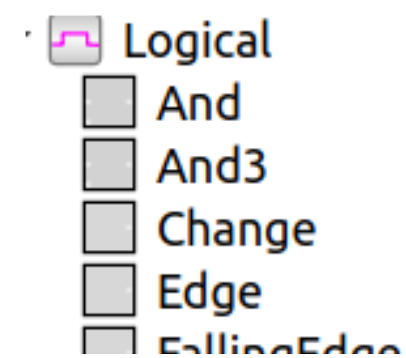


Basic elementary blocks are defined in a library that is immutable to the users (fixed by the specification).

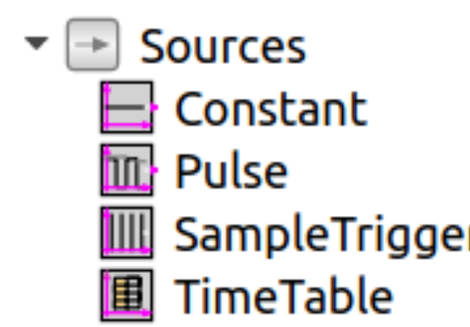
Basic blocks are organized in packages

- Constants
- Continuous
- Conversions
- Discrete
- Integers
- Logical
- Psychrometrics
- Routing
- SetPoints
- Utilities
- Types
- Interfaces

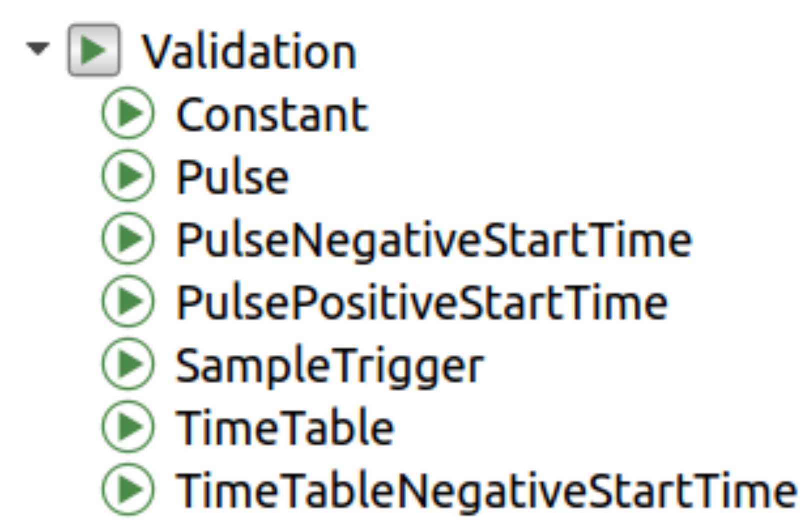
`blocks` are in `packages`:



Signal sources are in `Sources` sub package:



