RAMDE - Engenharia Orientada a Requisitos e Modelos

Project - Assignment 2
Modeling the Problem and the Solution

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2024-2025

Instituto Superior de Engenharia do Porto

P.PORTO

Outline

1. Prerequisites
2. Description / Tasks
3. Modelling the Problem
   - Black-box Perspective
   - White-box Perspective
4. Modelling the Solution
   - System Level
   - Subsystem Level
   - Safety and Reliability
5. Deadlines

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Required: Team and Project Repository

It is the same team and repository for all the assignments.

1. Have you already formed a team (2 students) to develop the project?
   - NO!!! What are you waiting for...
2. Have you already informed the teacher by email of your team?
   - NO!!! Do it ASAP to "pam@isep.ipp.pt"
   - Do not forget to had your team mate(s) in "cc"
3. Did you receive the link/invitation to the assigned team project repository?
   - NO!!! Please, contact the teacher reporting this issue (if necessary)
4. Did you check that you have read/write access to the assigned team project repository?
   - NO!!! Do it ASAP
   - Please, contact the teacher in case you do not have read/write access to it

When you answer "Yes" to all these questions, then you are ready to proceed.

Software and Tools

Before proceeding to the assignment tasks, ensure that you have the following tools installed and properly operational:

- **Eclipse Papyrus**
  - An industrial-grade open source Model-Based Engineering tool
  - Has notably been used successfully in industrial projects and is the base platform for several industrial modeling tools
  - It implements standards such as **UML** and **SysML**
  - More info: `https://www.eclipse.org/papyrus/`
- Git
- Bitbucket account registered with ISEP email

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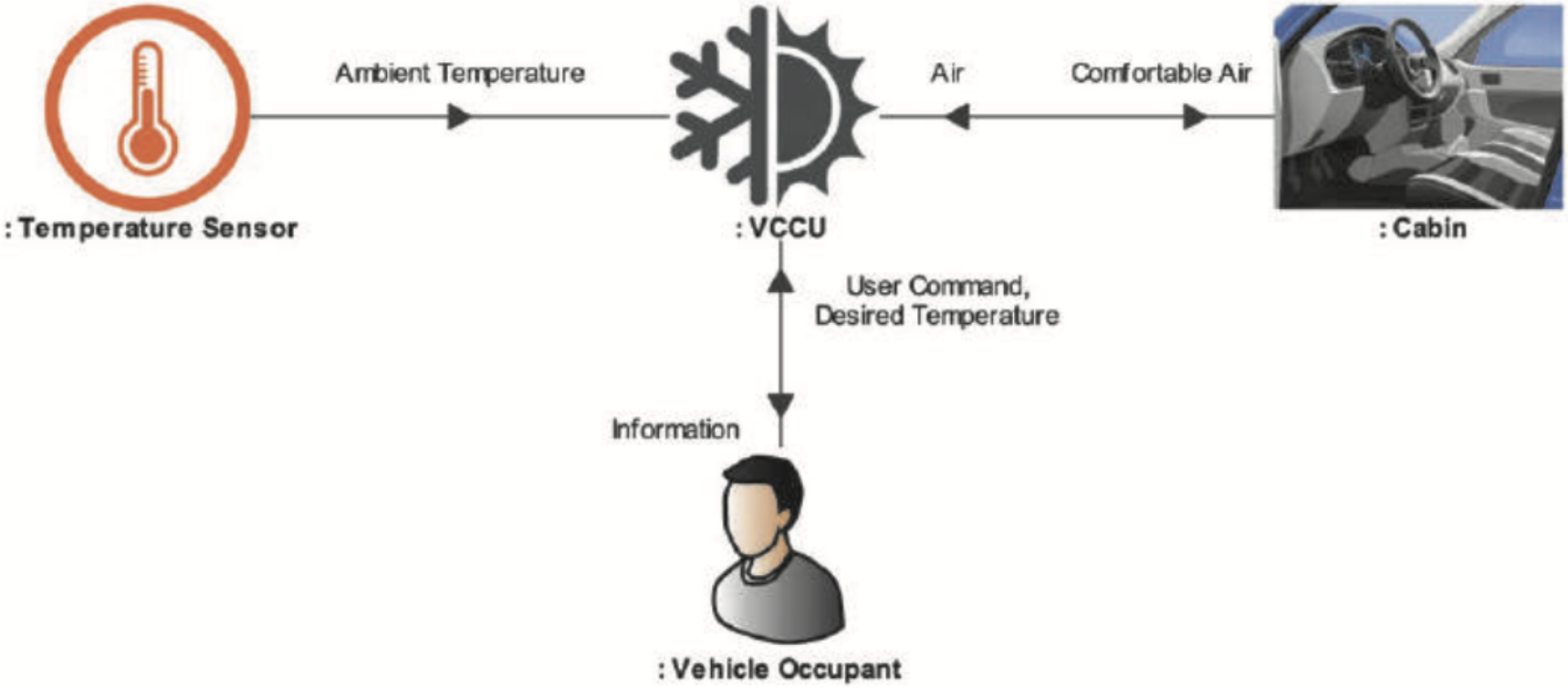
Context

This assignment is based on the Vehicle Climate Control System (VCCS) example described in the book **"MagicGrid Book of Knowledge, A Practical Guide to Systems Modeling using MagicGrid from Dassault Systemes"** [1].



Two Goals

This assignment consist on modelling a "Vehicle Climate Control Unit" in two sequencial goals:

1. To **Model the Problem**
2. To **Model the Solution**

Each goal has its own instructions, presented next.

Goal 1 - Modelling the Problem

- Access to the **Papyrus Tutorial** described in *"A Practical Guide to Systems Modeling with Papyrus and SysML"* available in Moodle
- Follow the steps described in the tutorial to:
  1. Capture the Stakeholder's needs in a Requirements Table
  2. Model the System Context with a Use Case Diagram
  3. Model the behaviour of a Use Case with an Activity Diagram
  4. Create an Internal Block Diagram
  5. Capture the Measures of Effectiveness (MoE)
- Report your work in the readme file of the repository, including images for the produced diagrams

Goal 2 - Modelling the Solution

- Access to the tutorial **"MagicGrid Book of Knowledge, A Practical Guide to Systems Modeling using MagicGrid from Dassault Systemes"** available in Moodle
- In this tutorial, focus particularly on the **"Solution Domain"** chapter
- Try to replicate the described solution with Papyrus, in order to:
  1. Create System Requirements
  2. Relate System Requirements and Stakeholder Needs
  3. Create a System High Level Architecture
  4. Model Subsystem Requirements
  5. Model Subsystem Structure
  6. Model Subsystem Behaviour (with State Machines)
  7. Model Subsystem Parameters
- Explore possible modelling alternatives for previous tasks
- Read the **"Annex A: Safety & Reliability Analysis"**
  1. Use this to elaborate a theoretical Safety and Reliability analysis
- Report your work in the readme file of the repository, including images for the produced diagrams

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The Problem Domain

- Black-box Perspective
- White-box Perspective

Domain		Pillar				
		Requirements	Structure	Behavior	Parameters	Safety & Reliability
Problem	Black Box	Stakeholder Needs	System Context	Use Cases	Measures of Effectiveness (MoEs)	Conceptual and Functional Failure Mode & Effects Analysis (FMEA)
Problem	White Box		Conceptual Subsystems	Functional Analysis	MoEs for Subsystems	Conceptual Subsystems FMEA
Solution		System Requirements	System Structure	System Behavior	System Parameters	System Safety & Reliability (S&R)
Solution		Subsystem Requirements	Subsystem Structure	Subsystem Behavior	Subsystem Parameters	Subsystem S&R
Solution		Component Requirements	Component Structure	Component Behavior	Component Parameters	Component S&R
Implementation		Implementation Requirements				

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Adopting a Black-box Perspective

Domain		Pillar				
		Requirements	Structure	Behavior	Parameters	Safety & Reliability
Problem	Black Box	Stakeholder Needs	System Context	Use Cases	Measures of Effectiveness (MoEs)	Conceptual and Functional Failure Mode & Effects Analysis (FMEA)
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Implementation		Implementation Requirements				

Capturing Stakeholder's Needs (1/2)

- Stakeholder's needs in a Requirements Table

#	Name	Text
1	Ambient Temperature	I want to see the ambient temperature on the screen or some other output device.
2	Comfortable Temperature	I'd like to feel comfortable temperature while being in the cabin.
3	Desired Temperature	It should be a possibility to easily specify the desired temperature.
4	Heating & Cooling	The unit must be able to heat and cool.
5	Energy Consumption	I'd like the unit to consume as little energy as possible.
6	Manual Control	I should be able to start and stop climate control by myself.
7	Sound Level	Climate control unit in max mode shall not be louder than engine.
8	Total Mass	Mass of the unit shall not exceed 2 percent of the total car mass.

