UML Extensions: the SysML profile

Excerpts from Bran Selic (IBM) tutorial on UML & SysML (2007)

Charles ANDRE - UNSA

Rationale

Systems engineering typically involves complex combinations of diverse disciplines and technologies

- Difficult to understand
- Many integration problems

Modeling can alleviate many of these problems

- Raising the level of abstraction hides technological detail that can be confusing

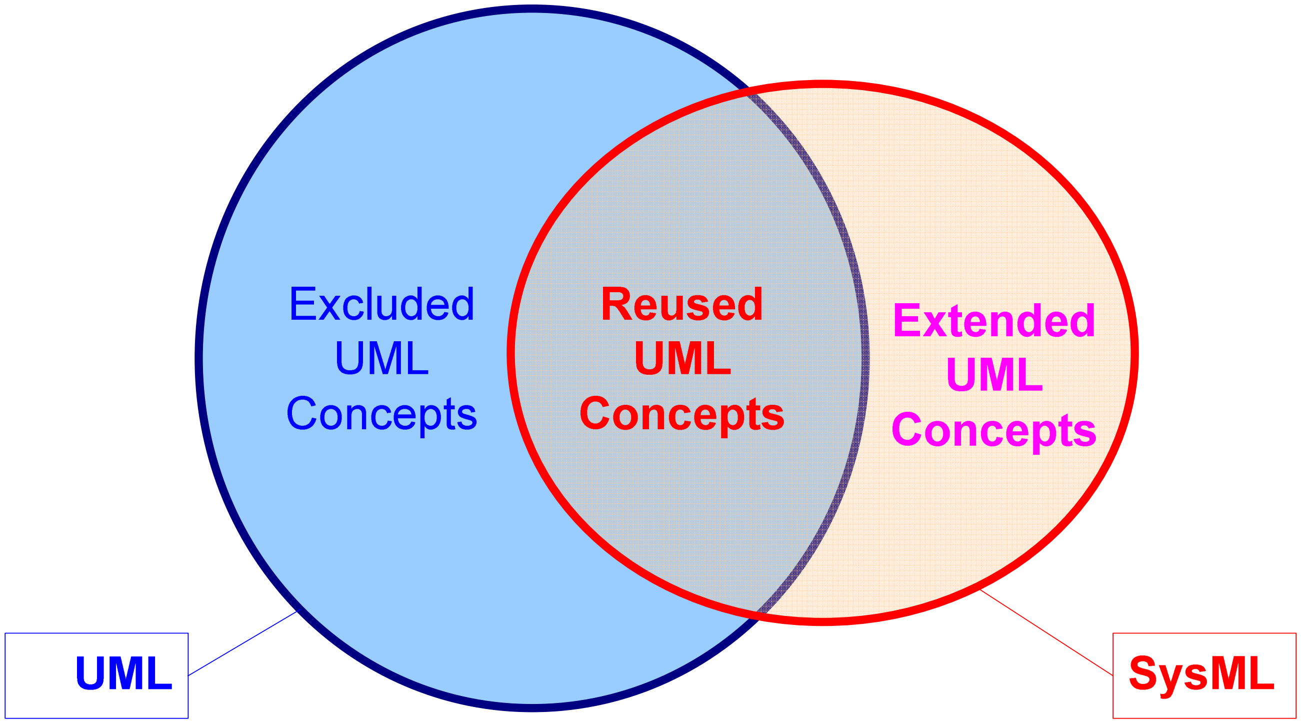
Why a UML profile?

- Reuse of widely-available UML expertise
- Reuse of UML tooling

UML 2 and SysML

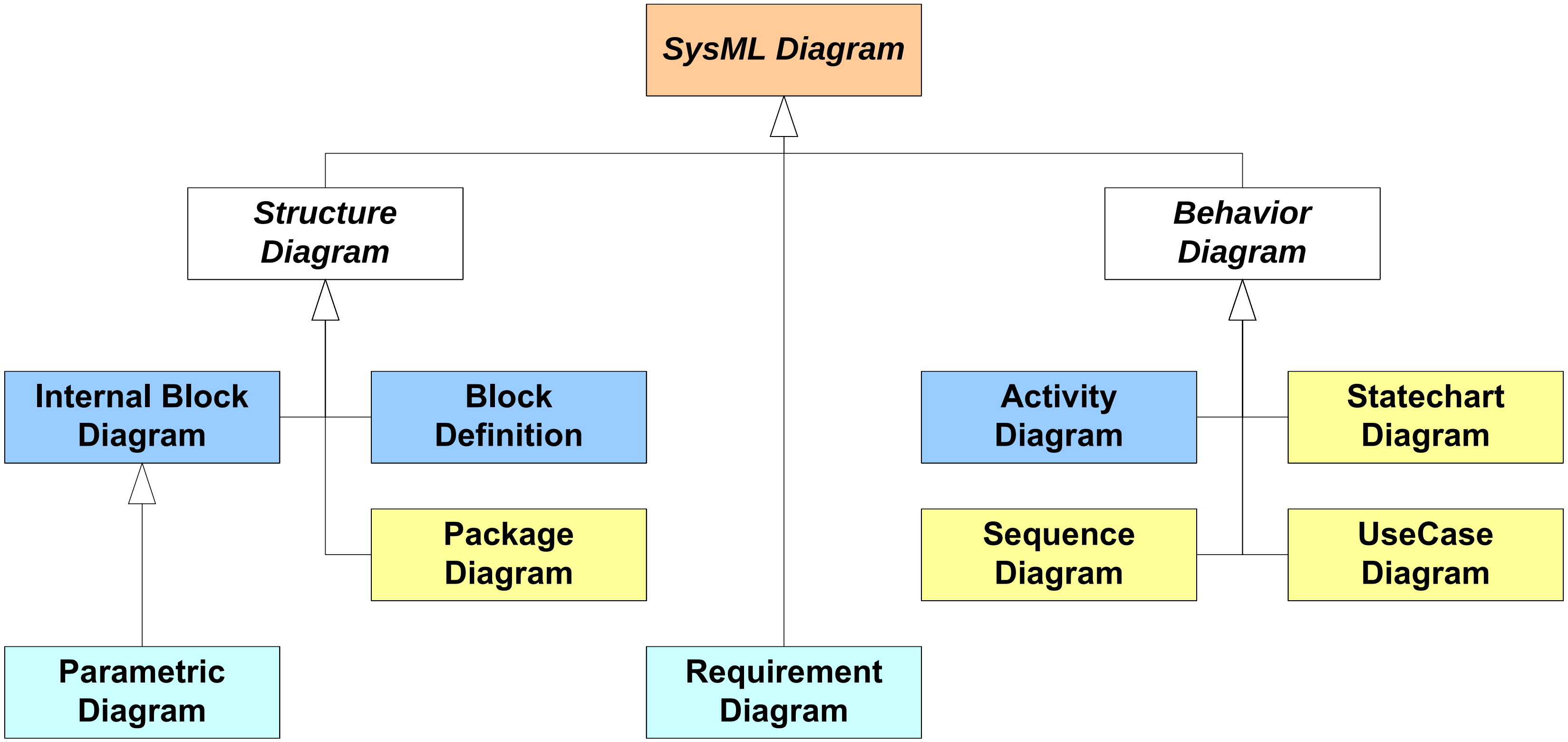
Uses a subset of UML concepts

- Simplified language
- Provides SE-specific customization of certain UML concepts
- However, it is possible to combine the excluded concepts if desired



SysML Diagram Types

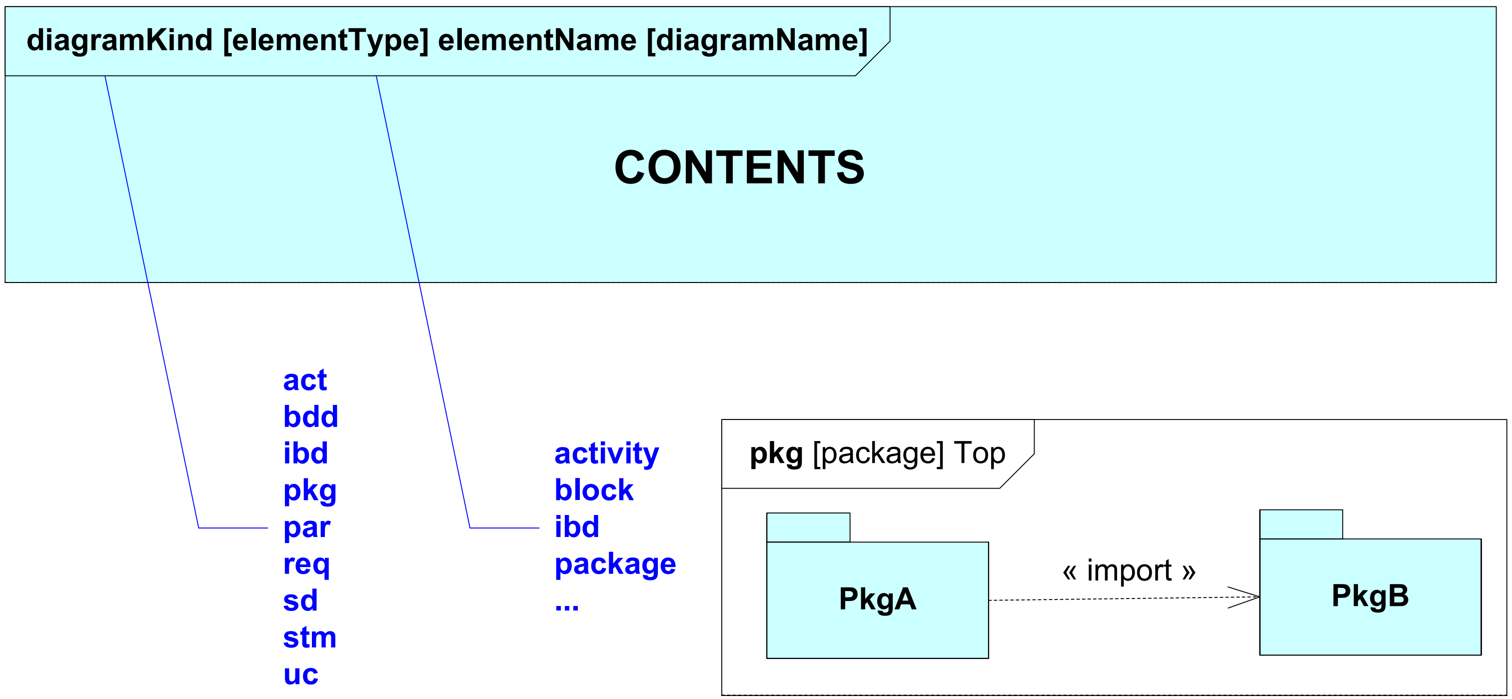
Some UML diagrams were modified , others omitted, and new SysMLspecific diagrams added



SysML Diagram format

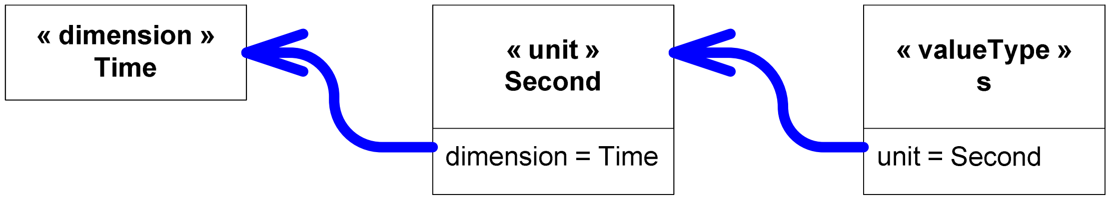
Simpler and more systematic approach than UML

– All diagrams have a common format



Defining & Specifying Physical Quantities

- Using *value types*
  - e.g. a delay expressed in seconds: timeDelay : s
- ValueType is a specialization of the UML DataType concept and has
  - a dimension and
  - a unit:

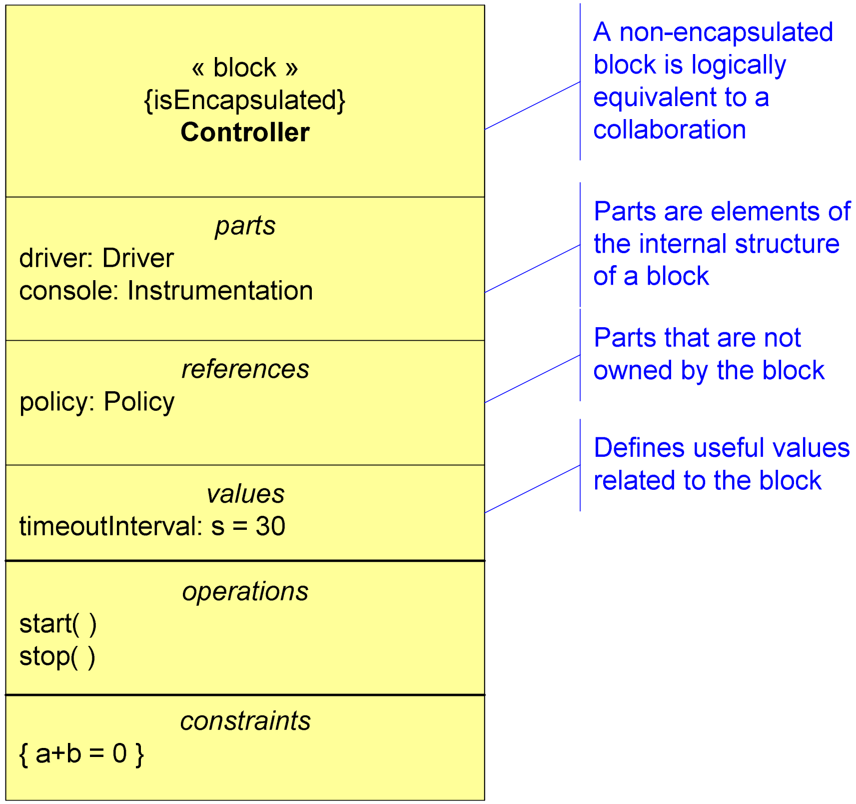


Pre-defined units

- **Time**
- **Length**
- **Mass**
- **Power**
- **…**

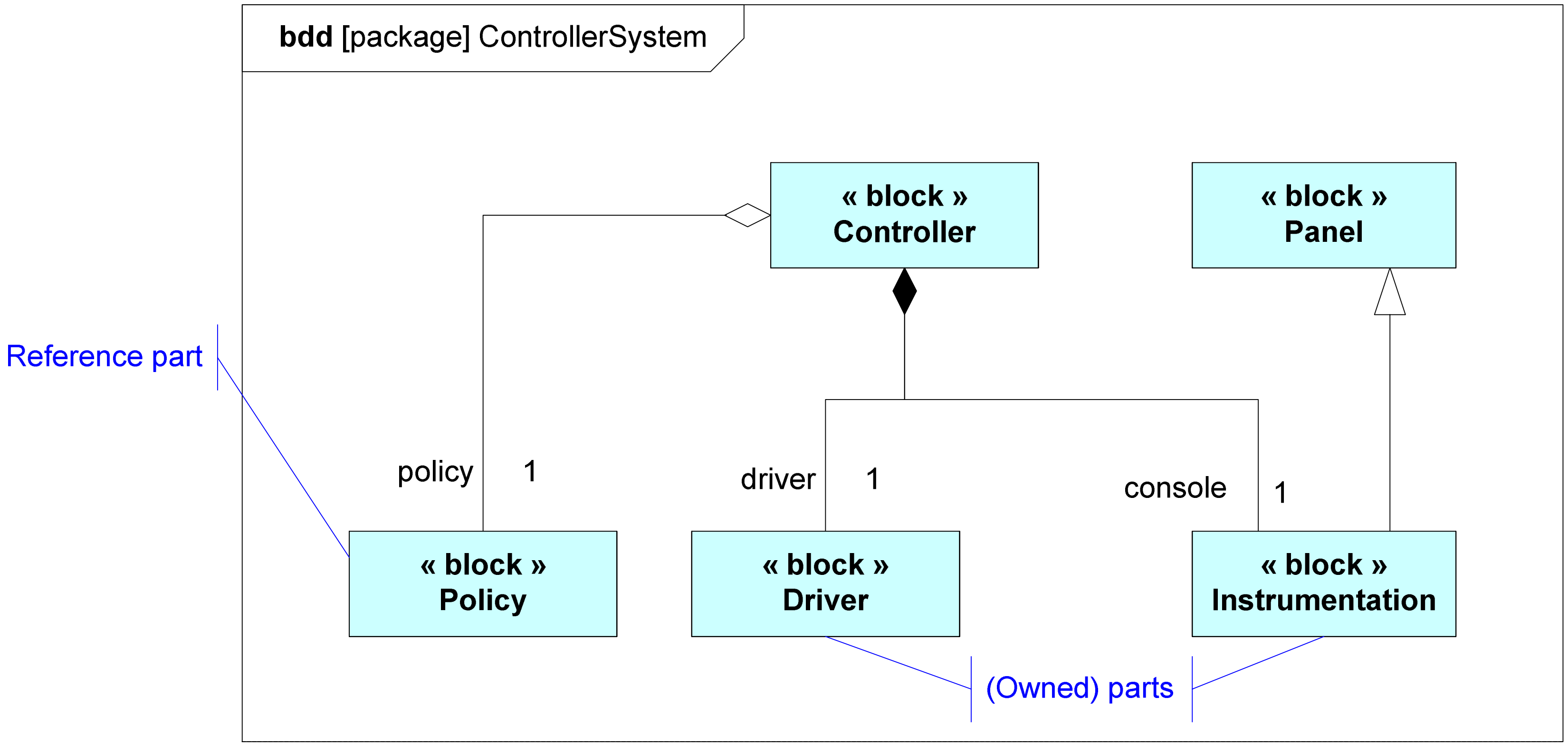
SysML Blocks

- *Block* = a unifying SysML concept that unifies the UML Class and Collaboration concepts into a concept more familiar to systems engineers
- Models:
  - Hardware
  - Software
  - Data
  - Facilities
  - Physical entities
  - etc.

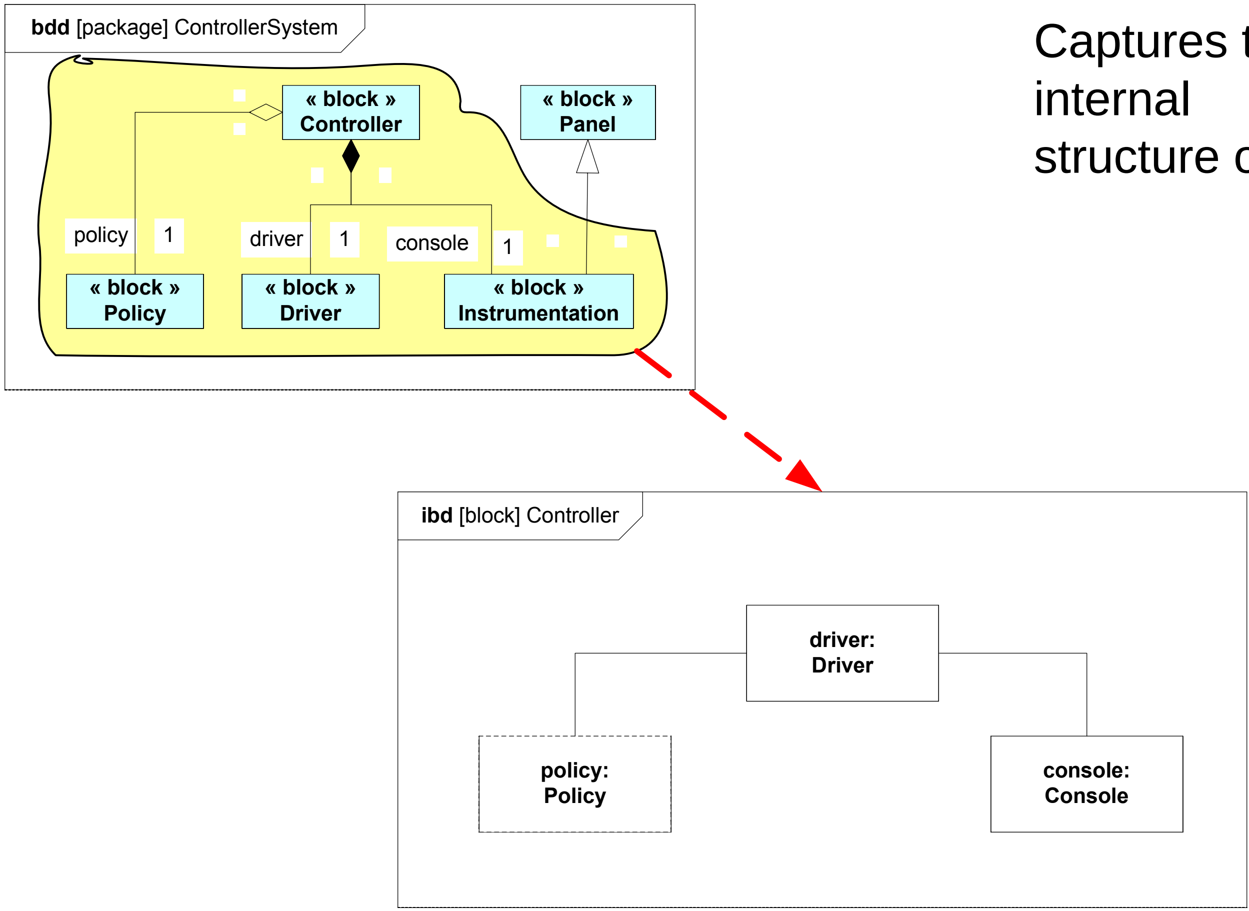


Block Definition Diagrams (bdd)

- Play the same role as UML Class diagrams



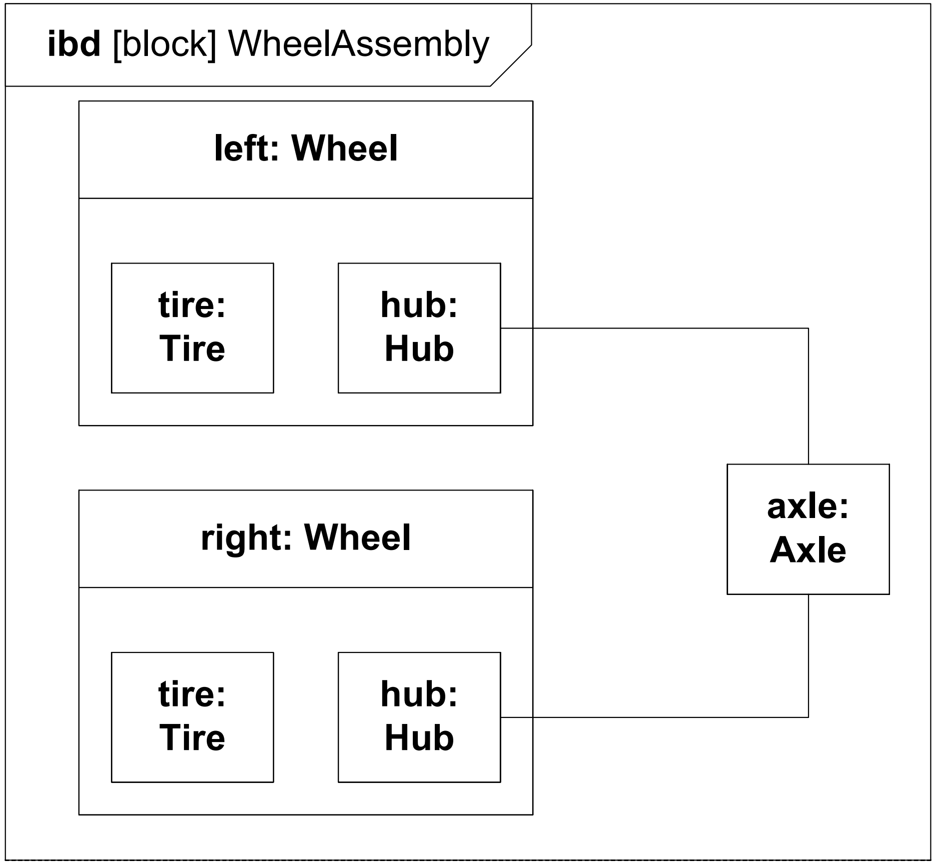
Internal Block diagram (ibd)



Captures the internal structure of a block

Nested Connectors

- Connectors that reach inside a non-encapsulated block instance



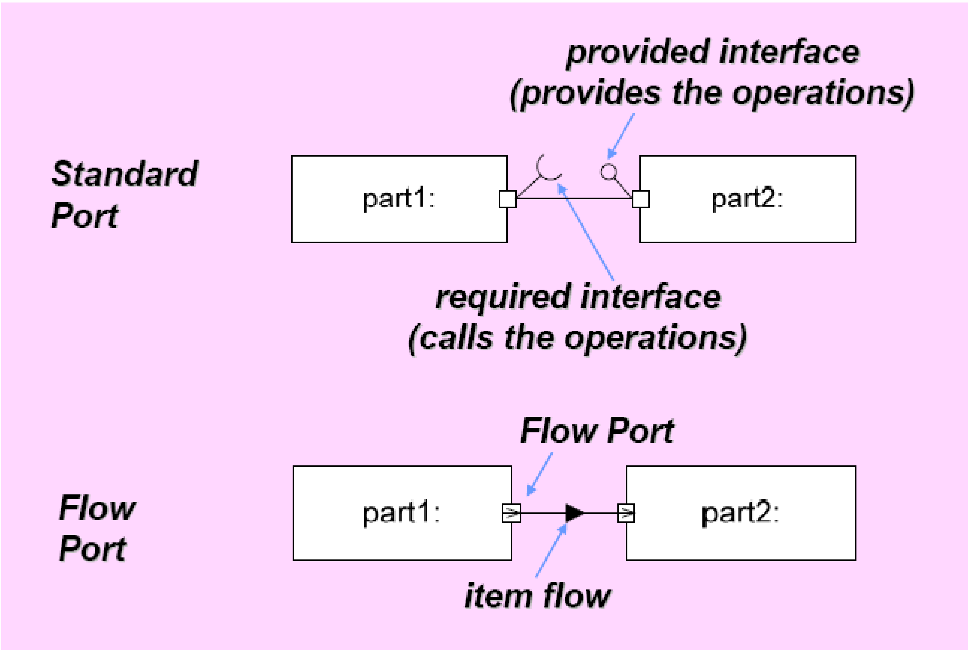
SysML Ports and Flows

Two kinds:

- Standard ports = UML ports
- Flow ports = support the transfer of *flows*

A flow models a *streaming* phenomena (energy, liquids, electrical currents, data streams, etc,)

- Flows have a *direction* relative to a block



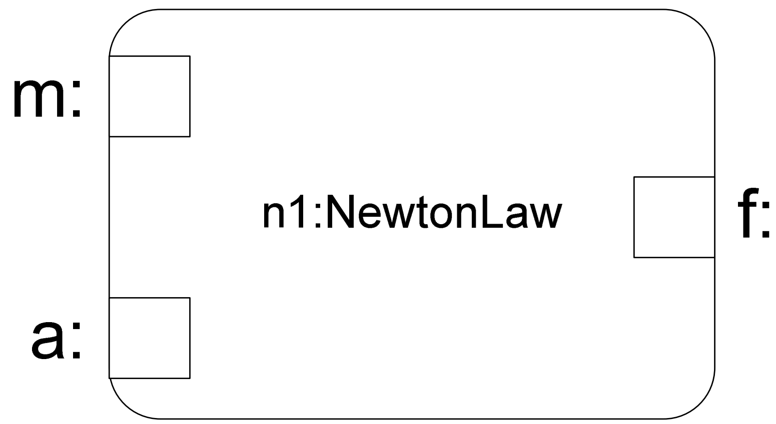
SysML Parametrics

- Specify relationships (equations) between value properties
  - Used for engineering analysis
  - Have a block-like syntax
- *Constraint blocks* define a constraint and identify its parameters