Blocks for validation and CI tests are in `Validation` package



See https://obc.lbl.gov/specification/cdl.html#elementary-building-blocks

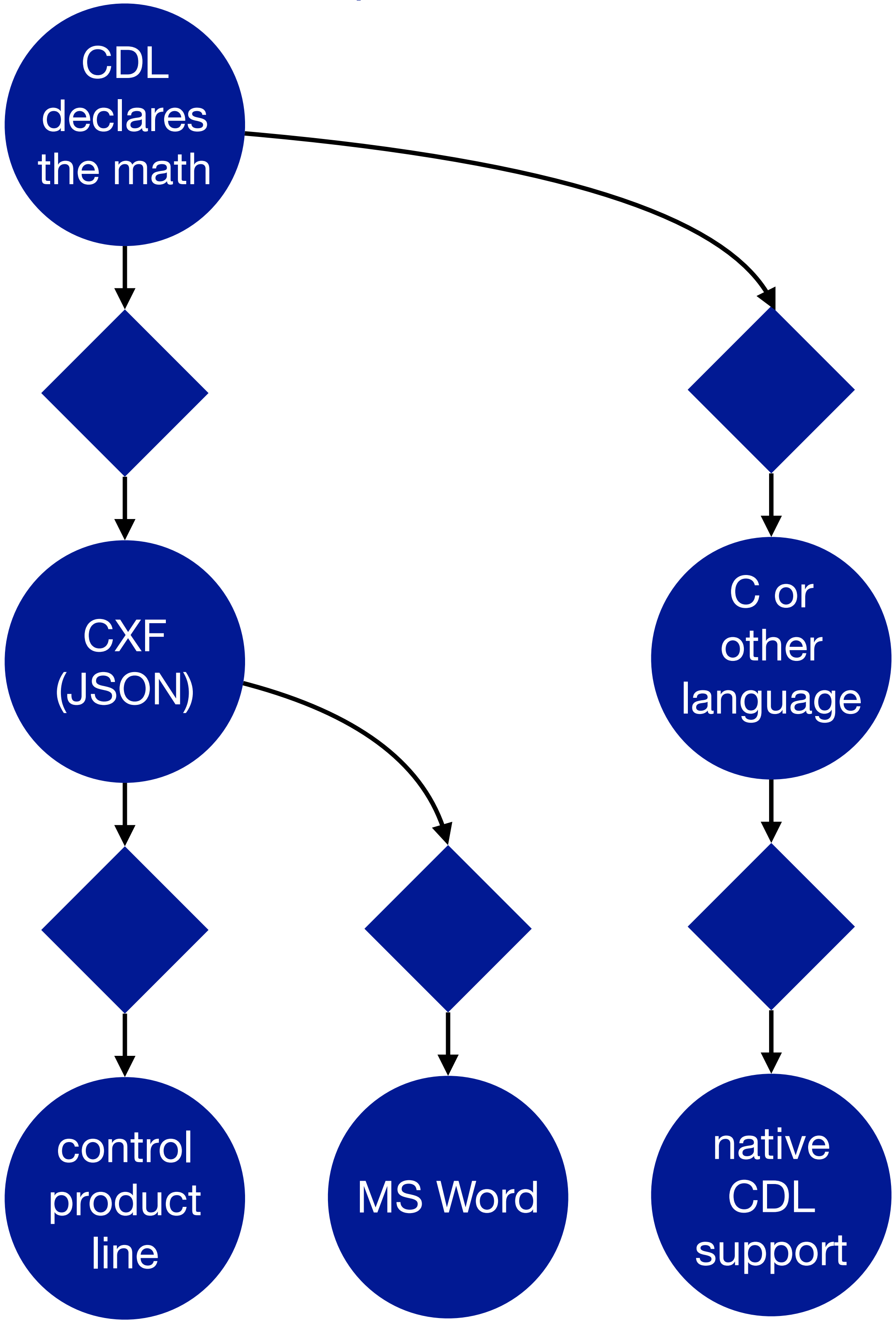
Basic elementary blocks are defined in a library that is immutable to the users (fixed by the specification).