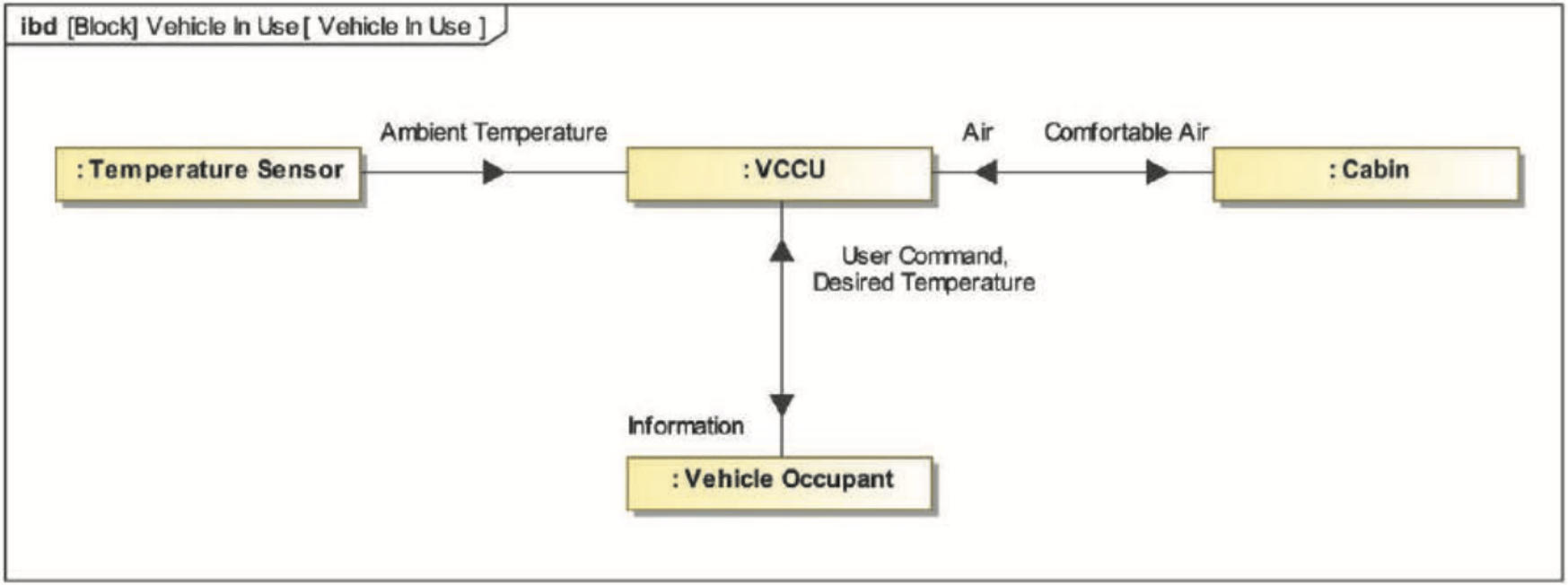
Capturing Stakeholder's Needs (2/2)

- Grouping, numbering and typing requirements
- E.g.: Functional requirements are depicted as **F**

#	△ Name	Text
1	⊟ R SN-1 Stakeholder Needs	
2	⊟ R SN-1.1 User Needs	
3	R SN-1.1.1 Sound Level	Climate control unit in max mode shall not be louder than engine.
4	F SN-1.1.2 Manual Control	I should be able to start and stop climate control by myself.
5	F SN-1.1.3 Heating & Cooling	The unit must be able to heat and cool.
6	R SN-1.1.4 Energy Consumption	I'd like the unit to consume as little energy as possible.
7	F SN-1.1.5 Ambient Temperature	I want to see the ambient temperature on the screen or some other output device.
8	F SN-1.1.6 Desired Temperature	It should be a possibility to easily specify the desired temperature.
9	F SN-1.1.7 Comfortable Temperature	I'd like to feel comfortable temperature while being in the cabin
10	⊟ R SN-1.2 Design Constraints	
11	R SN-1.2.1 Total Mass	Mass of the unit shall not exceed 2 percent of the total car mass.

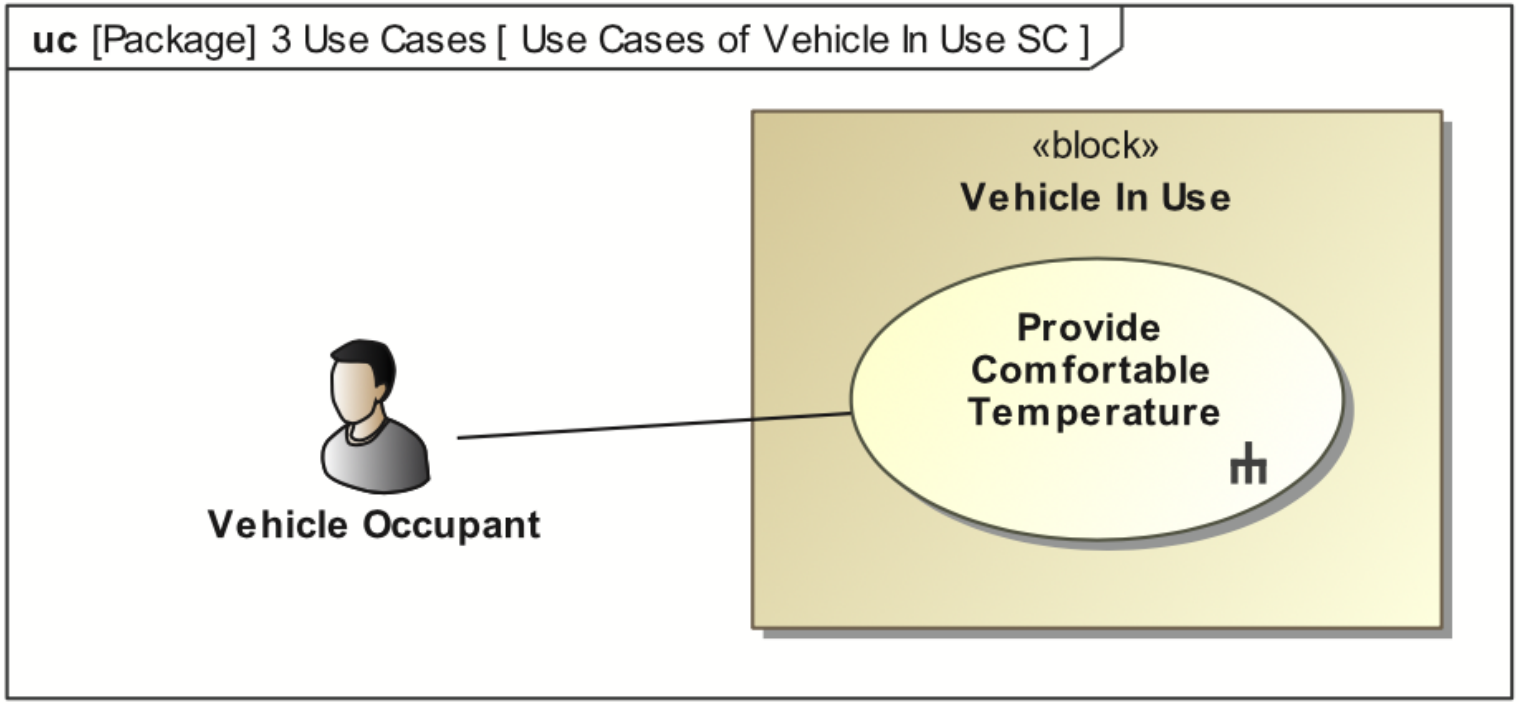
System Context

- At the center of the diagram you should represent the **System of Interest (SoI)**, which in this example is the VCCU