« constraint »
NewtonLaw

constraints
{ f = m*a }

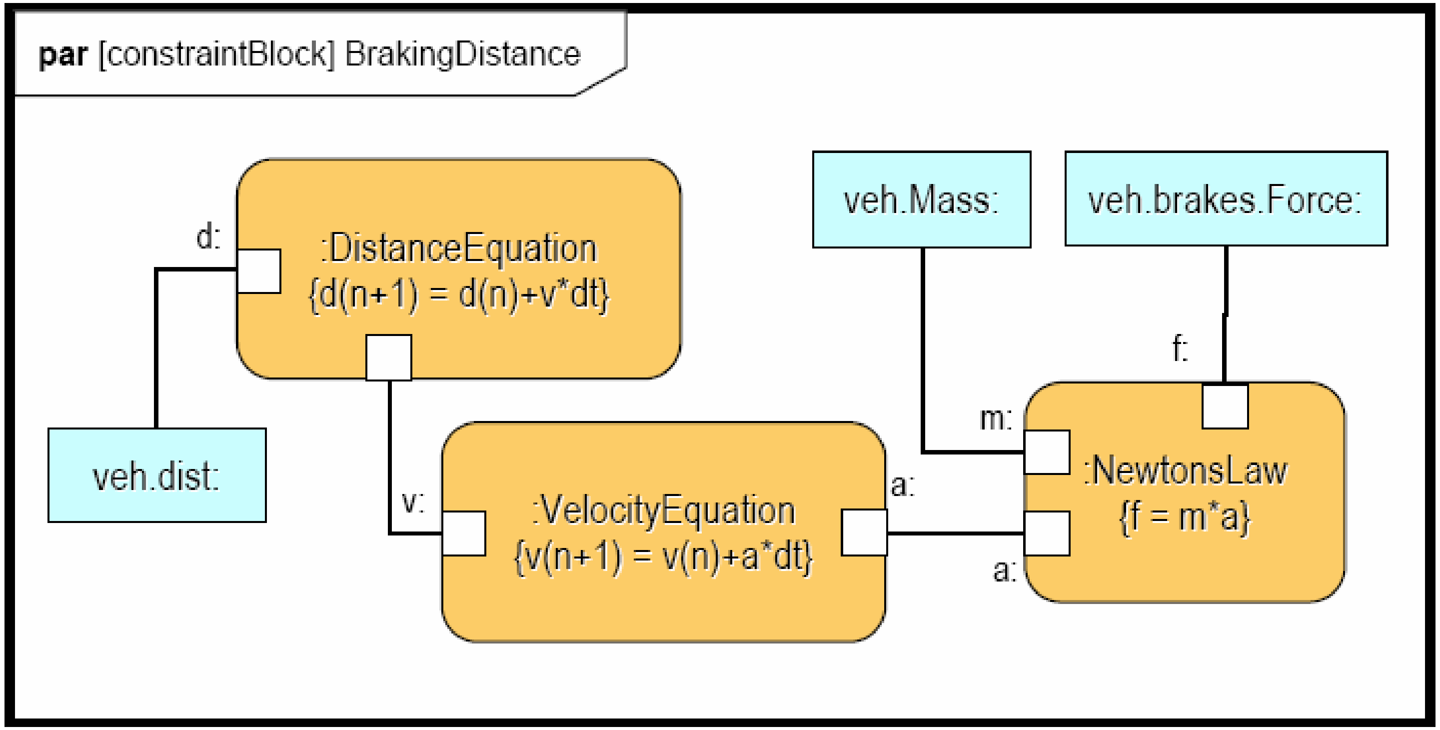
parameters
m: Mass
a: Acceleration
f: Force



An occurrence of the constraint

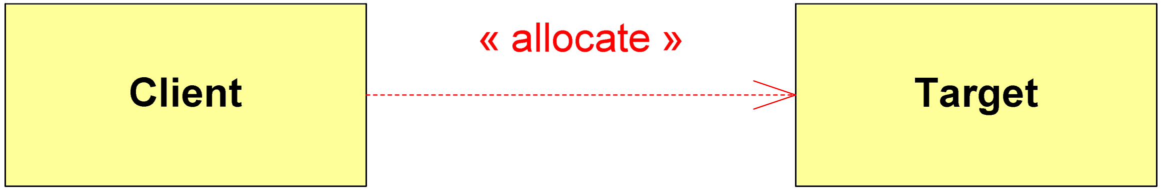
Parametrics Diagram

Used for engineering analysis



SysML Allocation

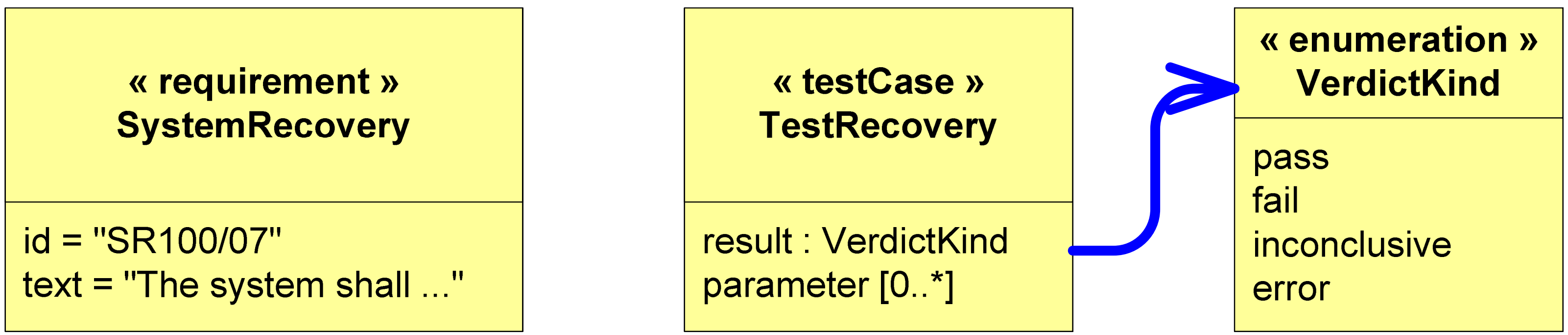
- Mapping of a set of (client) elements in a model to another (target) element



- An abstract concept with many potential interpretations
  - The target element is an implementation of the client elements
  - The client element is an abstract representation of the target
  - The target is the hardware on which the client software is deployed
  - The target is responsible for the behavior represented by the client
  - etc.

SysML Requirements Modeling

- Requirements represent an important and dynamic element of system engineering
  - SysML provides a set of modeling concepts and relationships for capturing requirements and their relationships to other system engineering artifacts
  - Complement to use case modeling
- Basic concepts:

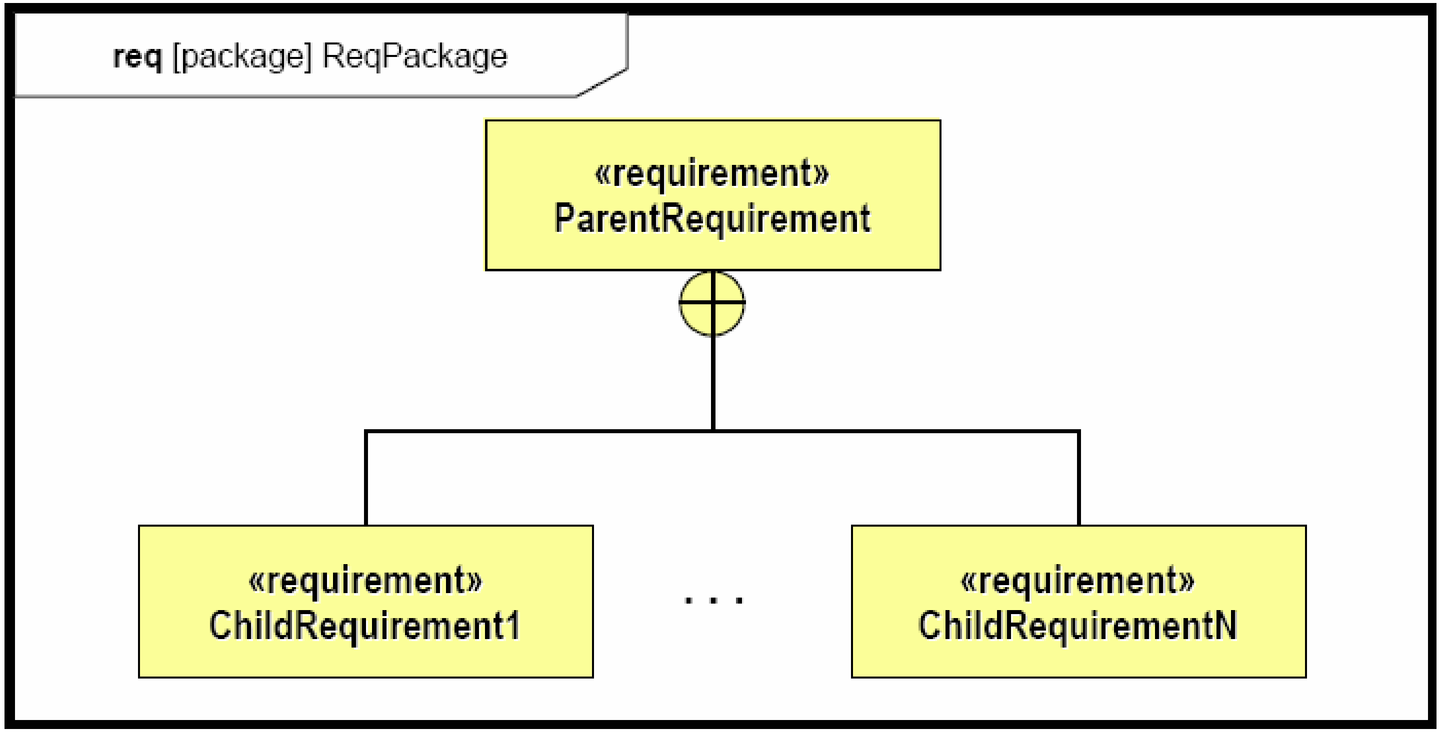


Requirement

TestCase

Hierarchical Requirements

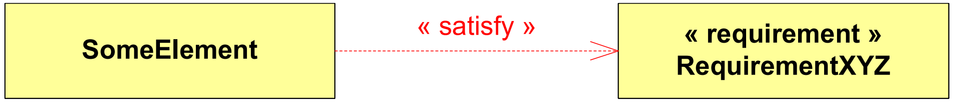
For decomposing complex requirements into sub-requirements



Requirements Relationships

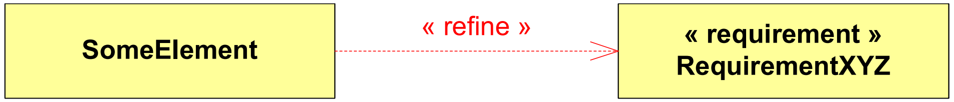
Derivation

Satisfaction

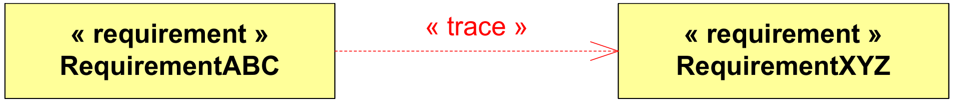


Verification

Refinement



Trace



References

OMG SysML website

http://www.omgsysml.org

OMG Systems Modeling Language, v1.0

http://www.omg.org/cgi-bin/doc?formal/2007-09-01

SysML tutorial

Sanford Friedenthal, Alan Moore, Rick Steiner

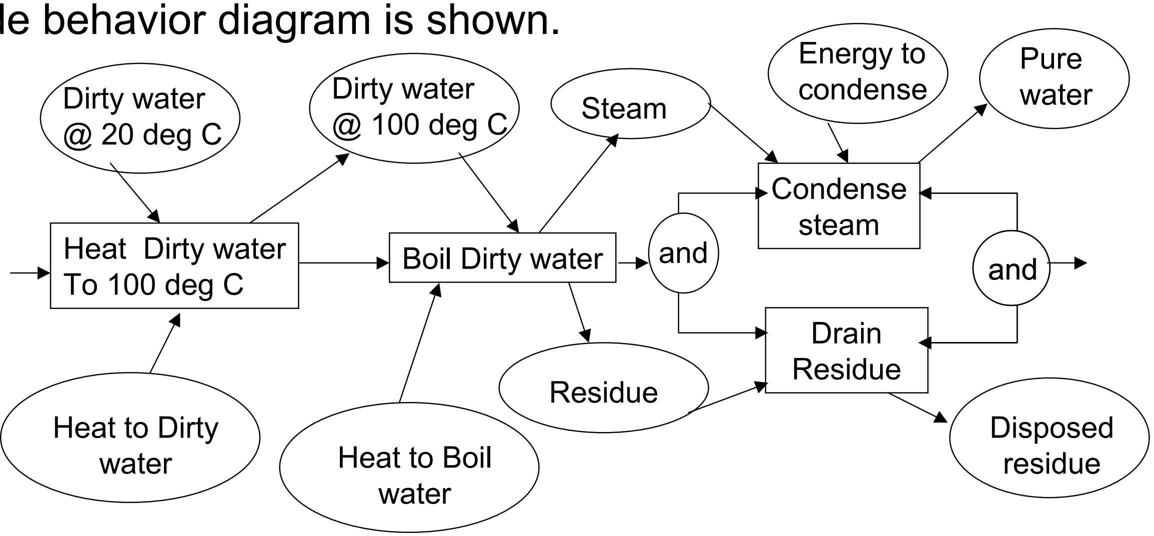
OMG Systems Modeling Language Tutorial

Incose 2007, San Diego, June 2007

Distiller Sample Problem

Distiller Problem Statement

- The following problem was posed to the SysMLteam in Dec ’05 by D. Oliver:
- Describe a system for purifying dirty water.
  - Heat dirty water and condense steam are performed by a Counter Flow Heat Exchanger
  - Boil dirty water is performed by a Boiler
  - Drain residue is performed by a Drain
  - The water has properties: vol = 1 liter, density 1 gm/cm3, temp 20 deg C, specific heat 1cal/gm deg C, heat of vaporization 540 cal/gm.
- A crude behavior diagram is shown.

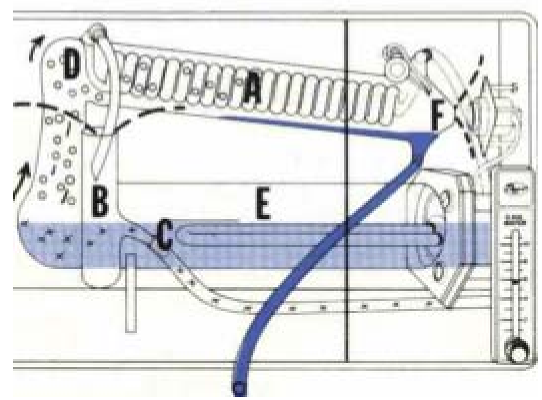


What are the real requirements?
How do we design the system?