Behavior is expressed mathematically,

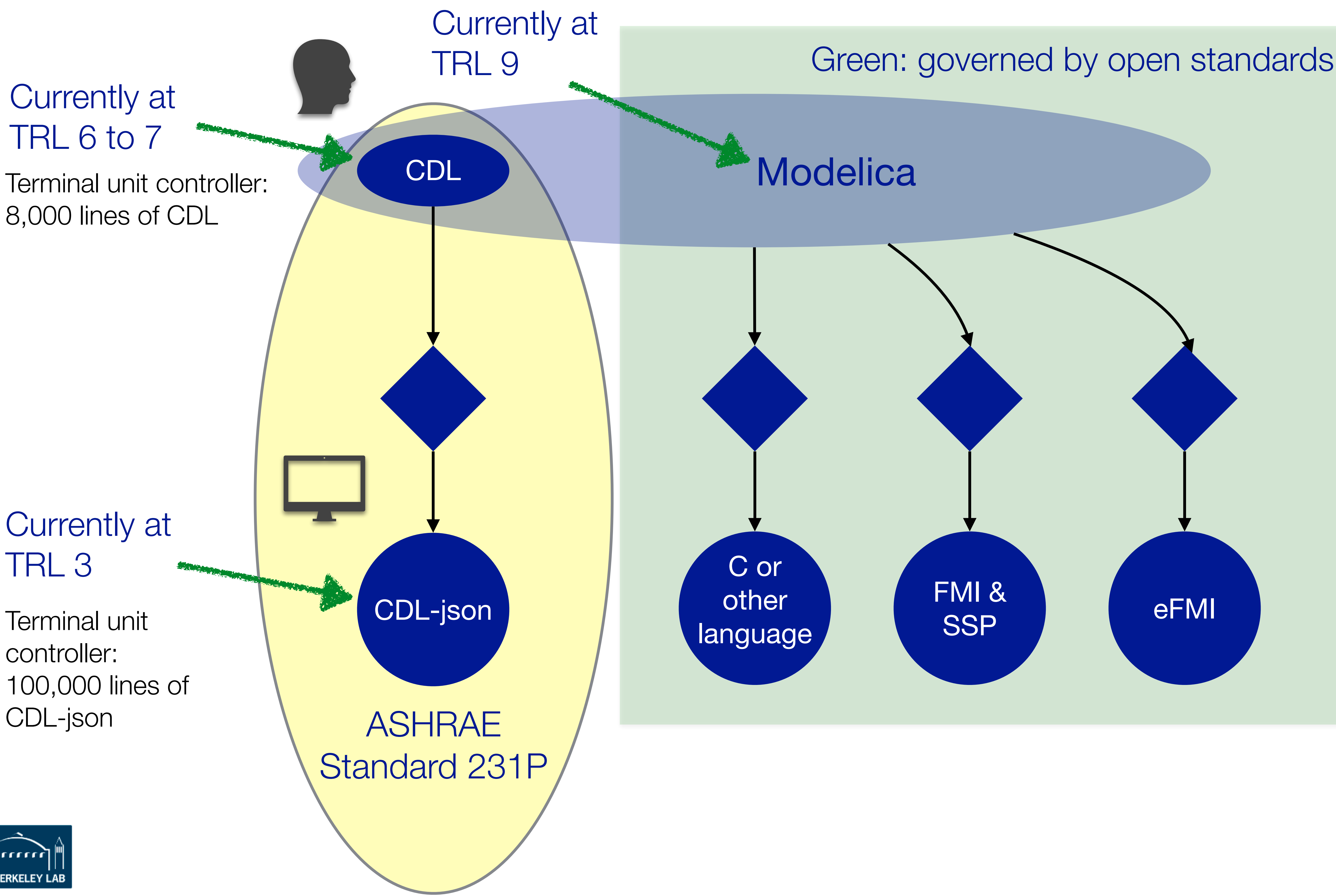
$$(p, t, u(t), x(t)) \mapsto y(t).$$

Software implementation is not part of the specification.

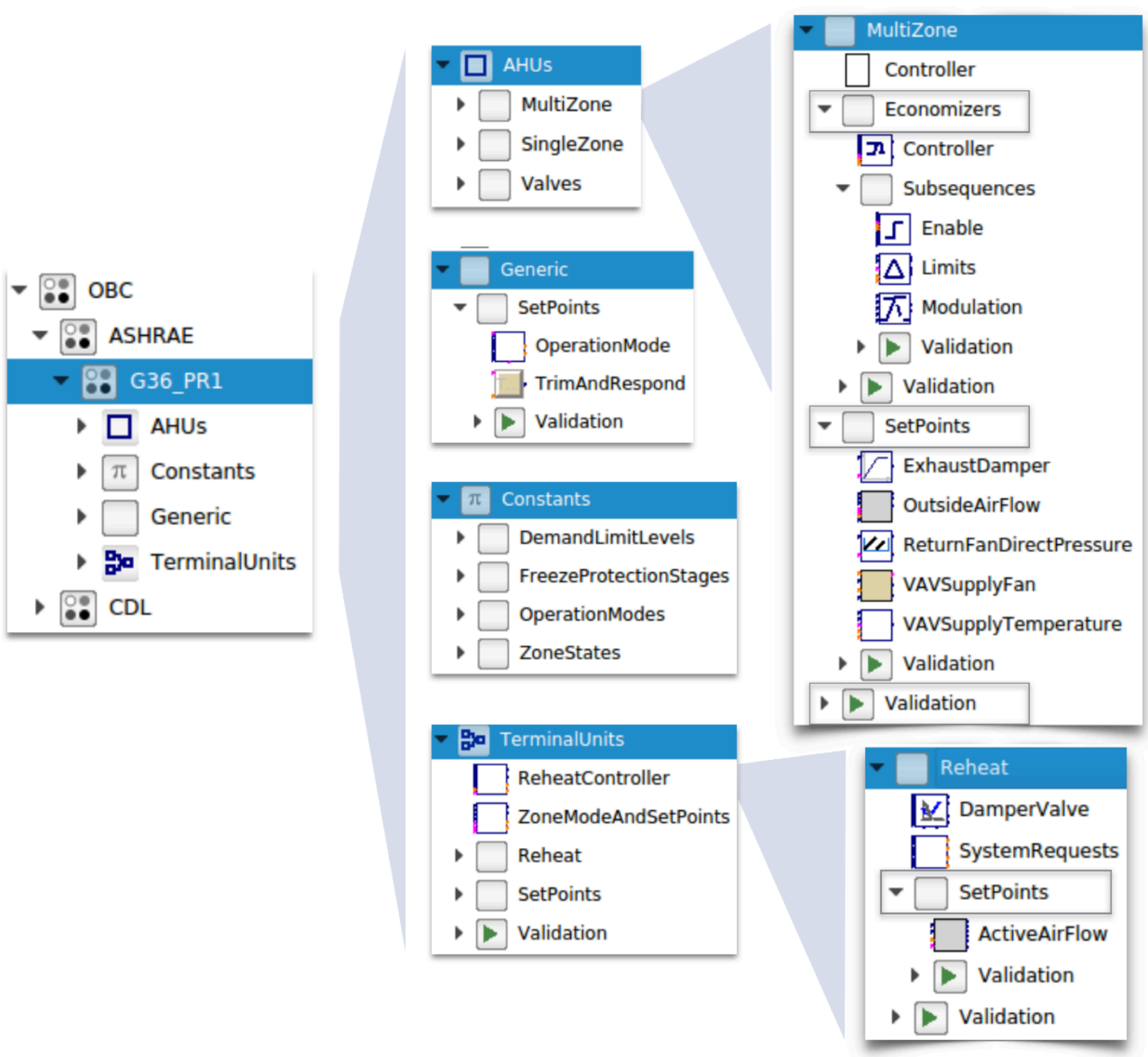
Control product line can use any language.