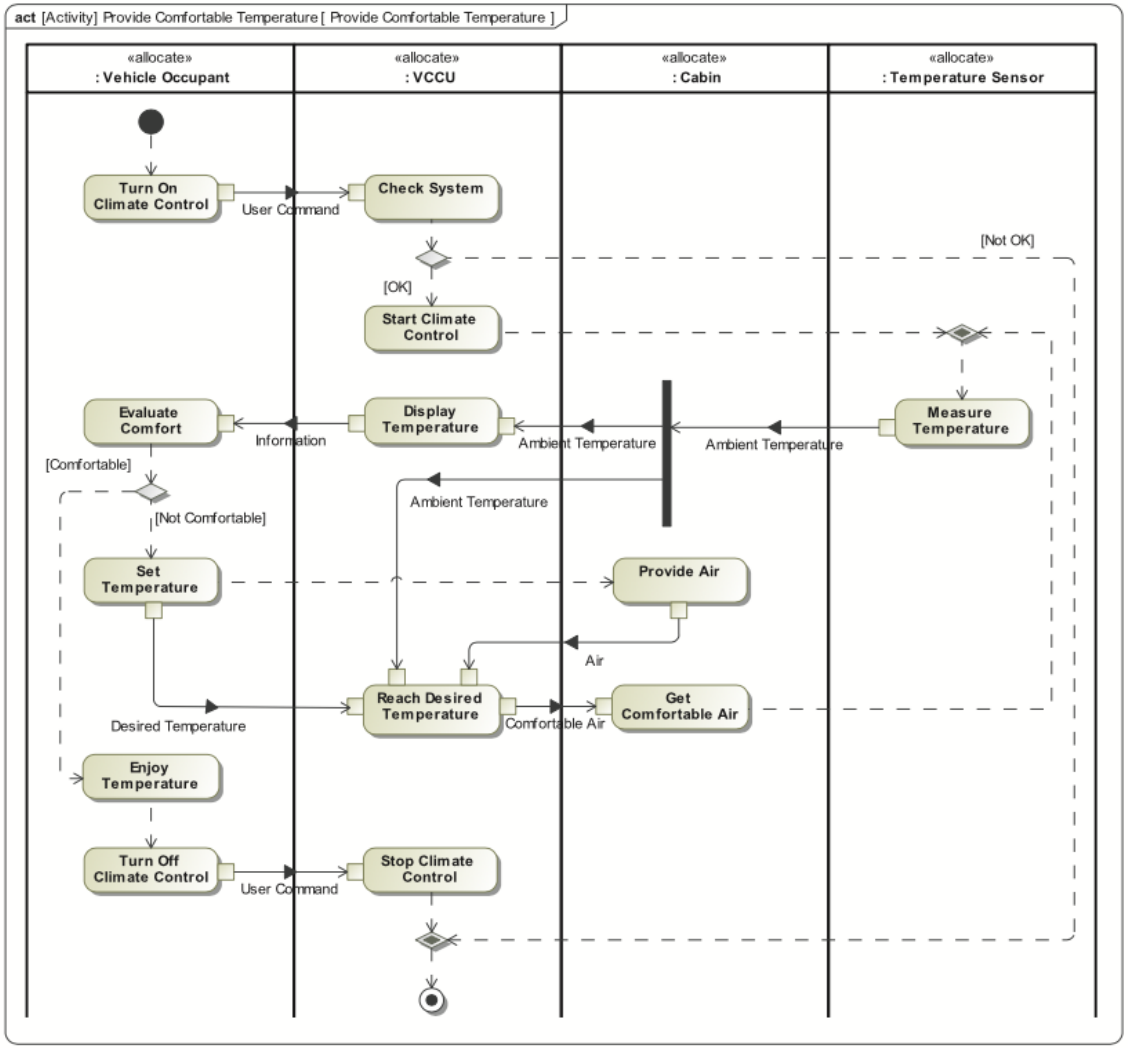
Use Case(s)

- Using a Use Case Diagram



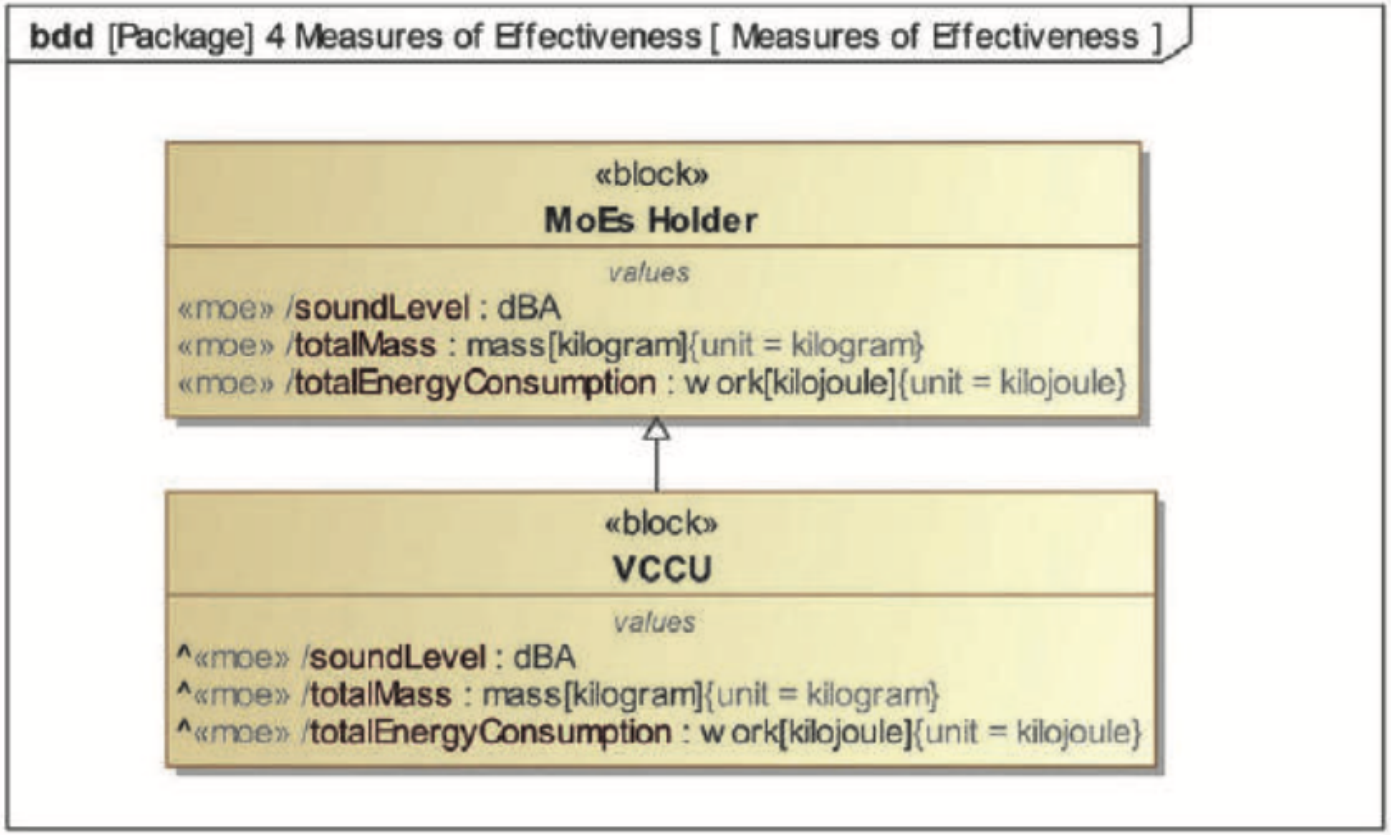
Use Case - Main Scenario

- Using an Activity Diagram
- Other scenarios might also be modelled for the same Use Case



Measures of Effectiveness (MoE)

- MoEs capture quantifiable characteristics of the SoI in a numerical format, i.e., quality requirements



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Adopting a White-box Perspective

Domain		Pillar: Requirements	Structure	Behavior	Parameters	Safety & Reliability
Problem	Black Box	Stakeholder Needs	System Context	Use Cases	Measures of Effectiveness (MoEs)	Conceptual and Functional Failure Mode & Effects Analysis (FMEA)
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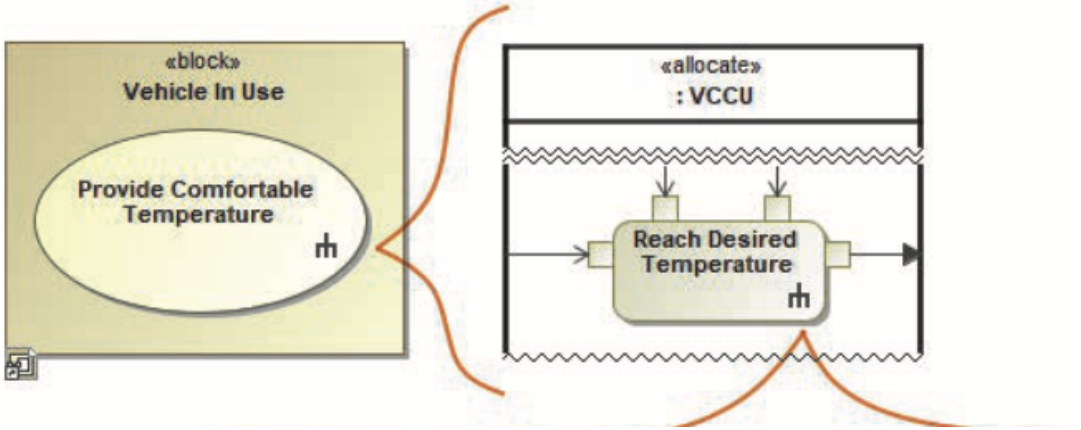
Implementation		Implementation Requirements				