Distiller Types

Batch Distiller

Continuous Distiller

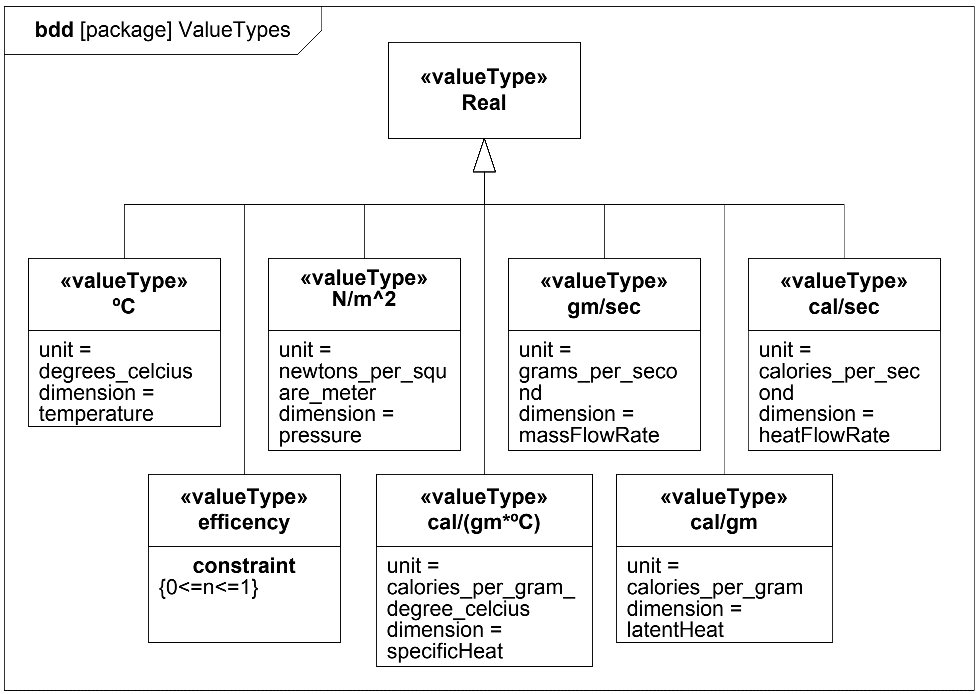


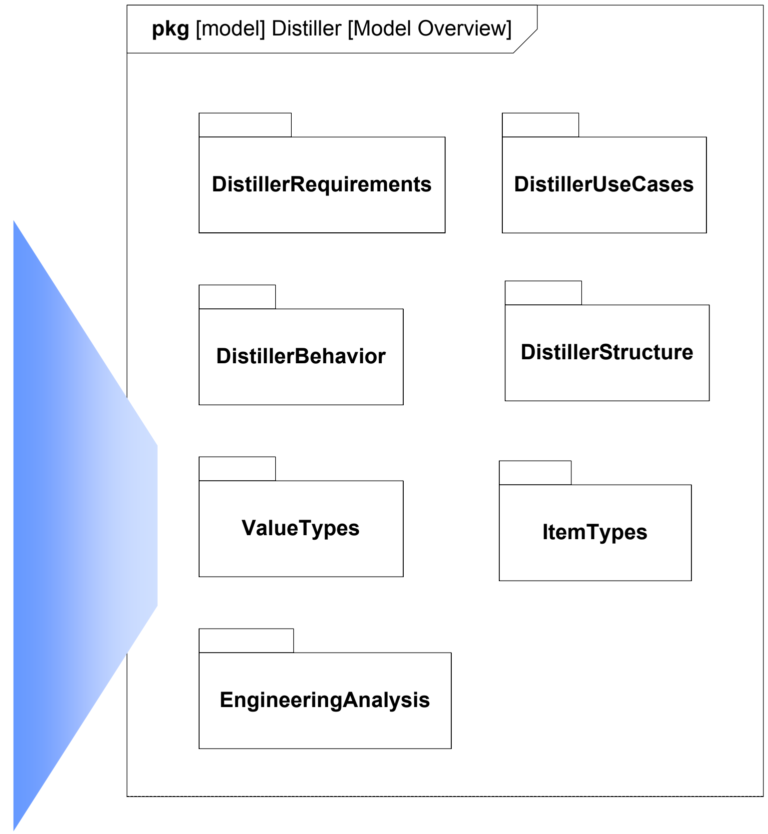
Note: Not all aspects of the distiller are modeled in the example

Distiller Problem – Process Used

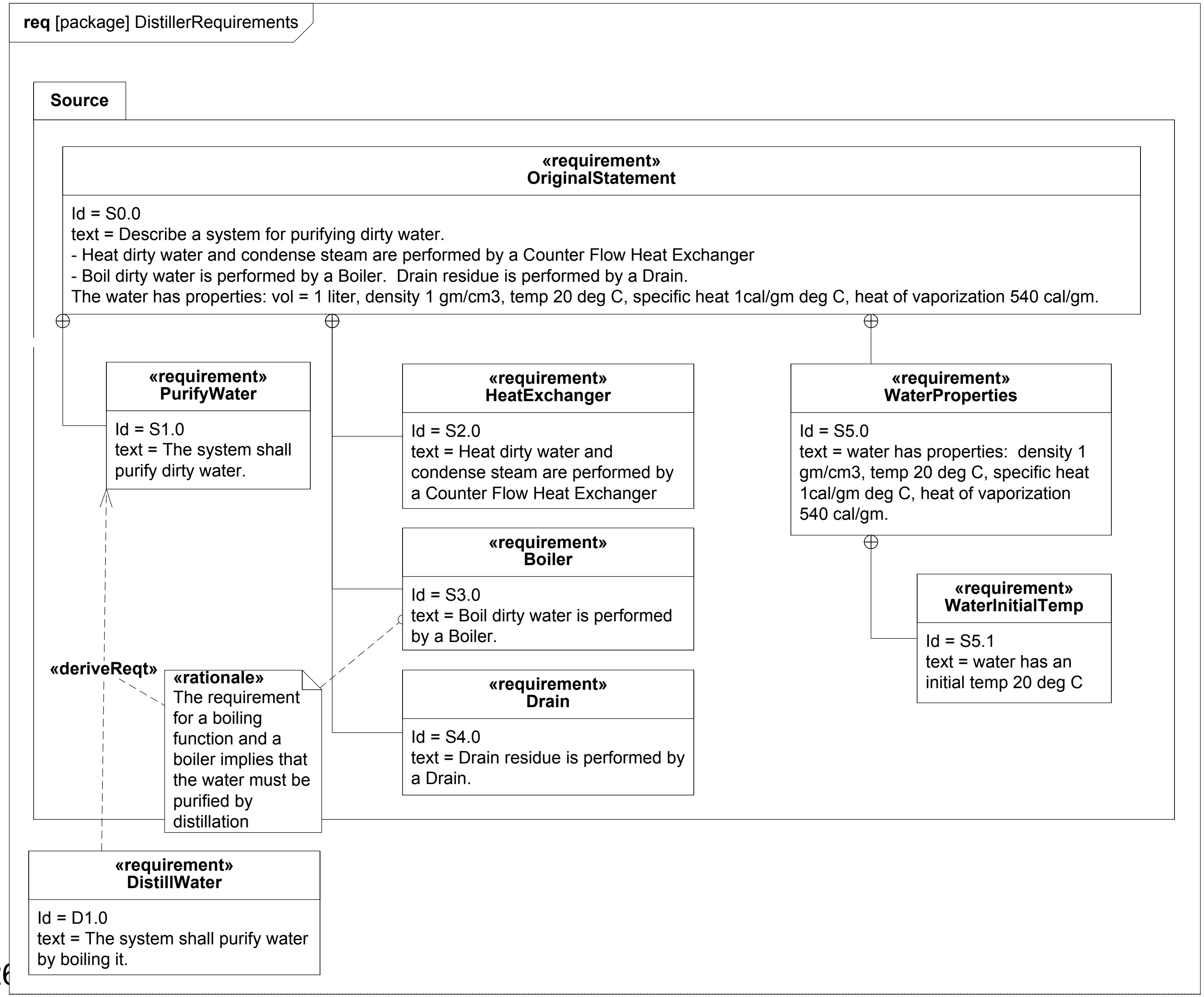
- Organize the model, identify libraries needed
- List requirements and assumptions
- Model behavior
  - In similar form to problem statement
  - Elaborate as necessary
- Model structure
  - Capture implied inputs and outputs
    - segregate I/O from behavioral flows
  - Allocate behavior onto structure, flow onto I/O
- Capture and evaluate parametric constraints
  - Heat balance equation
- Modify design as required to meet constraints
- Model the user interaction
- Modify design to reflect user interaction

Distiller Problem – Package Diagram: Model Structure and Libraries





Distiller Example Requirements Diagram



Distiller Example: Requirements Tables

table [requirement] OriginalStatement [Decomposition of OriginalStatement]

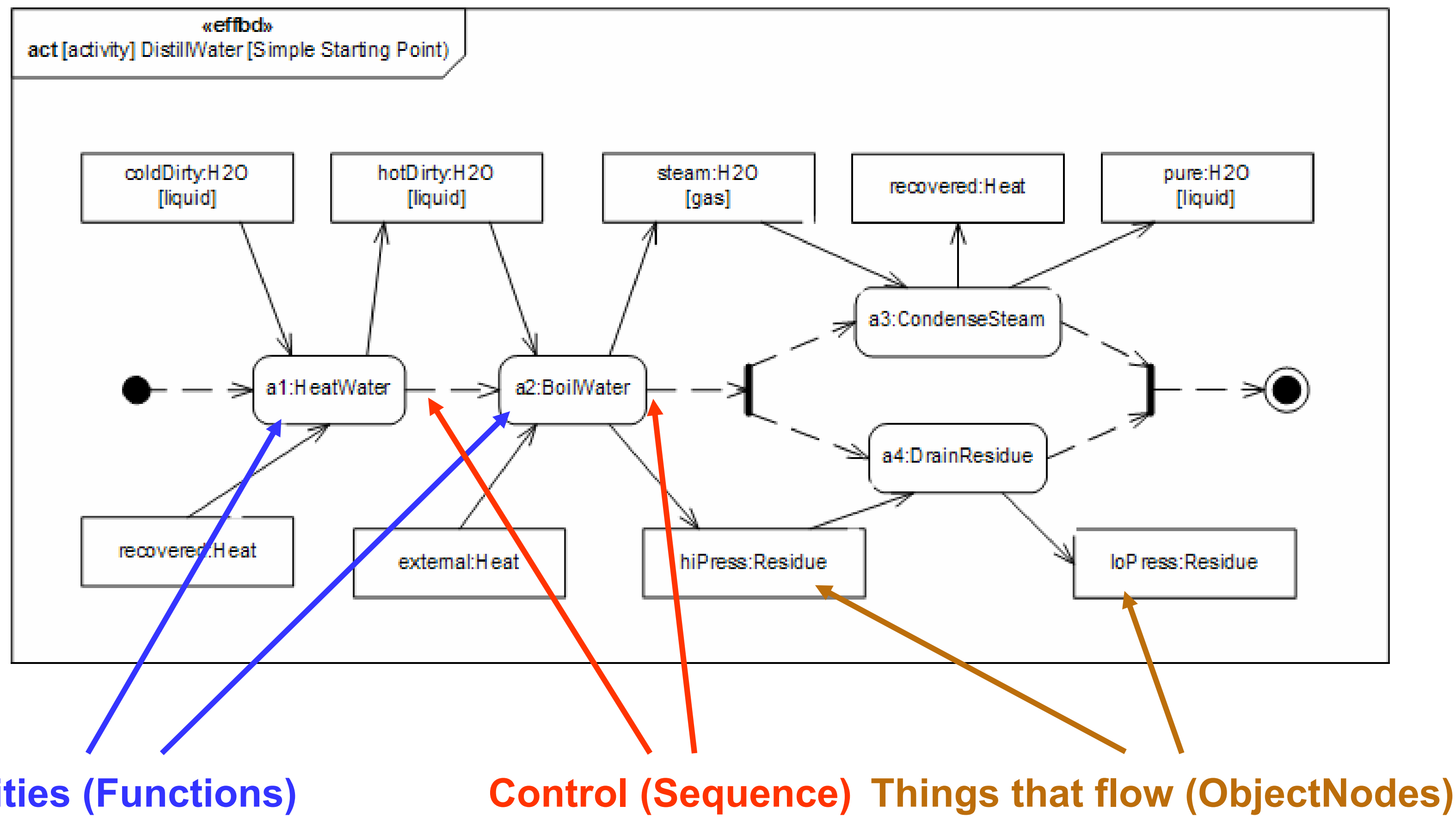
id	name	text
S0.0	OriginalStatement	Describe a system for purifying dirty water. …
S1.0	PurifyWater	The system shall purify dirty water.
S2.0	HeatExchanger	Heat dirty water and condense steam are performed by a …
S3.0	Boiler	Boil dirty water is performed by a Boiler.
S4.0	Drain	Drain residue is performed by a Drain.
S5.0	WaterProperties	water has properties: density 1 gm/cm3, temp 20 deg C, …
S5.1	WaterInitialTemp	water has an initial temp 20 deg C

table [requirement] PurifyWater [Requirements Tree]

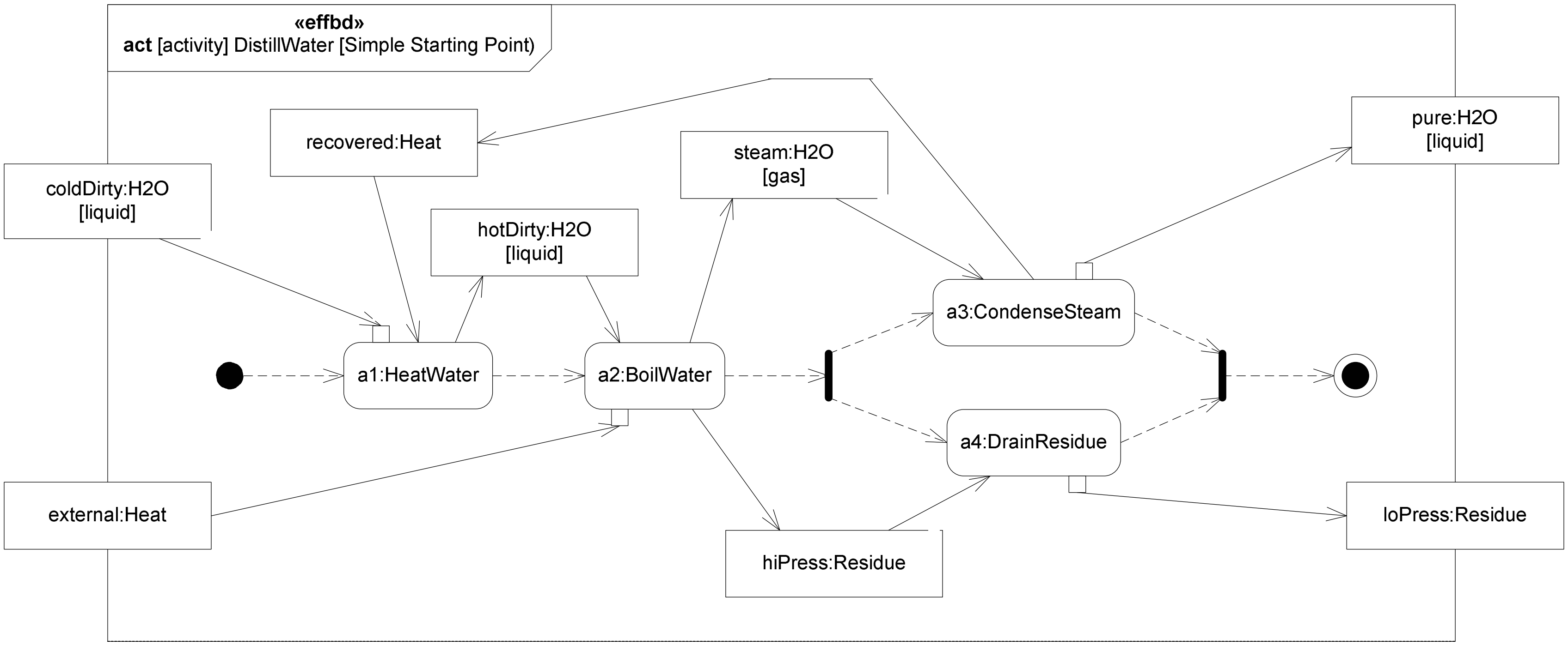
id	name	relation	id	name	Rationale
S1.0	PurifyWater	deriveReqt	D1.0	DistillWater	The requirement for a boiling function and a boiler implies that the water must be purified by distillation

Distiller Example – Activity Diagram: Initial Diagram for DistillWater

- This activity diagram applies the SysML EFFBD profile, and formalizes the diagram in the problem statement.