For implementation, can translate CDL to proprietary control product lines, or can use CDL natively



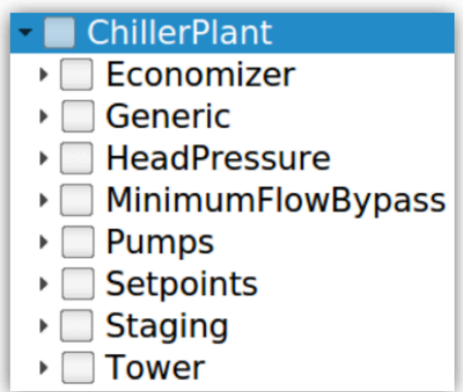
Library of Reference Sequence Implementations based on ASHRAE Guidelines

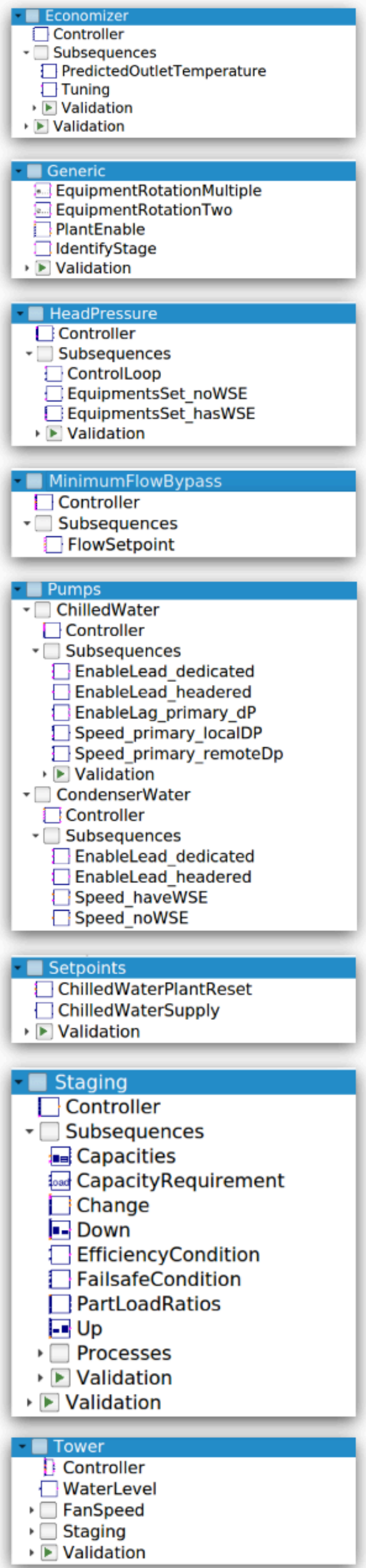


Source: Modelica Buildings Library

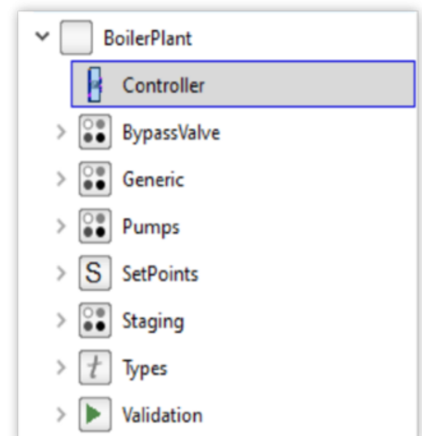
Library of Reference Sequence Implementations based on ASHRAE Guidelines