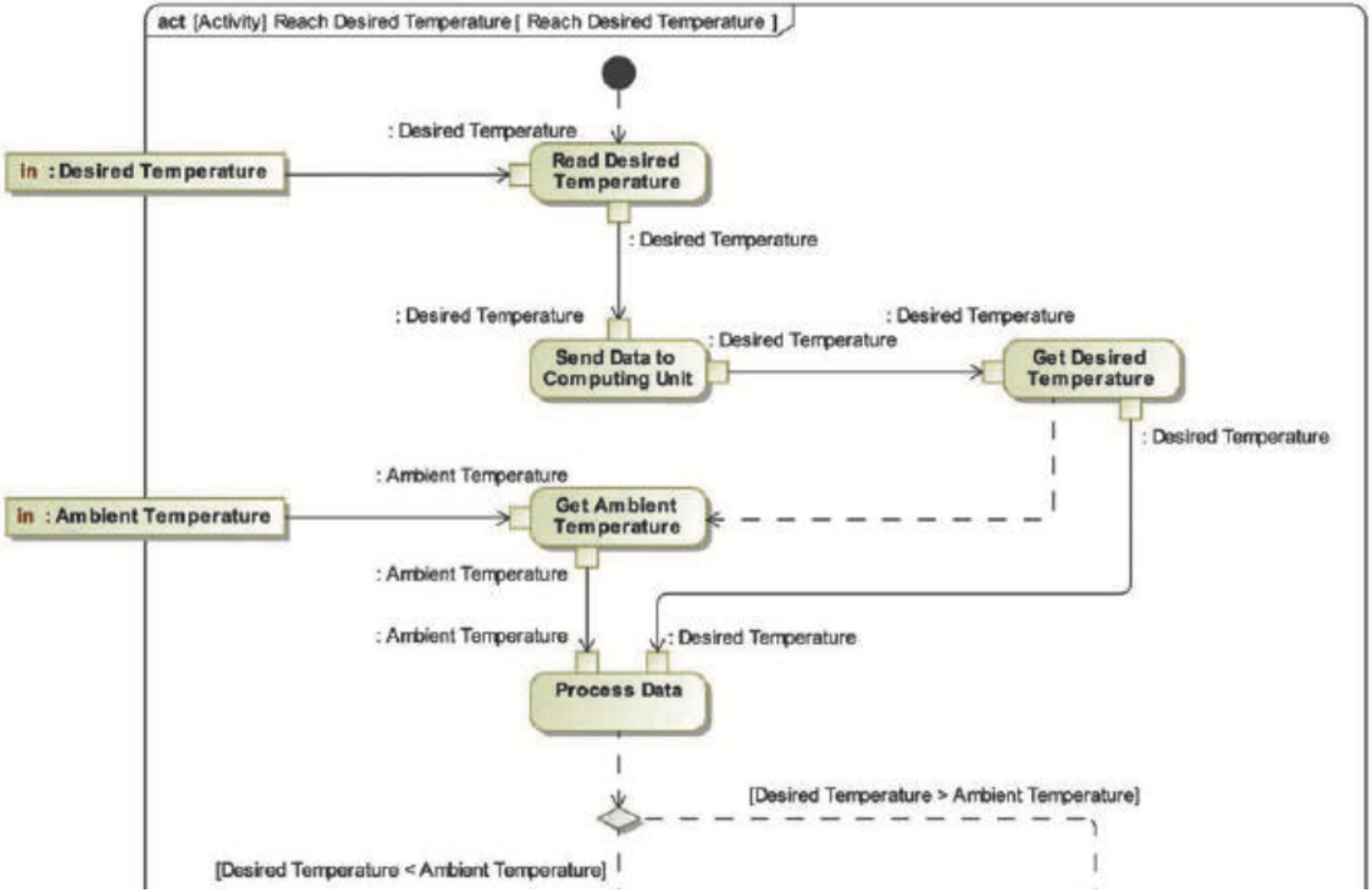
Functional Analysis

- From Black-Box to White-Box Perspective
- Functional Decompositions



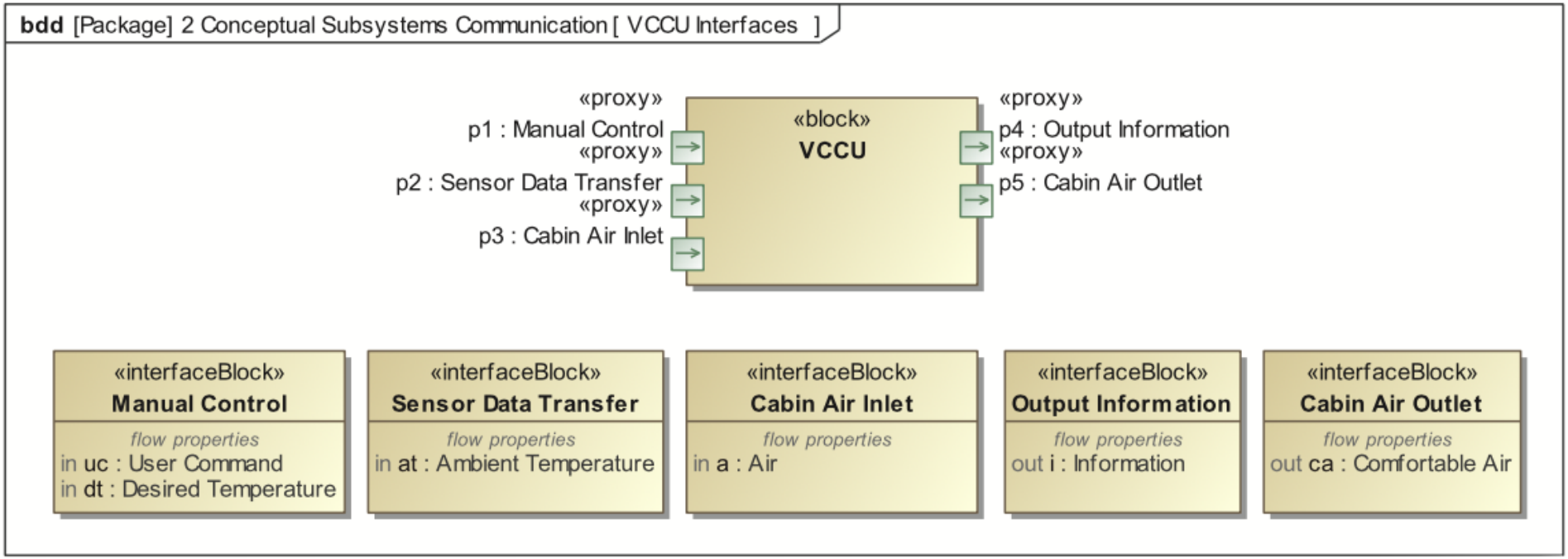
Functional Decomposition

- Decomposing the function "Reach Desired Temperature"