Distiller Example – Activity Diagram: Control-Driven: Serial Behavior

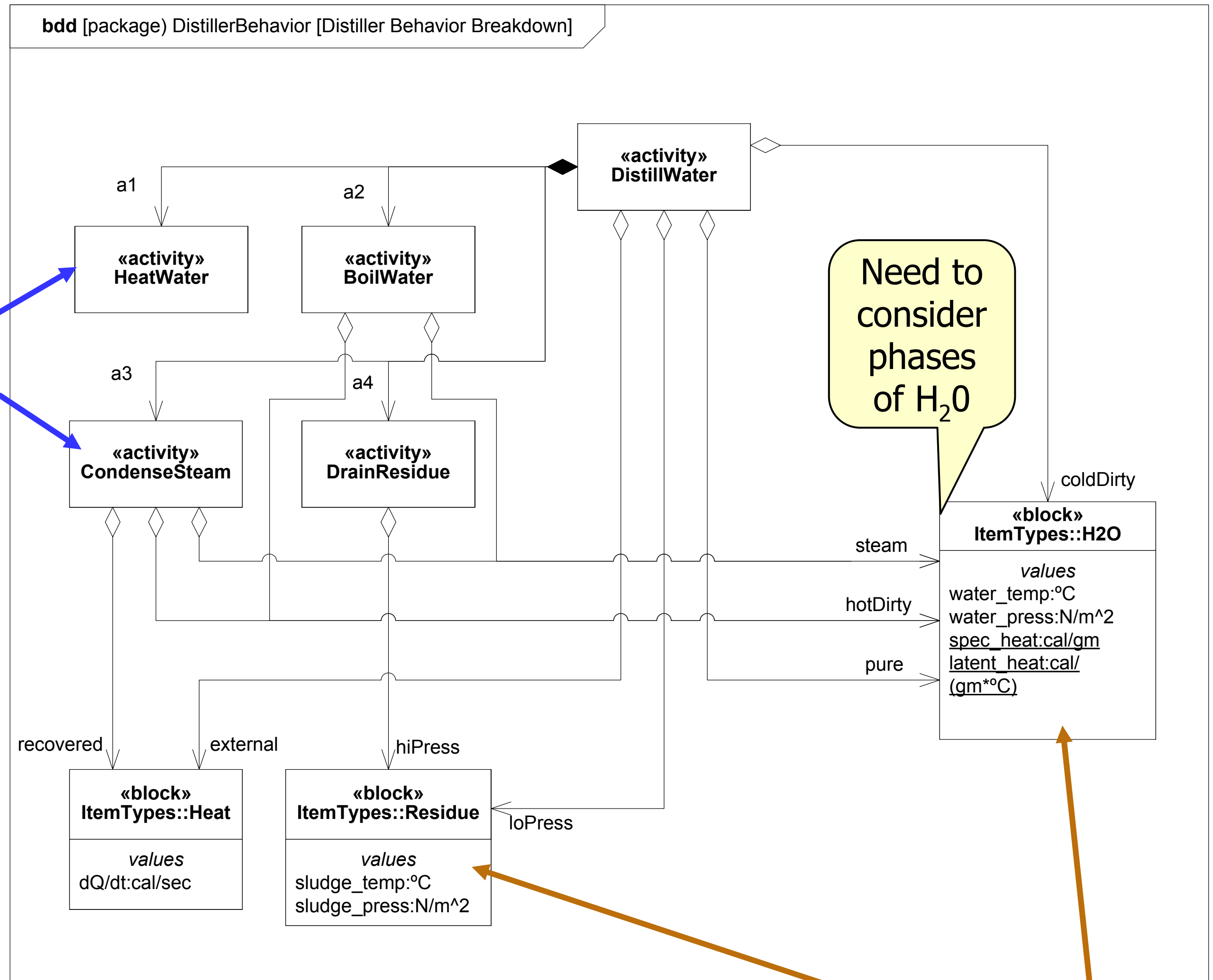


Continuous Distiller Here

Batch Distiller

Distiller Example – Block Definition Diagram: DistillerBehavior

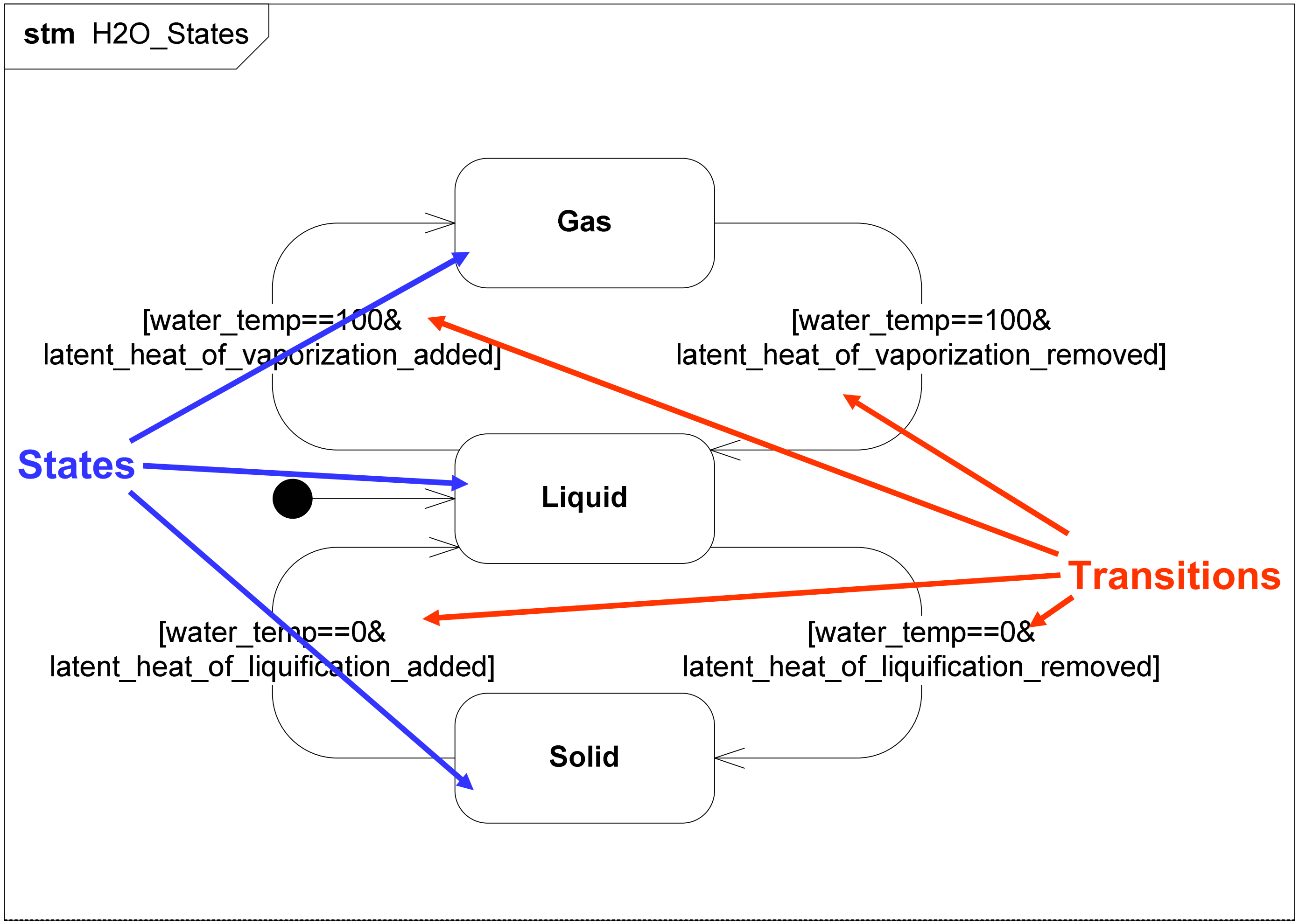
Activities (Functions)



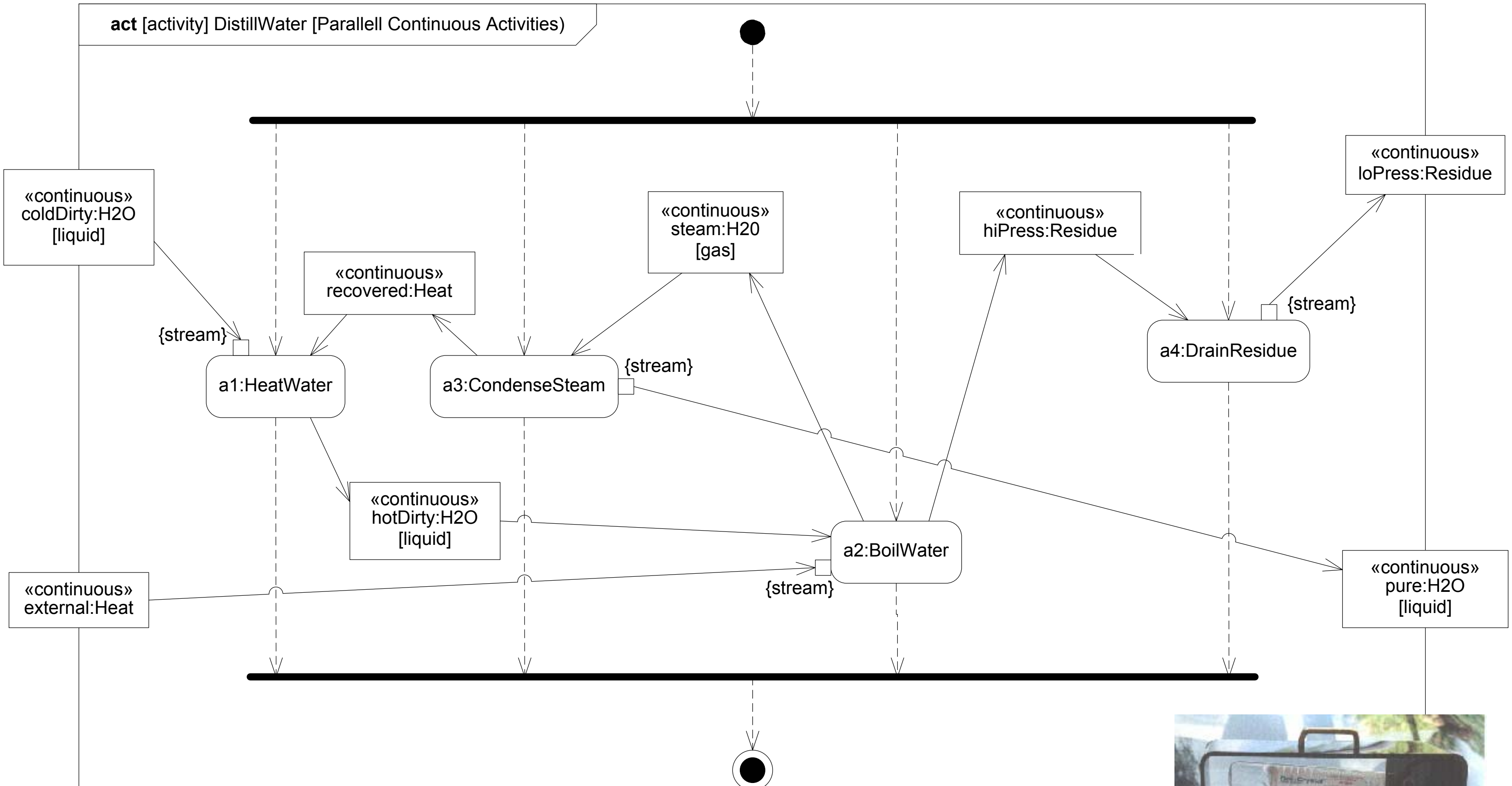
Control (not shown on BDD)

Things that flow (ObjectNodes)