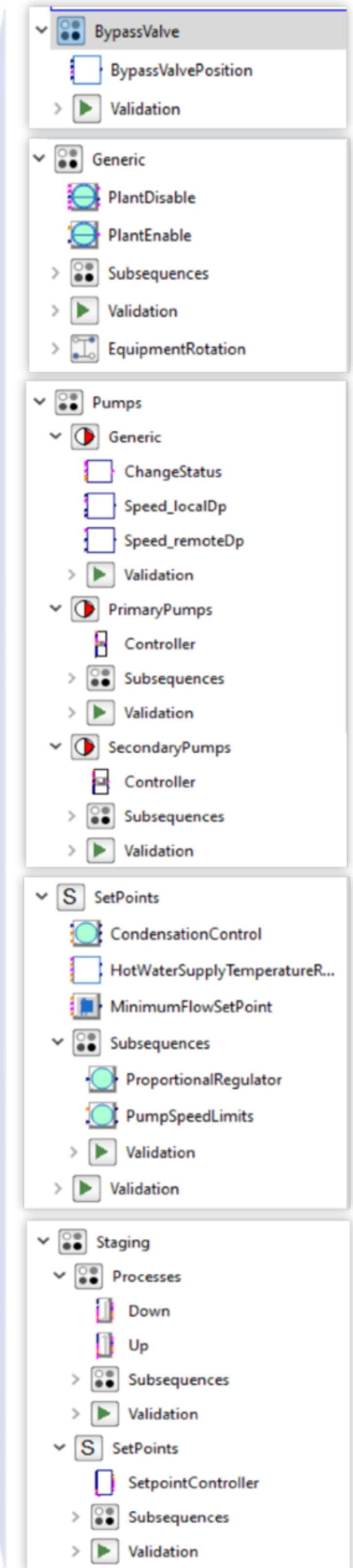
1711 Chiller Plant Control Sequences





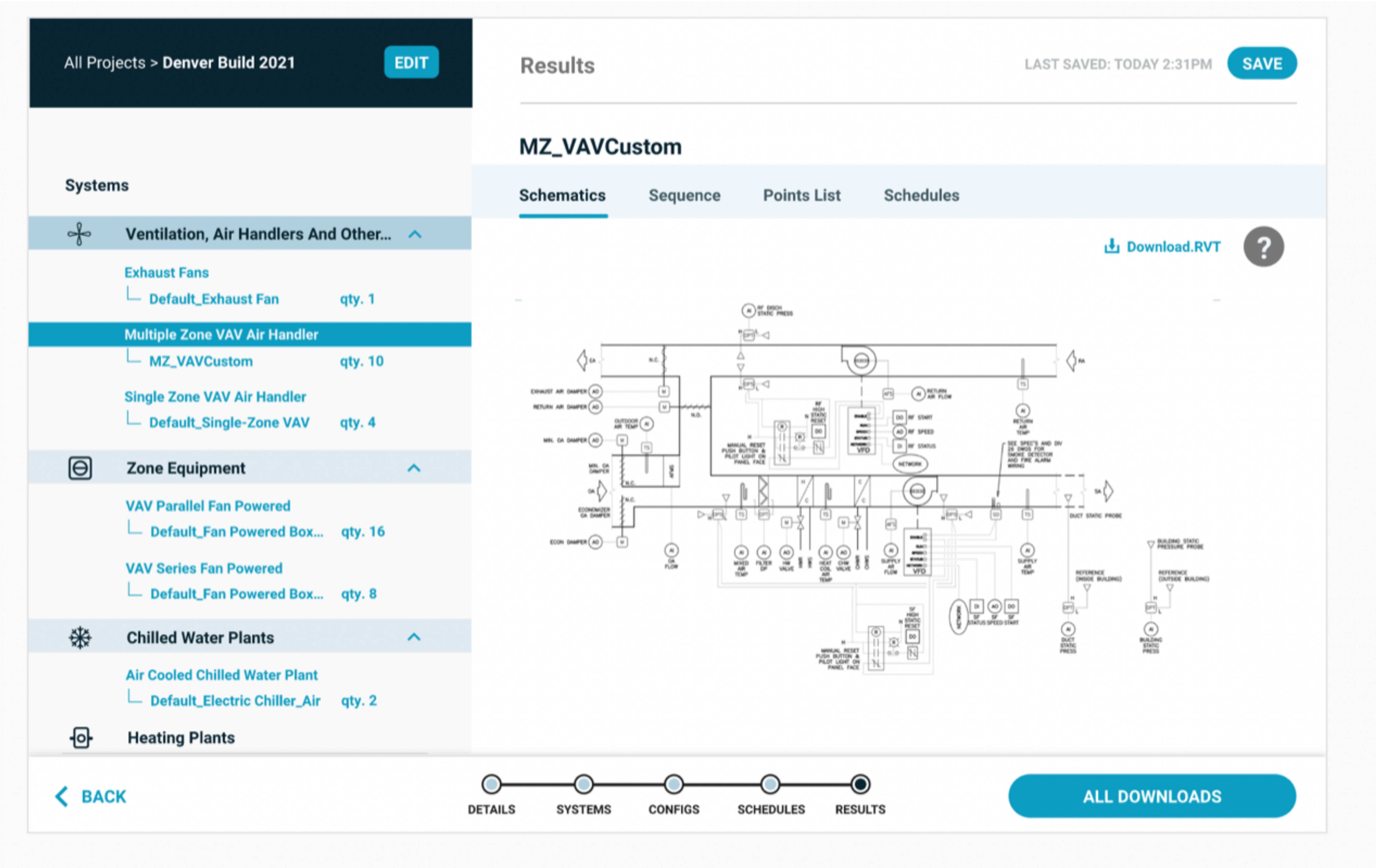