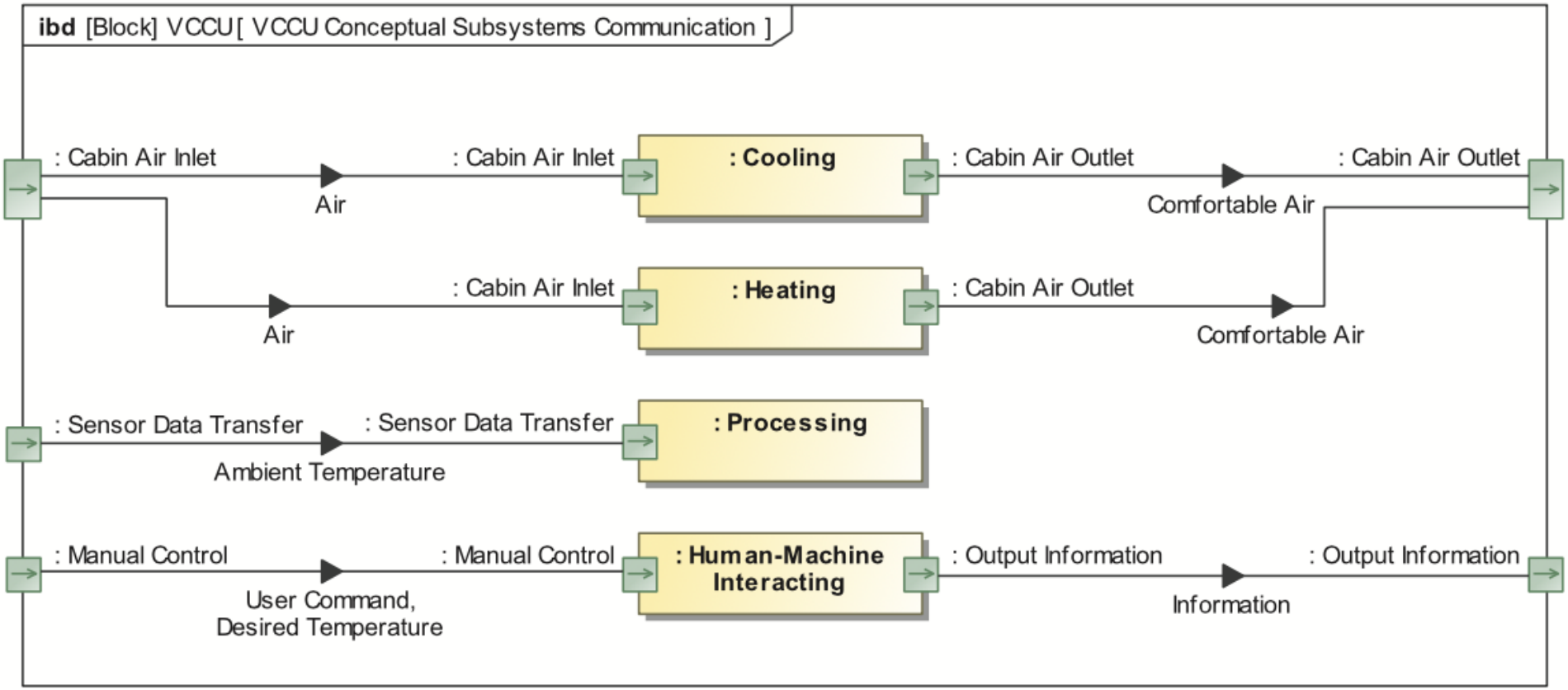
Conceptual Interfaces

- VCCU input and output interfaces

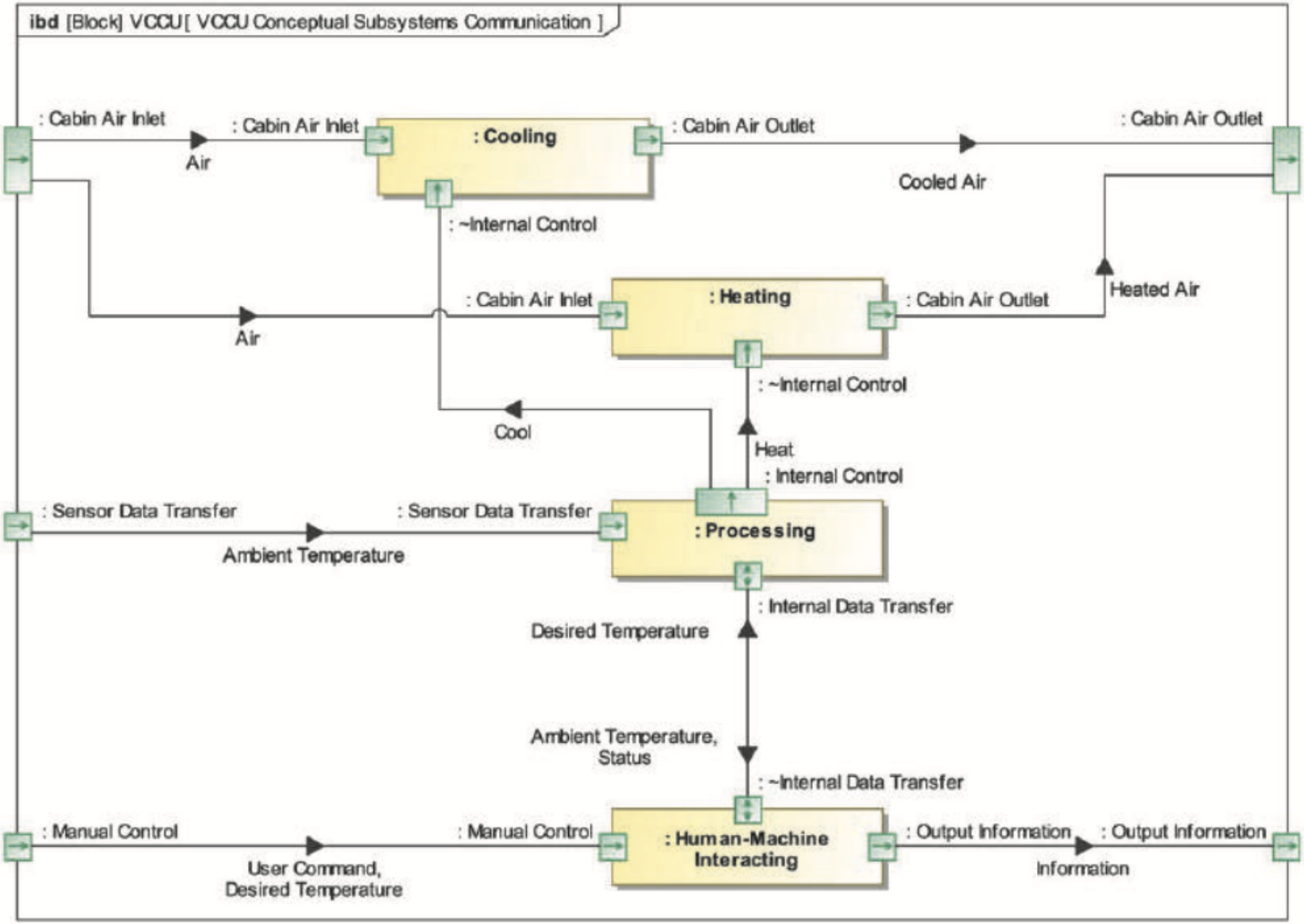


Conceptual Subsystems

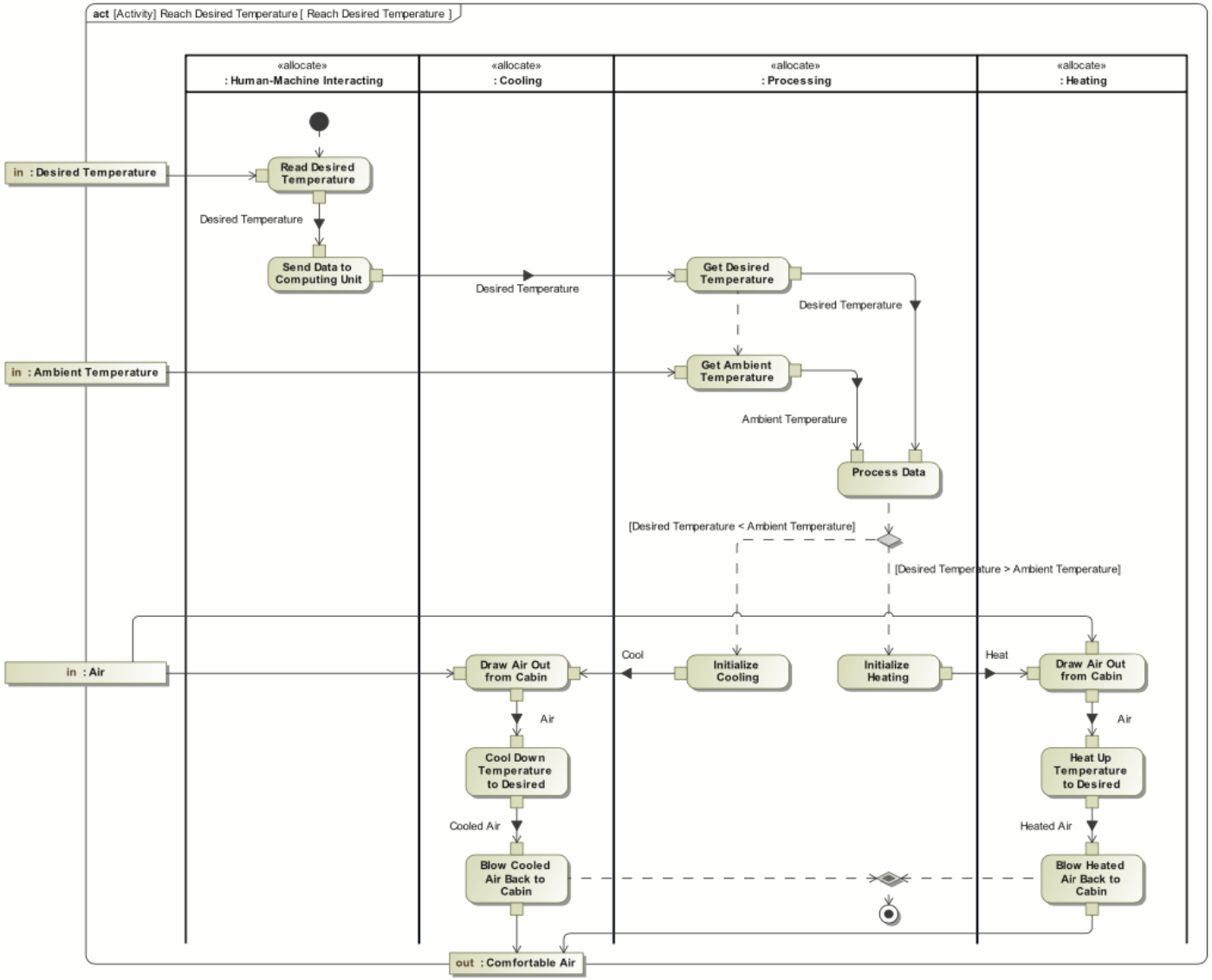
- VCCU internal susbsystems



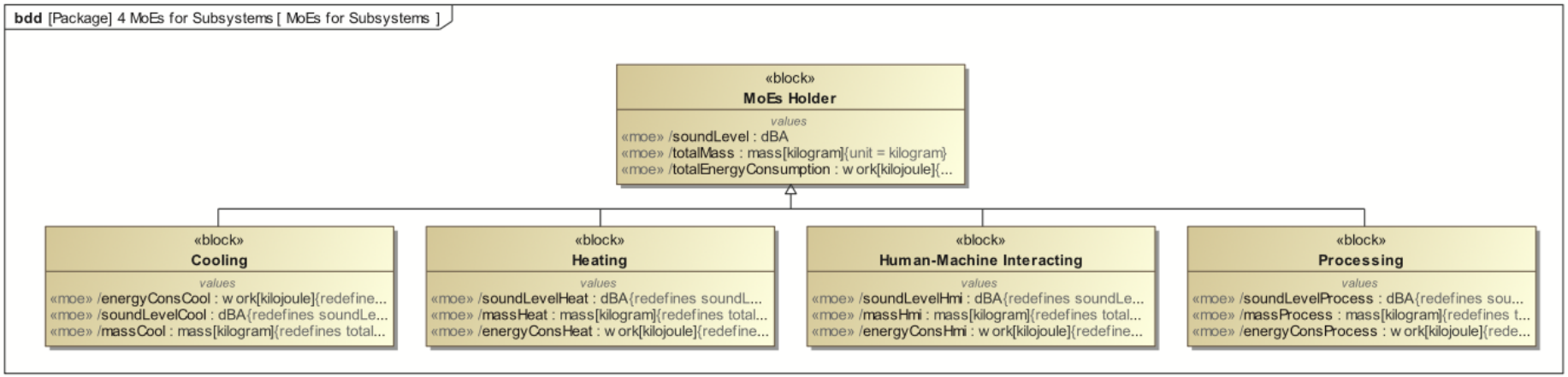
Interactions among Subsystems



Allocating Functions to Subsystems



Measures of Effectiveness for Subsystems



Traceability to Stakeholder Needs

- Using a Refine Requirement Matrix

Legend

- Refine
- Refine (Implied)

	SN-1 Stakeholder Needs										
	SN-1.1 User Needs										
	SN-1.1.1 Sound Level	SN-1.1.2 Manual Control	SN-1.1.3 Heating & Cooling	SN-1.1.4 Energy Consumption	SN-1.1.5 Ambient Temperature	SN-1.1.6 Desired Temperature	SN-1.1.7 Comfortable Temperature	SN-1.2 Design Constraints	SN-1.2.1 Total Mass		
	R	F	F	R	F	F	F	R	R		
2 White Box	47	42	5	3	14	5	6	5	11	5	5
2 Conceptual Subsystems Communication	34	29	5	3	8	5	6	2	3	5	5
2 Conceptual Subsystems	22	18	4	1	4	4	3	1	2	4	4
Cooling [1 Cooling]	6	5	1		2	1			1	1	1
/energyConsCool : work[kilojoule]	⇢	⇢				↗					
/massCool : mass[kilogram]	⇢									⇢	↗
/soundLevelCool : dBA	⇢	⇢	↗								
in p3 : Cabin Air Inlet	⇢	⇢			↗						
in p4 : ~Internal Control	⇢	⇢						↗			
out p5 : Cabin Air Outlet	⇢	⇢			↗						