Distiller Example – State Machine Diagram: States of H2O



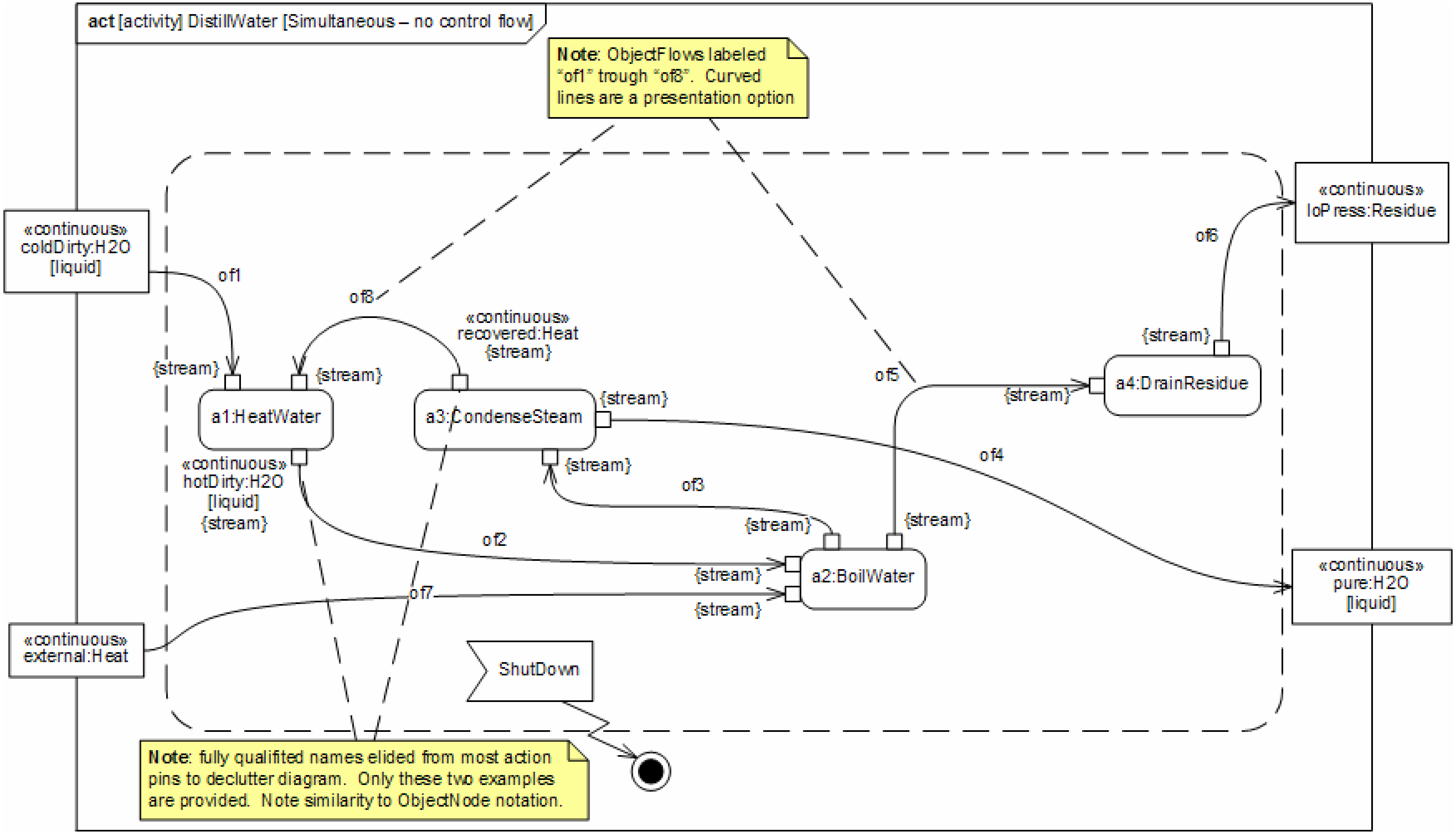
Distiller Example – Activity Diagram: I/O Driven: Continuous Parallel Behavior



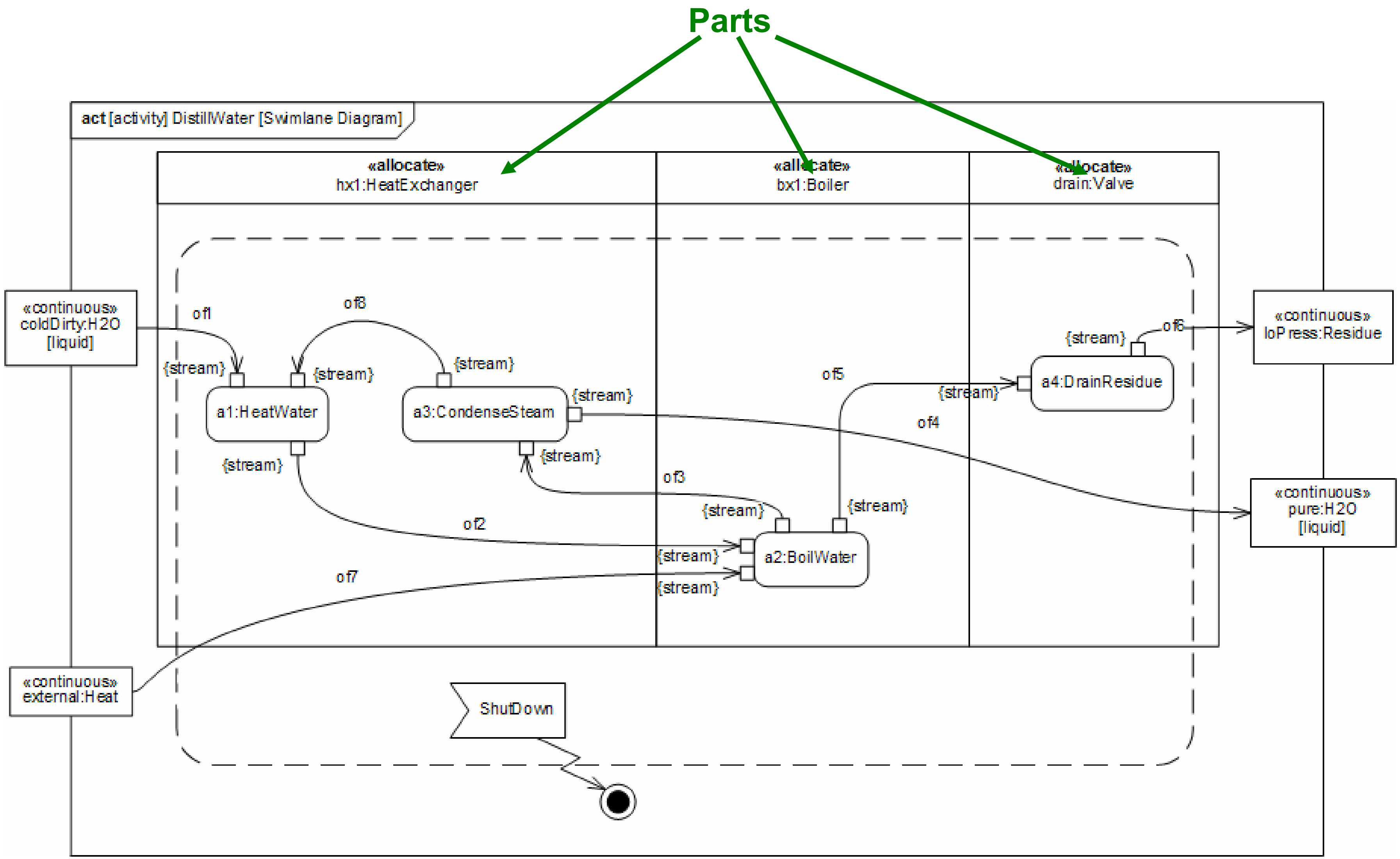
Continuous Distiller

Batch Distiller Here

Distiller Example – Activity Diagram: No Control Flow, ActionPin Notation, Simultaneous Behavior