1711 Boiler Plant Control Sequences



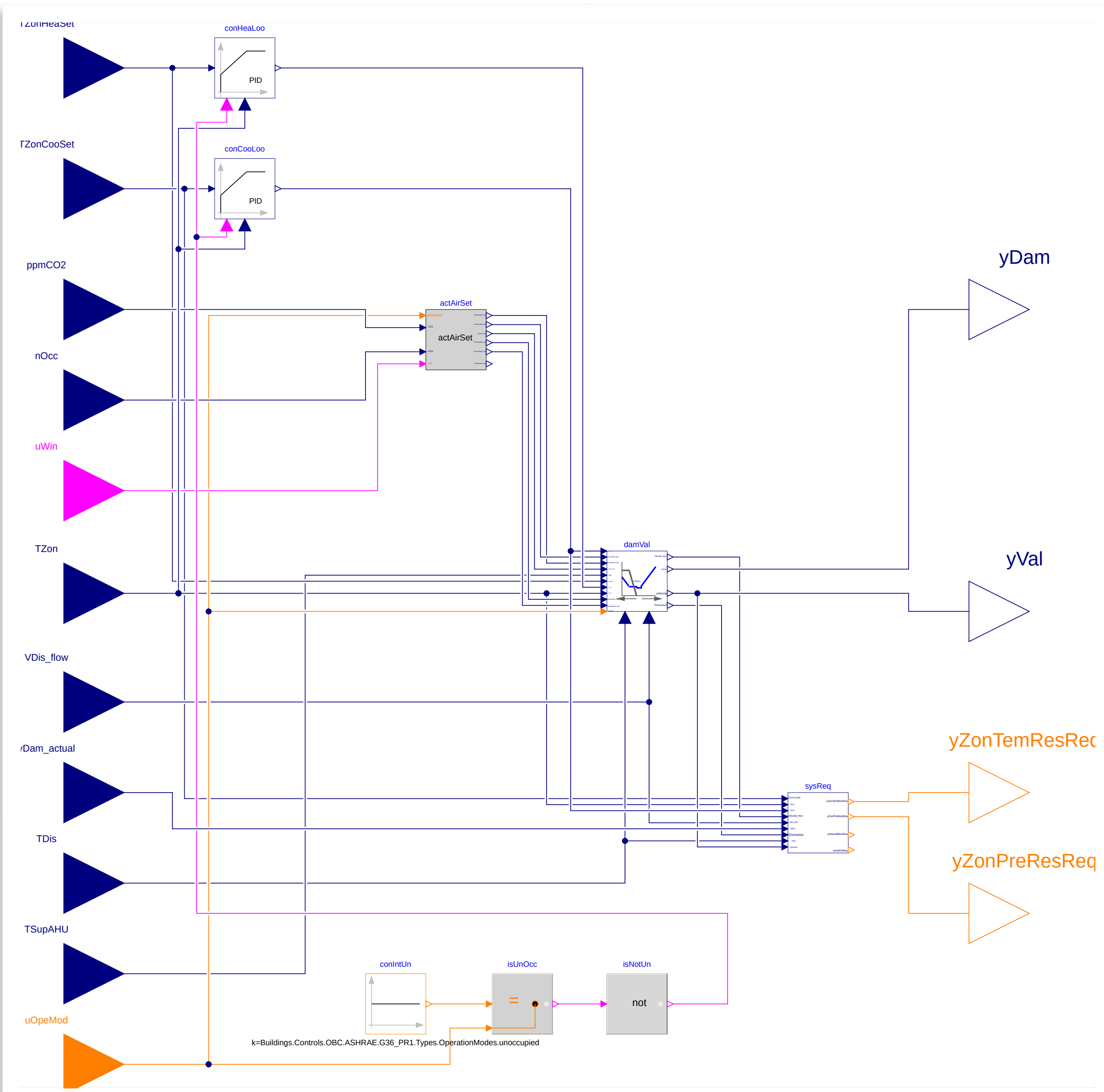


Source: Modelica Buildings Library