Heating [2 Heating]	5	4	1		2	1				1	1
/energyConsHeat : work[kilojoule]	⇢	⇢				↗					
/massHeat : mass[kilogram]	⇢									⇢	↗
/soundLevelHeat : dBA	⇢	⇢	↗								
in p3 : Cabin Air Inlet	⇢	⇢			↗						
in p4 : ~Internal Control											
out p5 : Cabin Air Outlet	⇢	⇢			↗						

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The Solution Domain

Specifying requirements, structure, behaviour, and parameters of the SoI at:

- System level
- Subsystem(s) level
- Component(s) level

			Pillar				
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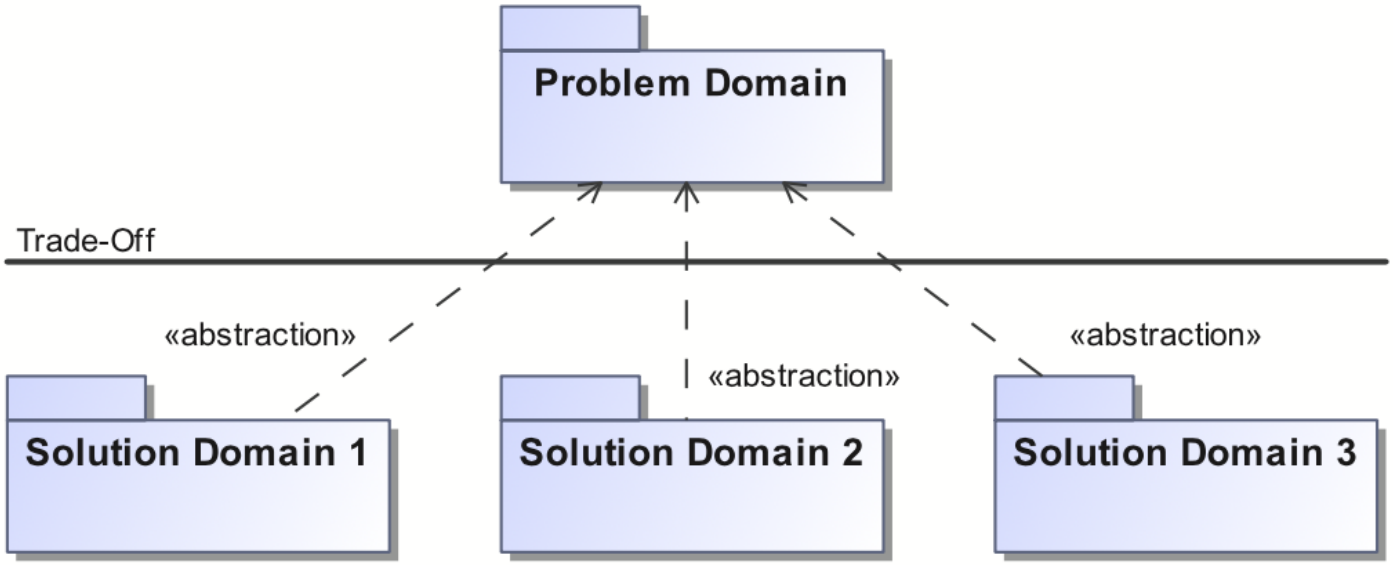
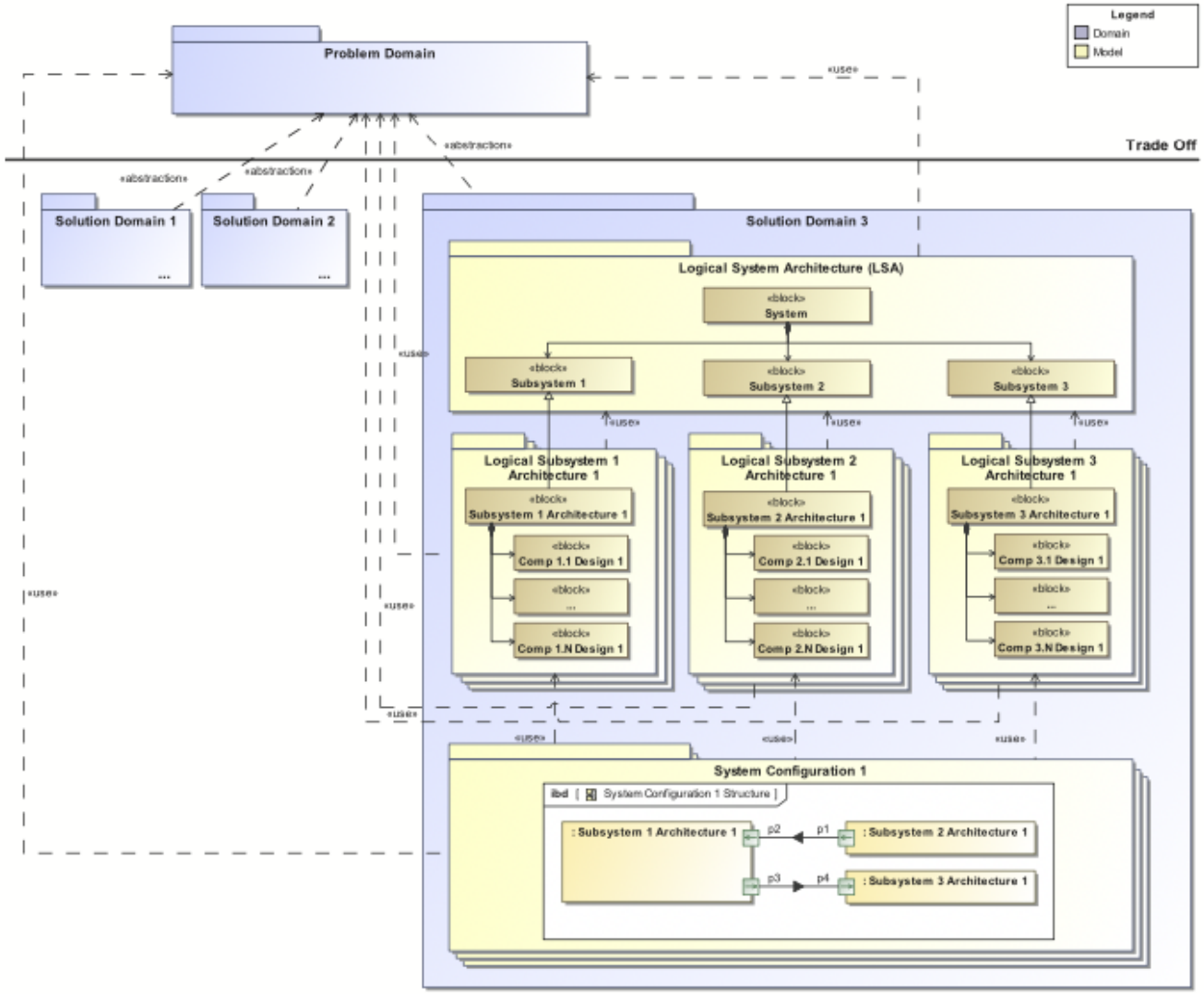
	Implementation		Implementation Requirements				

From the Problem Domain to The Solution Domain

- **One problem** might have **multiple alternative solutions**



Solution Domain - Overview (1/2)



Solution Domain - Overview (2/2)

A **System Specification** (i.e., requirements, structure, behaviour, parameters, safety and reliability) might lead to:

- Multiple Specifications of each identified Subsystem, i.e. **Subsystem Specification**
- Multiple **System Configurations**

Similarly, one Subsystem Specification might lead to:

- Multiple Component(s) Specifications
- Multiple Subsystem Configurations

And, so on...