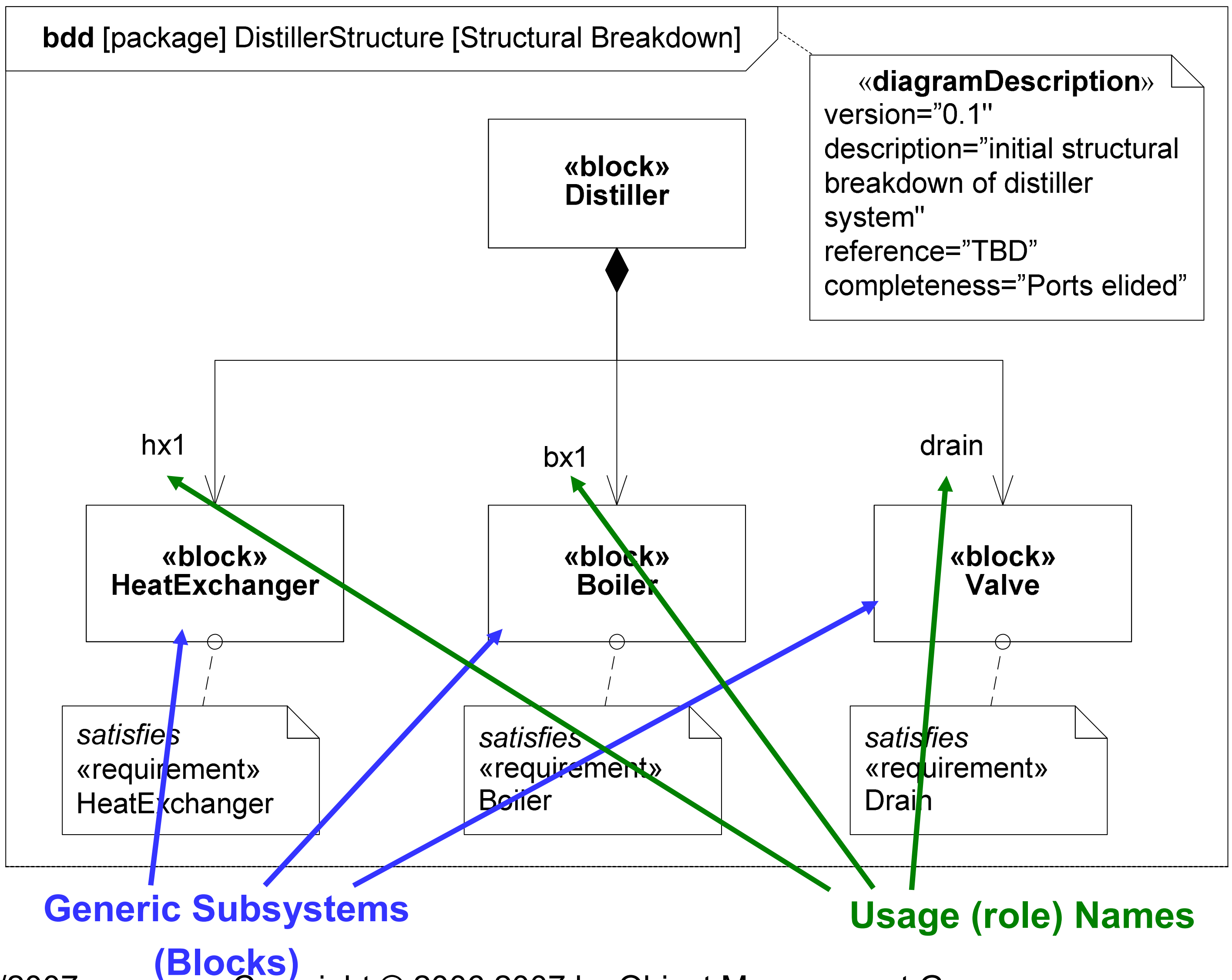


Distiller Example – Activity Diagram (with Swimlanes): DistillWater

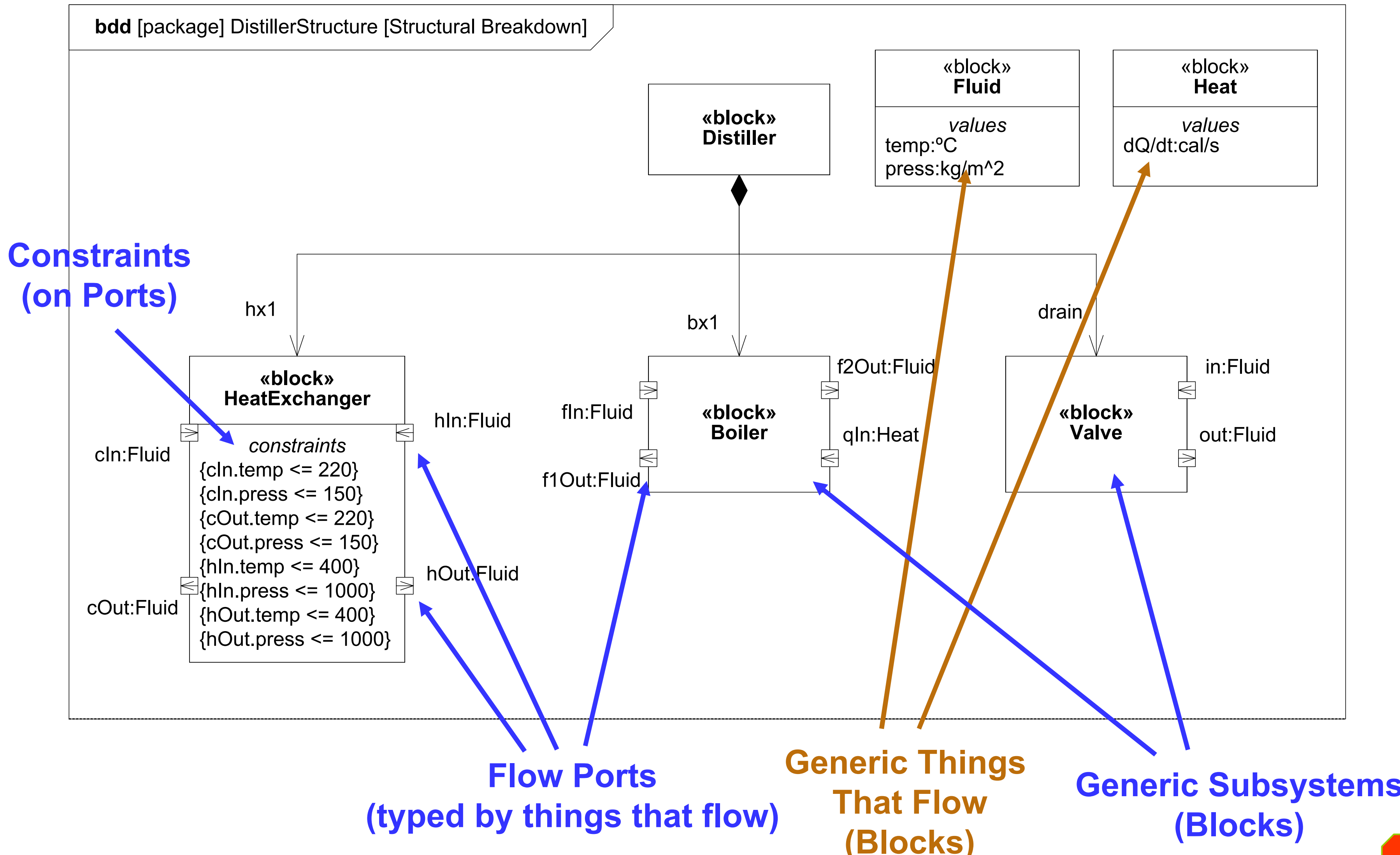


Allocated **ibd**

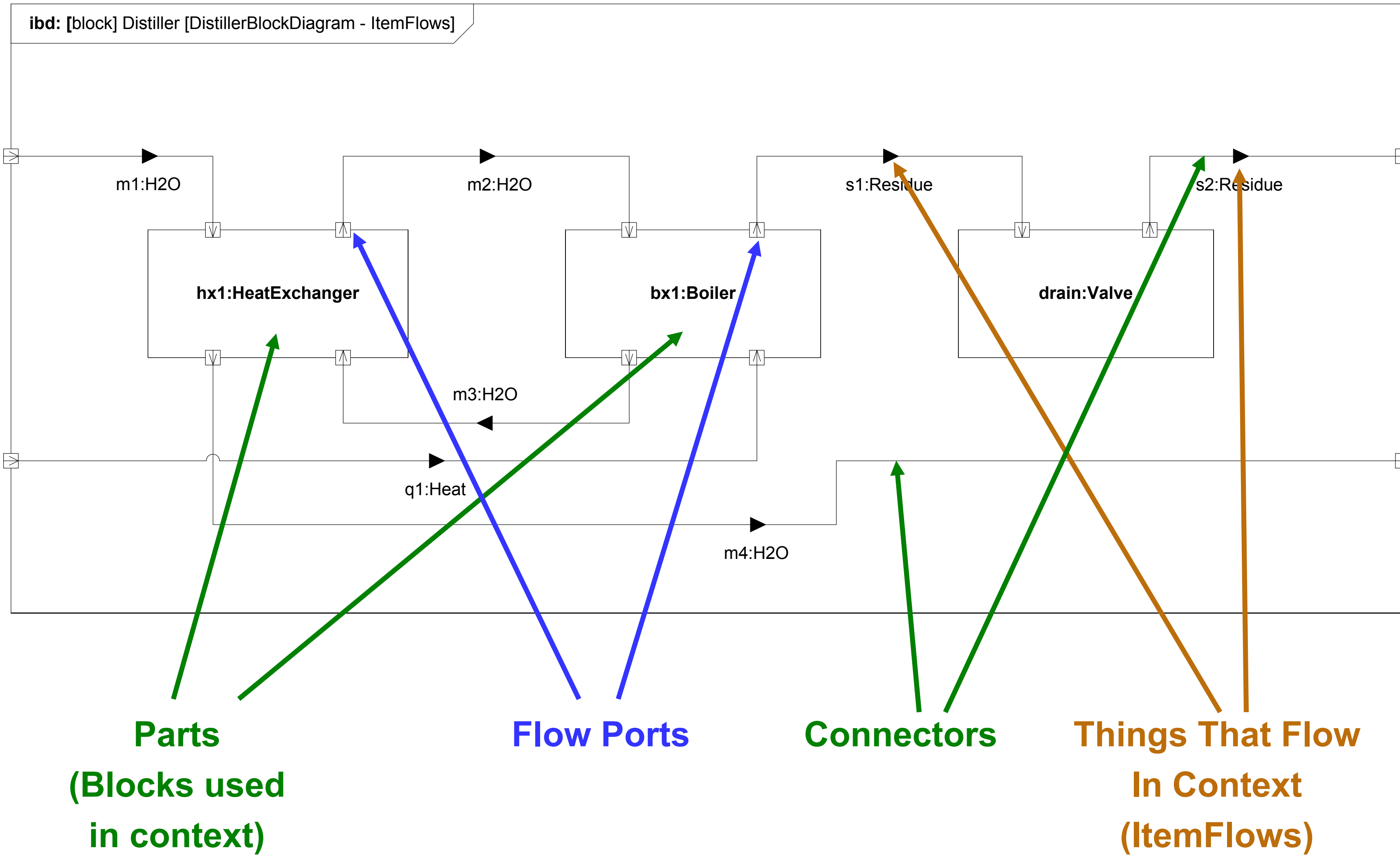
Distiller Example – Block Definition Diagram: DistillerStructure



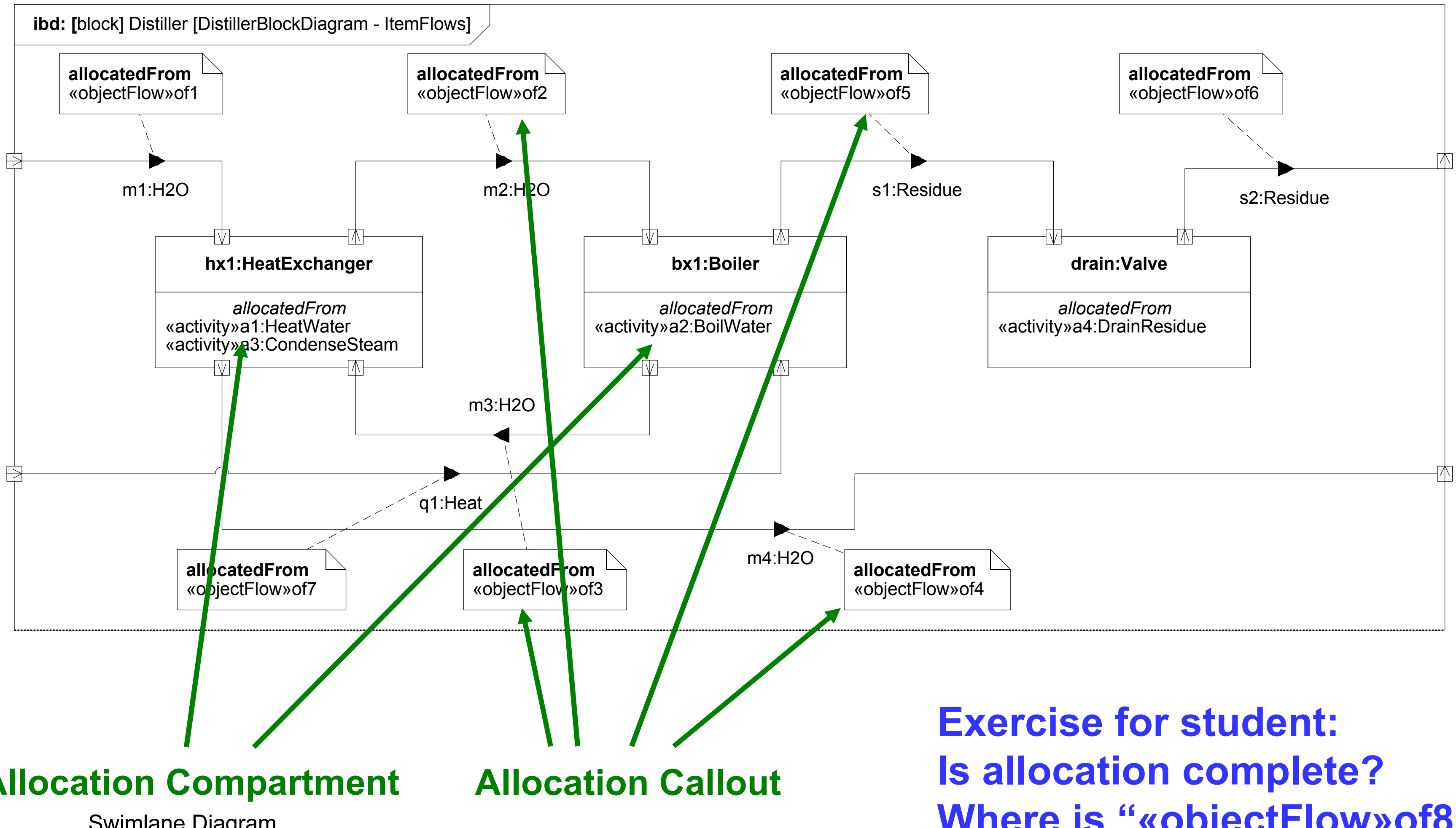
Distiller Example – Block Definition Diagram: Heat Exchanger Flow Ports



Distiller Example – Internal Block Diagram: Distiller Initial Design

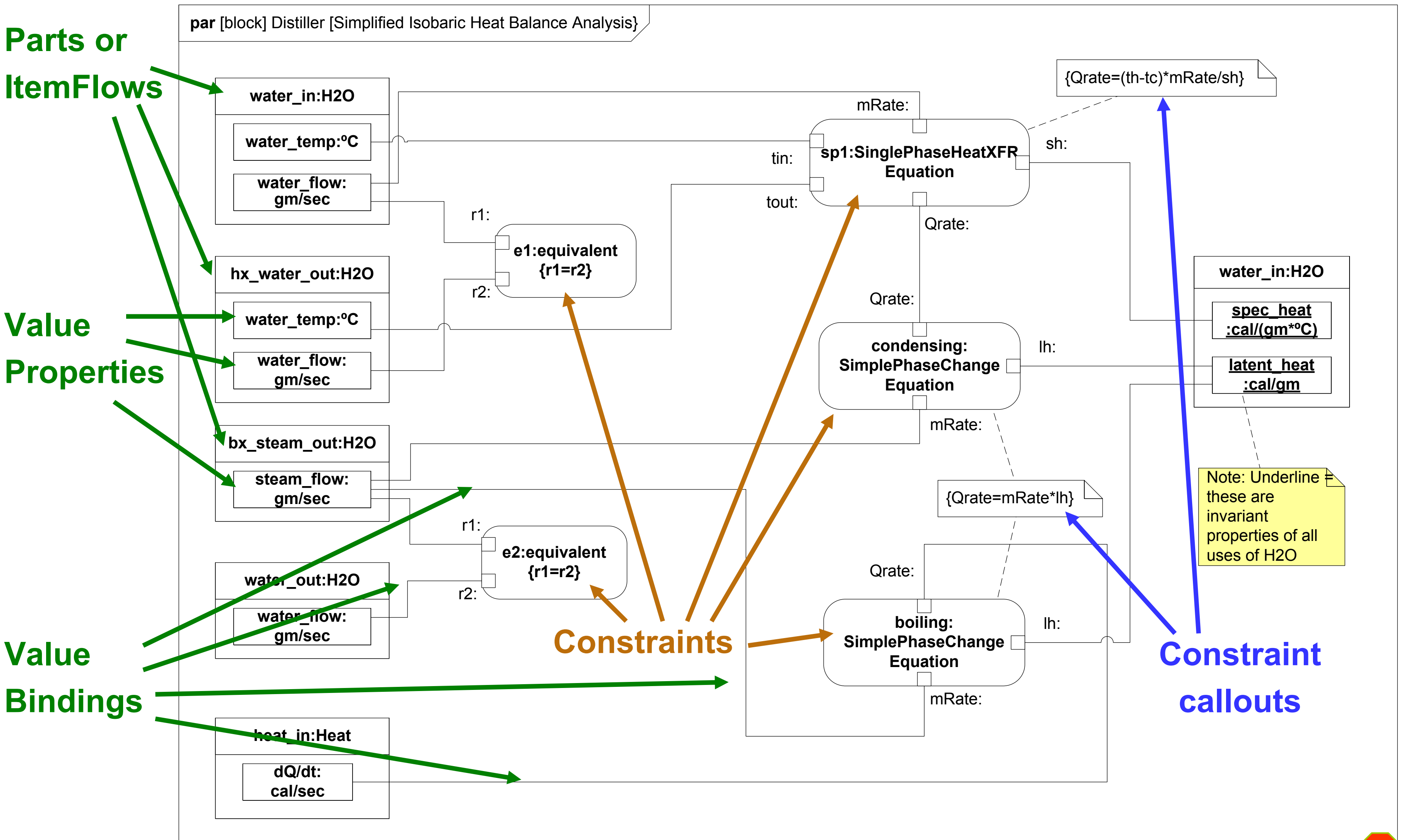


Distiller Example –Internal Block Diagram: Distiller with Allocation



Exercise for student:
Is allocation complete?
Where is "«objectFlow»of8"?

Distiller Example – Parametric Diagram: Heat Balance Equations



Distiller Example – Heat Balance Results

table IsobaricHeatBalance1 [Results of Isobaric Heat Balance]

specific heat cal/gm-°C	1
latent heat cal/cm	540

Satisfies «requirement» WaterSpecificHeat

Satisfies «requirement» WaterHeatOfVaporization

	water_in	hx_water_out	bx_water_in	bx_steam_out	water_out
mass flow rate gm/sec	6.75	6.75	1	1	1
temp °C	20	100	100	100	100