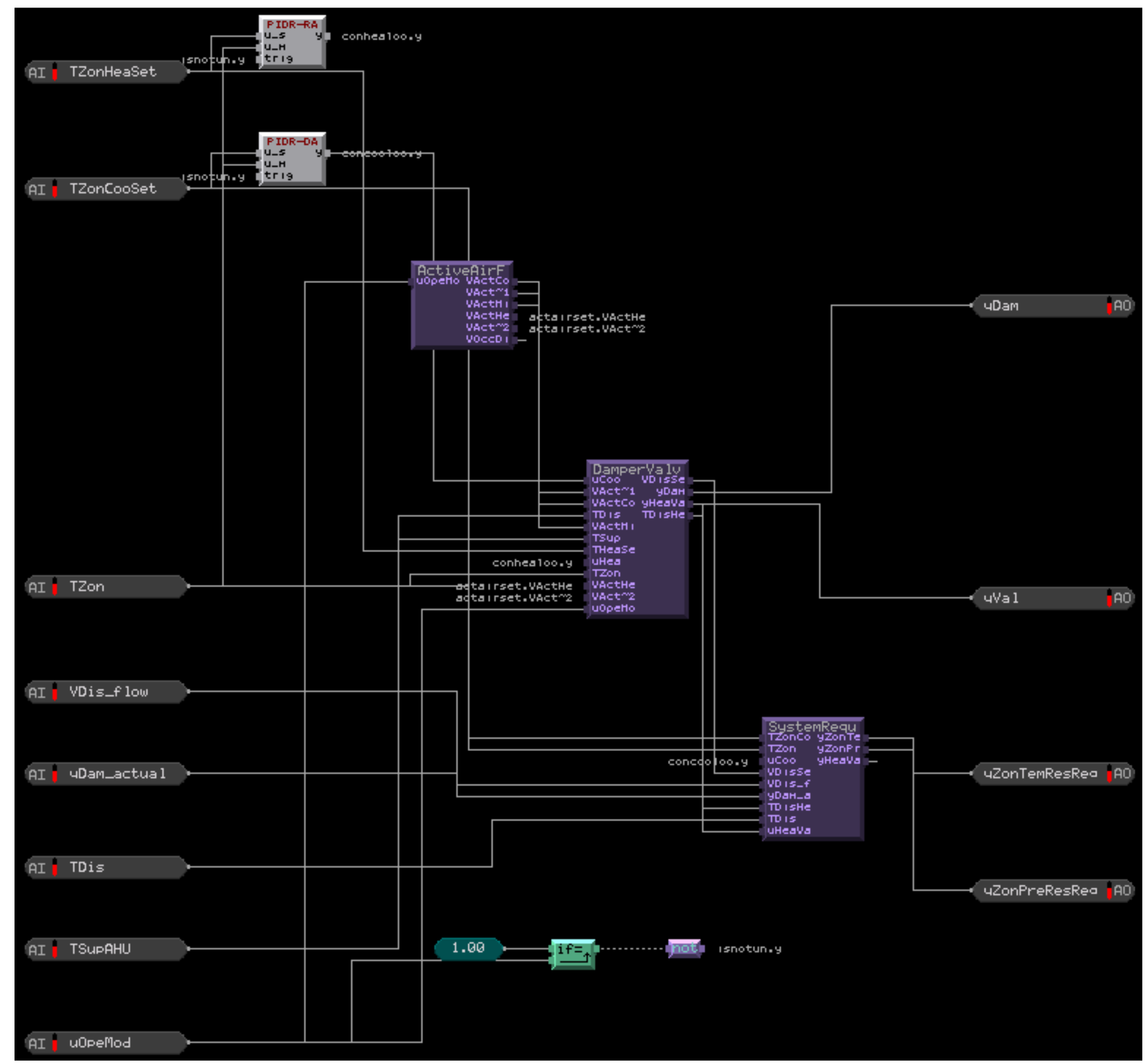
Sequence Selection and Configuration Tool “Linkage”