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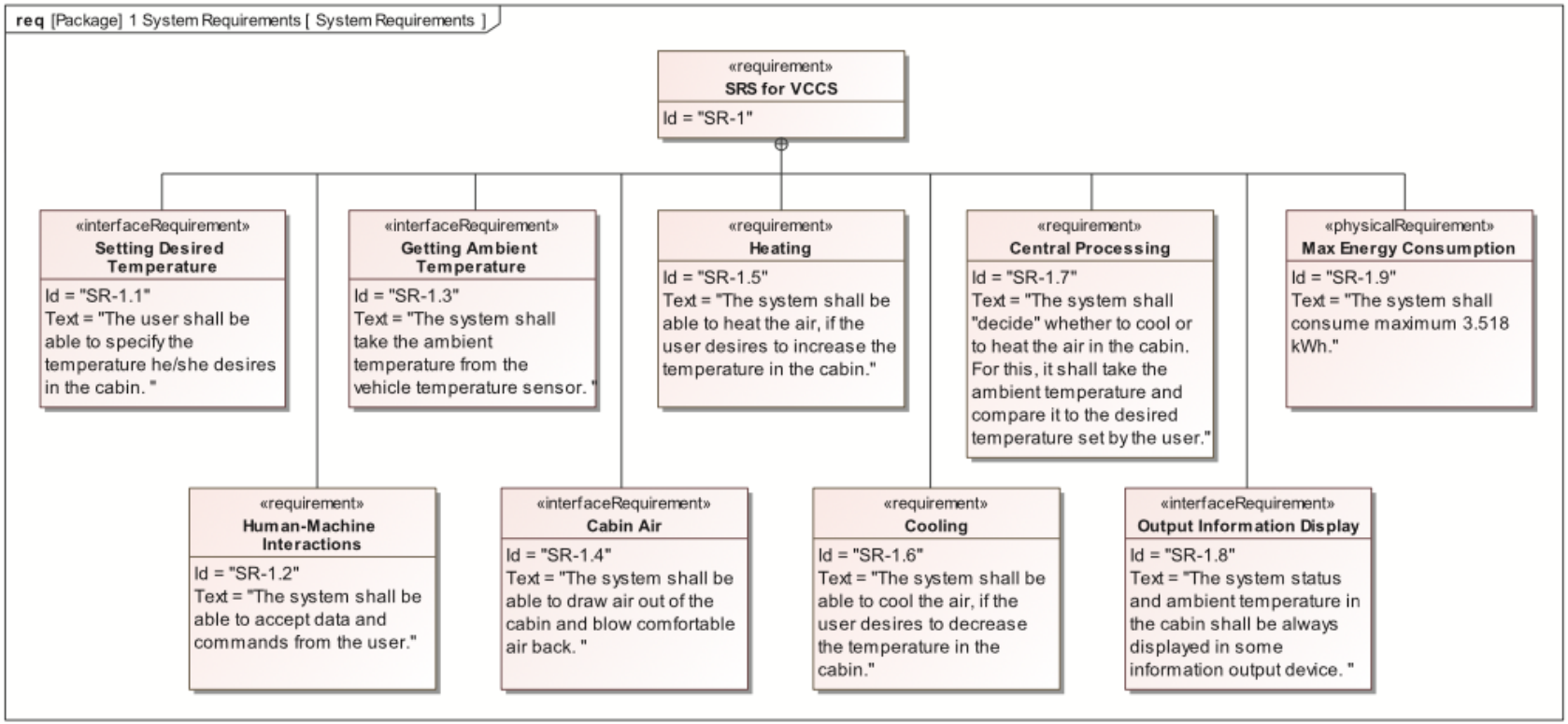
Creating System Requirements

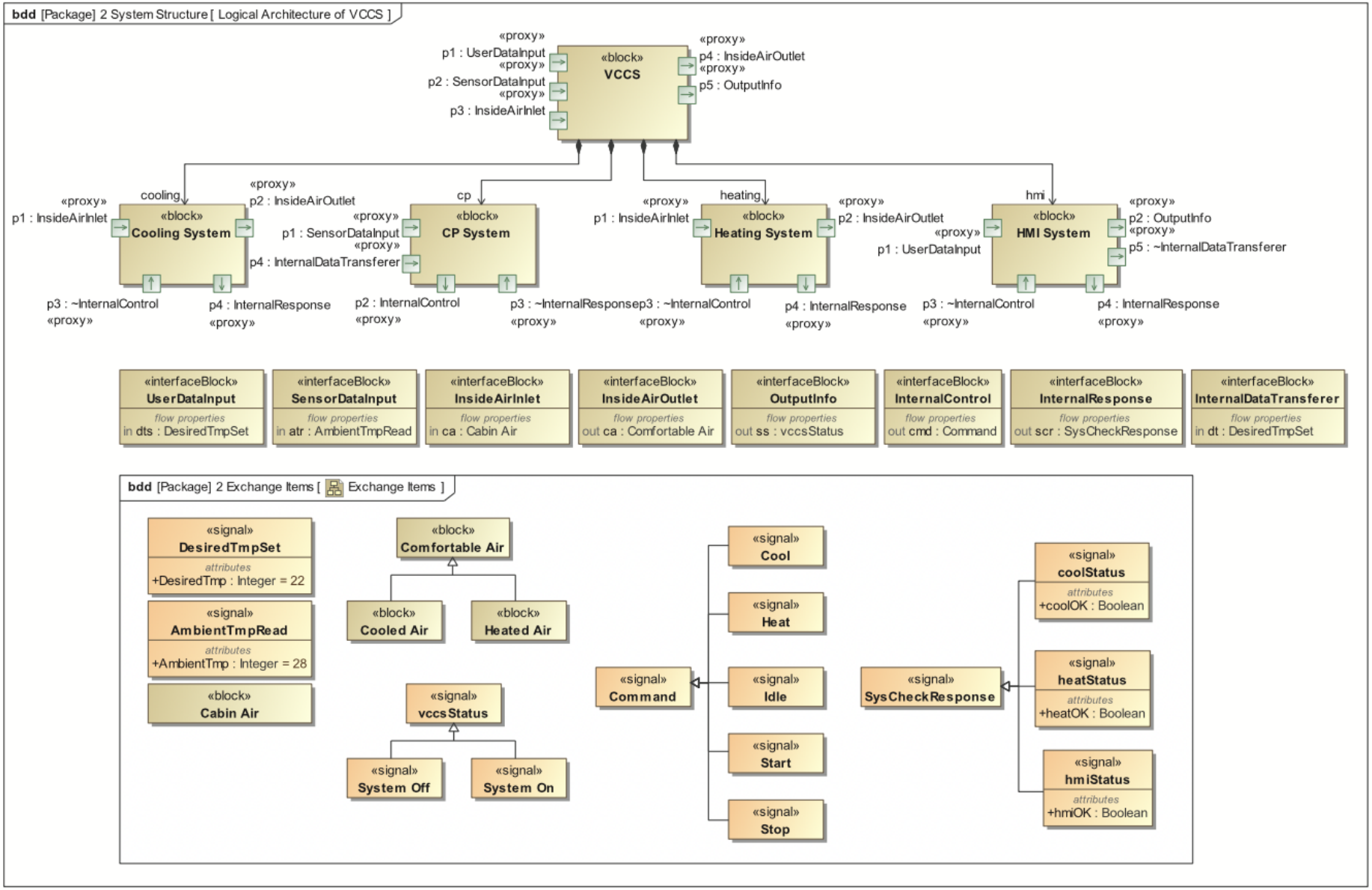
- System requirements must be derived from stakeholder needs; and/or
- Refine one or more elements from the problem domain model



Traceability: System Requirements to Stakeholder's Needs

Legend	SN-1 Stakeholder Needs	SN-1.1 User Needs	SN-1.1.1 Sound Level	SN-1.1.2 Manual Control	SN-1.1.3 Heating & Cooling	SN-1.1.4 Energy Consumption	SN-1.1.5 Ambient Temperature	SN-1.1.6 Desired Temperature	SN-1.1.7 Comfortable Temperature	SN-1.2 Industry Standards	SN-1.2.1 Total Weight
DeriveReqt	R	R	R	F	F	R	F	F	F	R	R
SR-1 SRS for VCCS	R										
SR-1.1 Setting Desired Temperature	I							↗			
SR-1.2 Human-Machine Interactions	R			↗							
SR-1.3 Getting Ambient Temperature	I						↗				
SR-1.4 Cabin Air	I				↗						
SR-1.5 Heating	R				↗						
SR-1.6 Cooling	R				↗						
SR-1.7 Central Processing	R								↗		
SR-1.8 Output Information Display	I						↗				
SR-1.9 Max Energy Consumption	Ph					↗					

High Level System Architecture



What is missing?