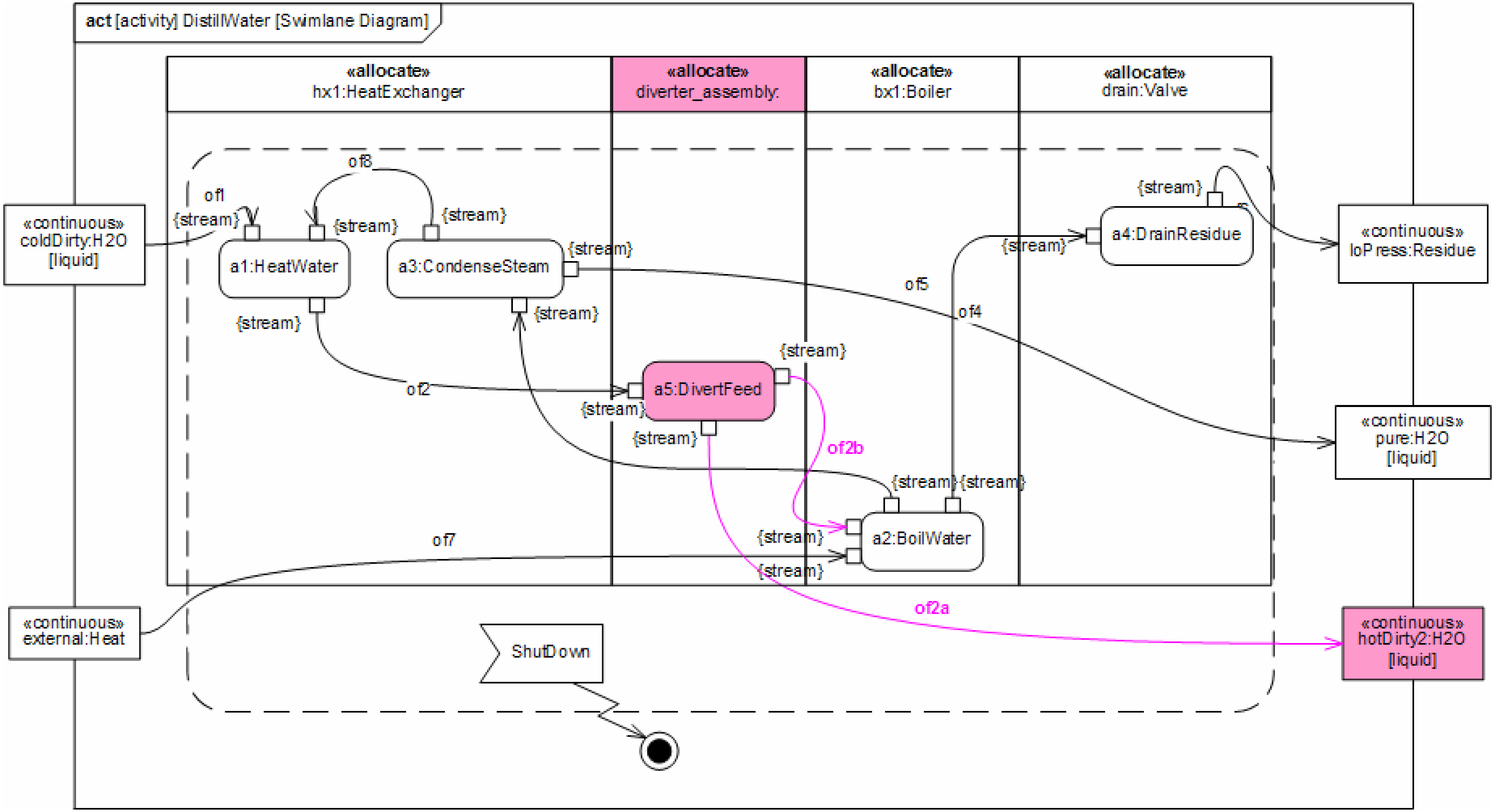
Satisfies «requirement» WaterInitialTemp

dQ/dt cooling water cal/sec	540
dQ/dt steam-condensate cal/sec	540
condenser efficency	1
heat deficit	0

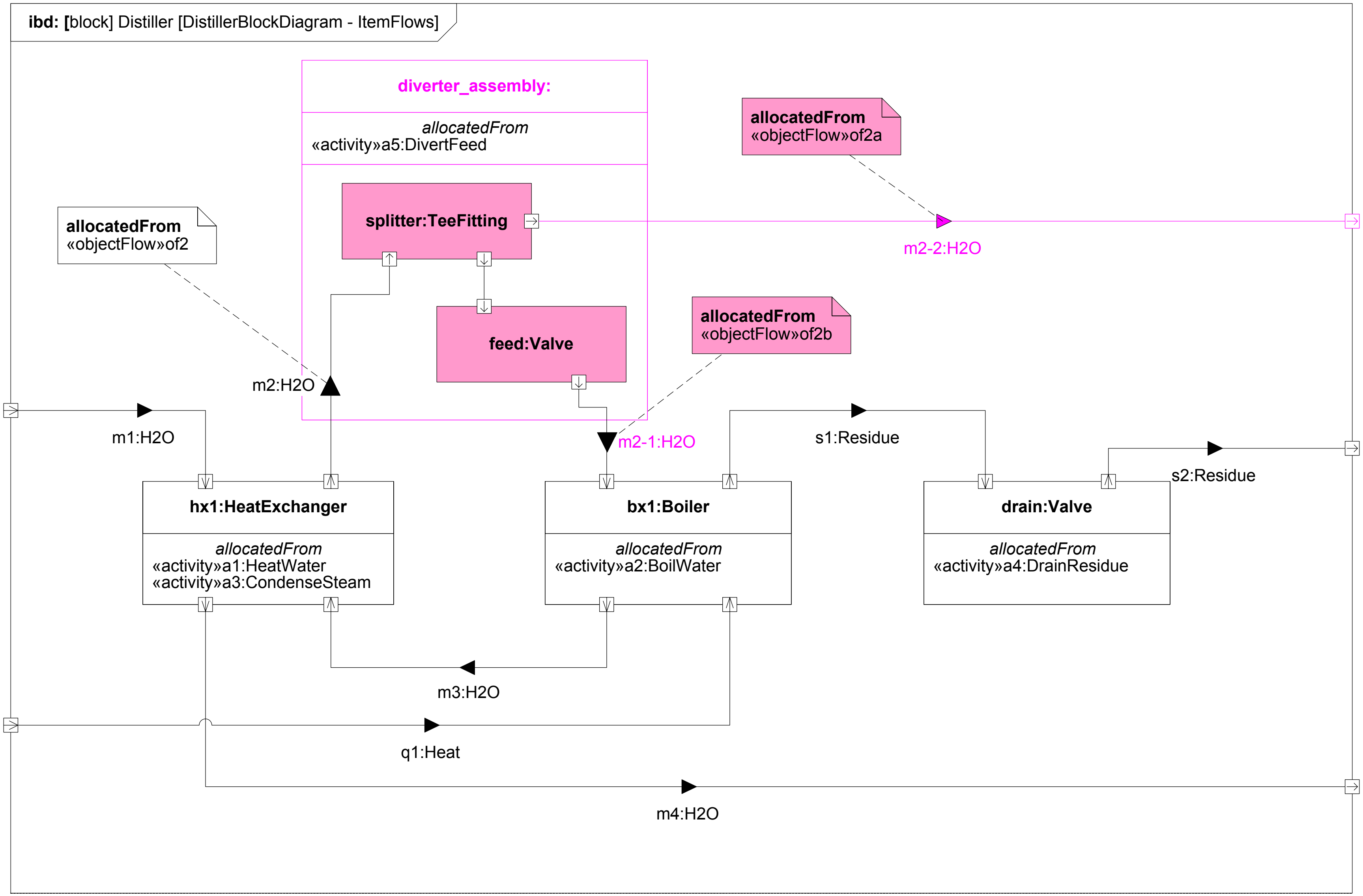
dQ/dt condensate-steam cal/sec	540
boiler efficiency	1
dQ/dt in boiler cal/sec	540

Note: Cooling water needs to have 6x flow of steam!
Need bypass between hx_water_out and bx_water_in!

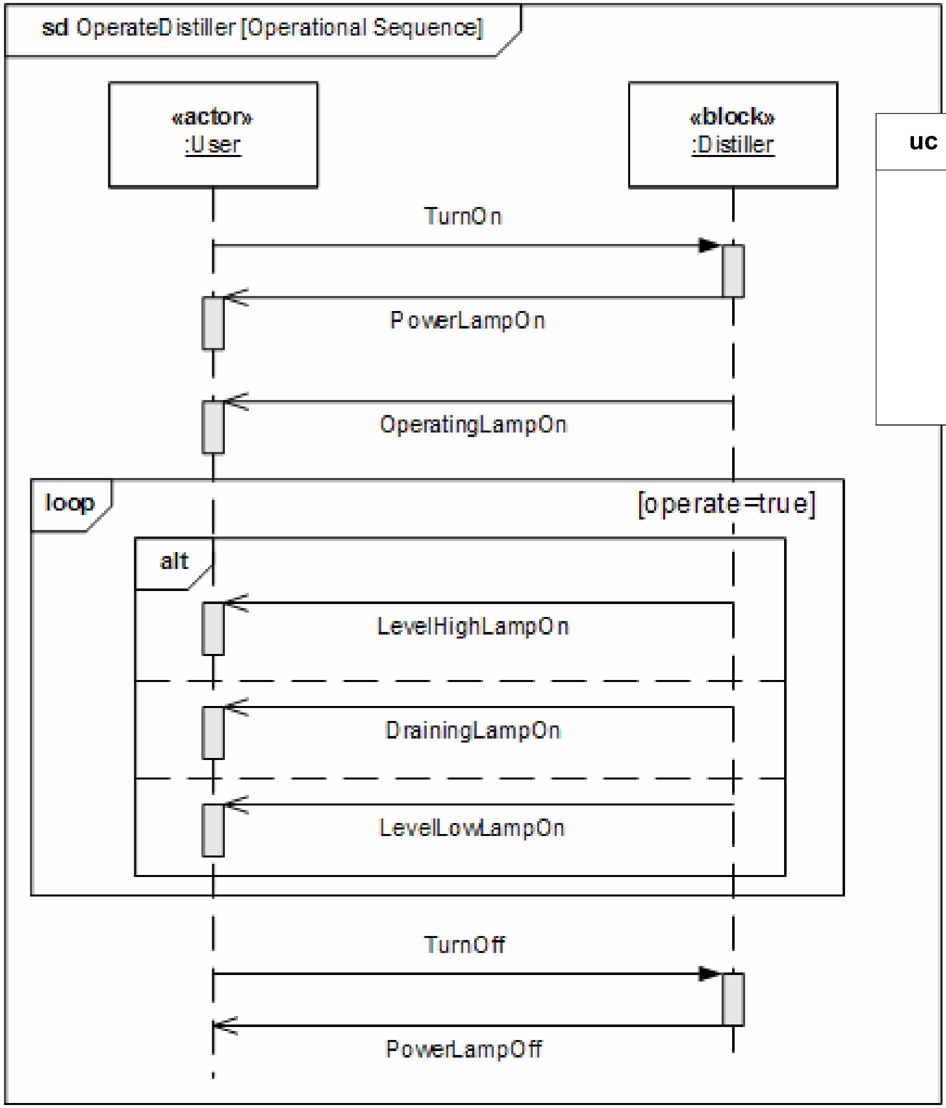
Distiller Example – Activity Diagram: Updated DistillWater

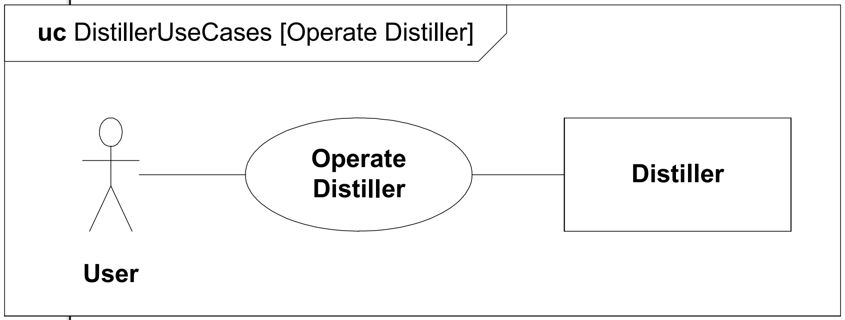


Distiller Example – Internal Block Diagram: Updated Distiller

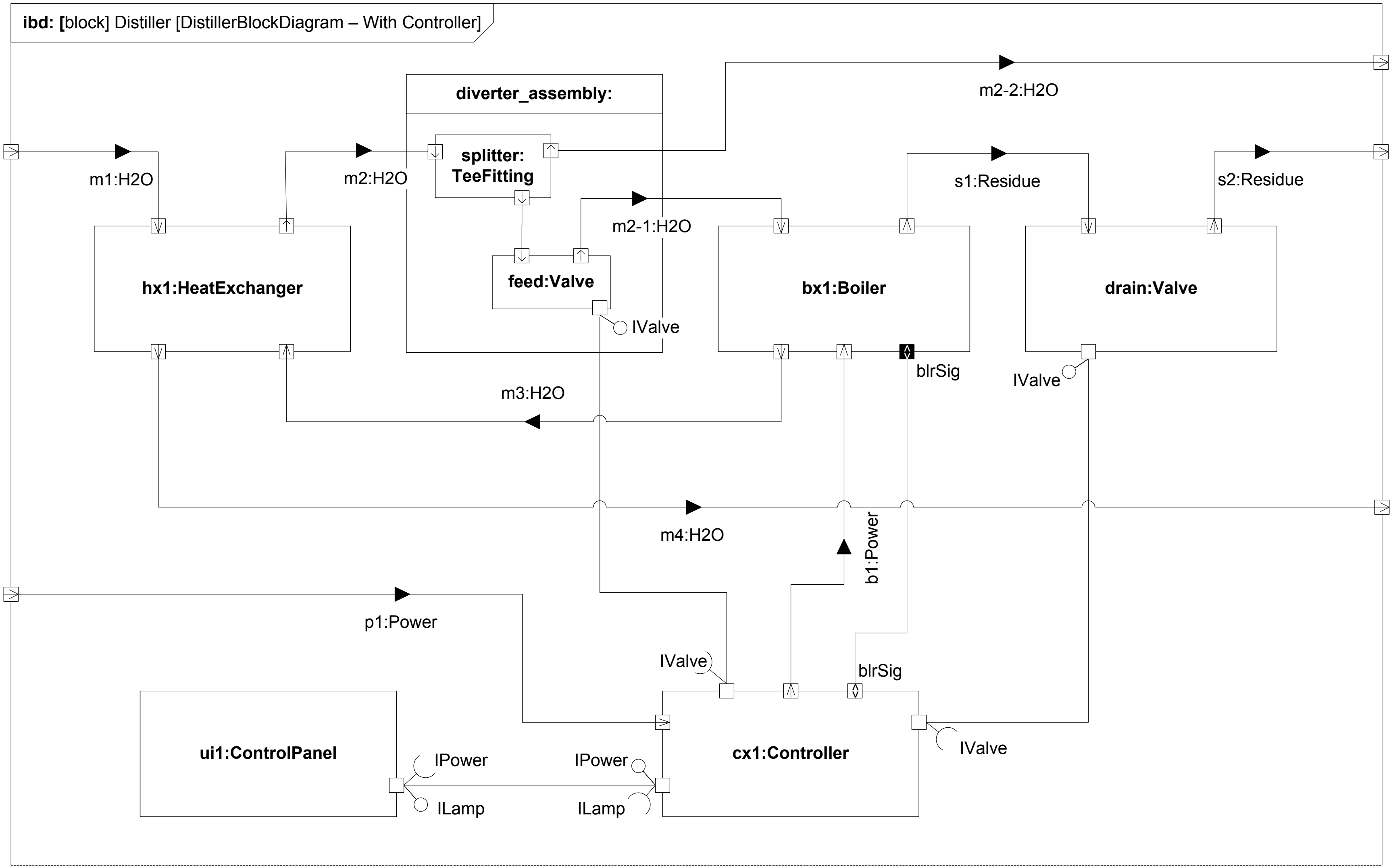


Distiller Example – Use Case and Sequence Diagrams





Distiller Example – Internal Block Diagram: Distiller Controller



Distiller Example – State Machine Diagram: Distiller Controller