Prototype translation showed feasibility of translating Guideline 36 multi-zone VAV sequence to an existing control product line



Implementation in CDL



Translation to Automated Logic webCTRL

Summary

Overarching goal is to digitize control delivery to provide robust implementation of control sequences at scale.

- ASHRAE Standard 231P.
- Control repository
  - LBNL and PNNL are implementing sequences from ASHRAE Guideline 36 using CDL, and other sources.
  - Support for ASHRAE Guideline 36.
  - Expansion towards heat pump plants and systems with storage.
  - Spawn of EnergyPlus integration
- Sequence Selection and Configuration Tool
- Verification, in support of
  - Simulation Q&A
  - Commissioning agents
- Integration with
  - Other "advanced" methods such as MPC/RL.
  - Fault Detection and Diagnostics.
  - Semantic models.

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OpenBuildingControl: Digitizing the control delivery from building energy modeling to specification, implementation and formal verification

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ABSTRACT

The current process for specifying, installing and commissioning building control sequences is largely manual and based on ambiguous natural language specifications. It lacks a formal end-to-end quality control and it has been shown not to deliver high performance sequences at scale. While high-performance HVAC control sequences enable significant reductions in energy consumption, errors in implementing the control logic are common even for less advanced sequences. To improve this situation, we present a digitized building control delivery workflow with formal end-to-end verification, a Control Description Language for the digital specification of building control sequences within this workflow, and software tools that enable digitization of this process. Using the process and tools introduced here, mechanical designers can customize, test and improve these sequences within annual energy simulation, store them in a library for use in other projects, and export them for bidding. Control providers can implement the sequences on existing control product lines through code generation. Commissioning providers can formally verify whether as-installed sequences conform to the digital design specification that was exported by the mechanical designer. Moreover, control product development teams can use the reference implementations of these libraries within their product testing to ensure that their products reproduce the behavior of the reference implementations. This paper presents this process, the language and the supporting software, together with examples of all of the above steps. The presented work has given rise to a new proposed standard, ASHRAE 231P, that will allow digitizing the building control delivery process through the standardization of a control-vendor independent format for exchanging control logic that we pioneered through the here presented work.

1. Introduction

High performance building control sequences have been shown to significantly reduce energy consumption, with savings in the range of 23 %–30 % being common for most building types [11]. This requires control sequences to be properly designed and implemented. However, it also has been shown that in large commercial buildings with built-up HVAC systems, programming errors are the leading cause of control related problems [4]. The fact that control related problems are a key contributor to missed energy savings has been confirmed by a subsequent study from different authors, which identified in existing commercial buildings 481 operational issues. This study estimates the correction of control related problems to account for more than 75 % of the potential energy savings obtained in commissioning [9]. This energy savings potential is not surprising as today's process to specify, implement and verify control sequences is based on ambiguous and often incomplete English language specification of the controls intent that produces low quality implementations. Energy efficiency, occupant- and grid-responsiveness of control sequences are difficult to quantify and realize. As a result, the expected energy performance is often not achieved. This poses risks to building owners

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Questions?