At this point, at the system level it is missing:

- System Behaviour
- System Parameters
- System safety and Reliability

You can keep elaborating these missing artifacts... Or,
At this point, you can also start elaborating subsystems specifications.

There is no mandatory sequence of activities to follow.

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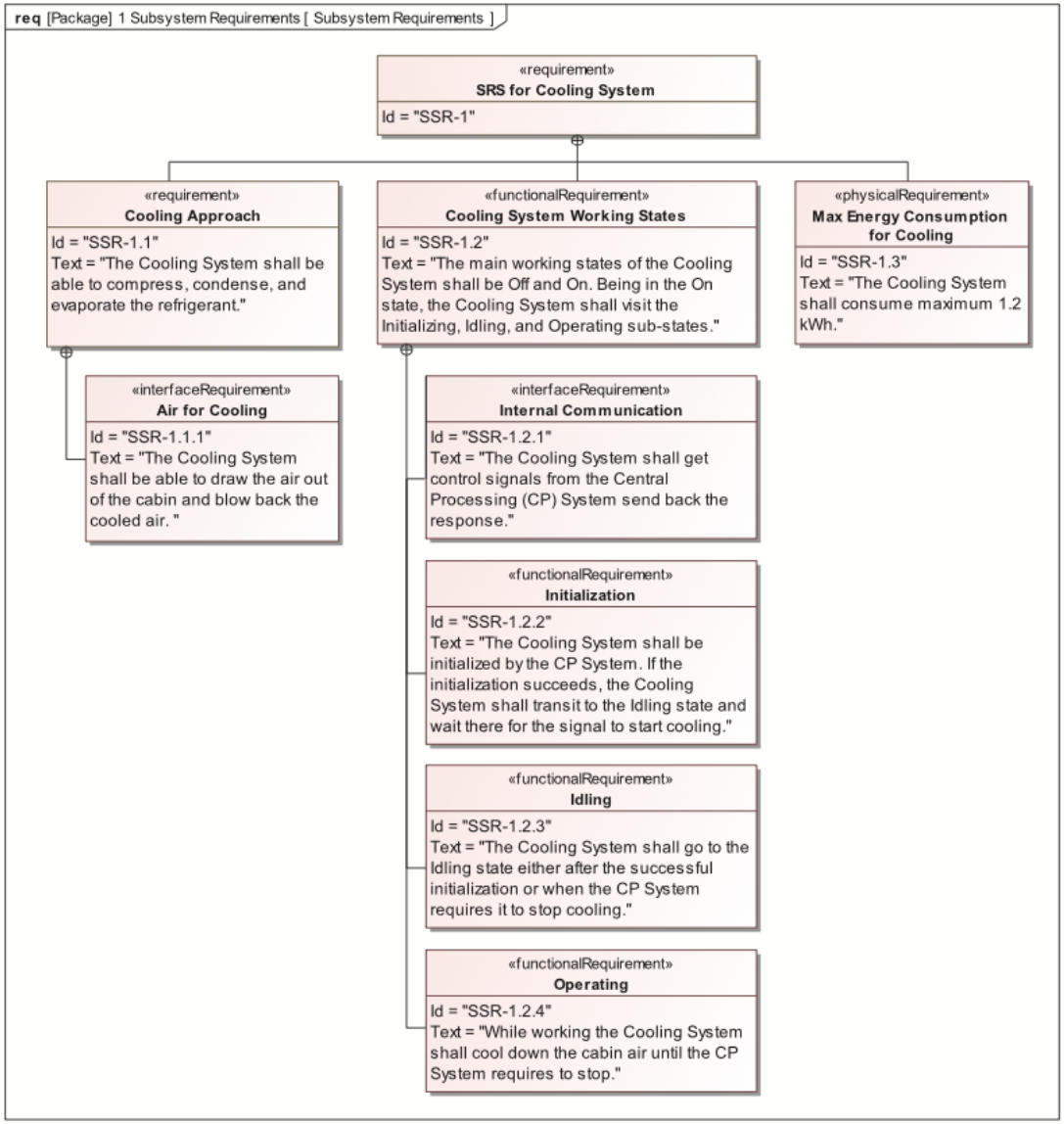
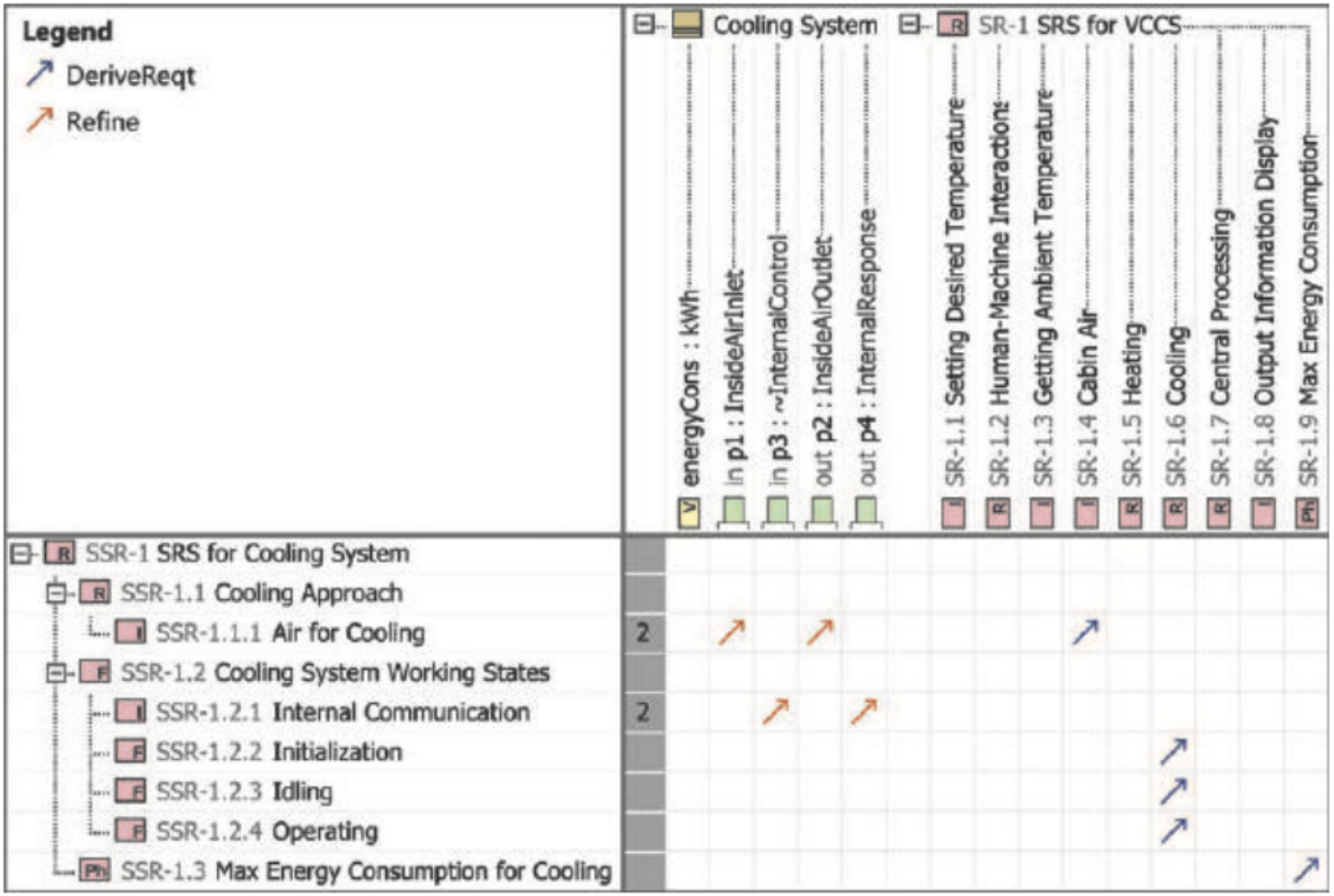
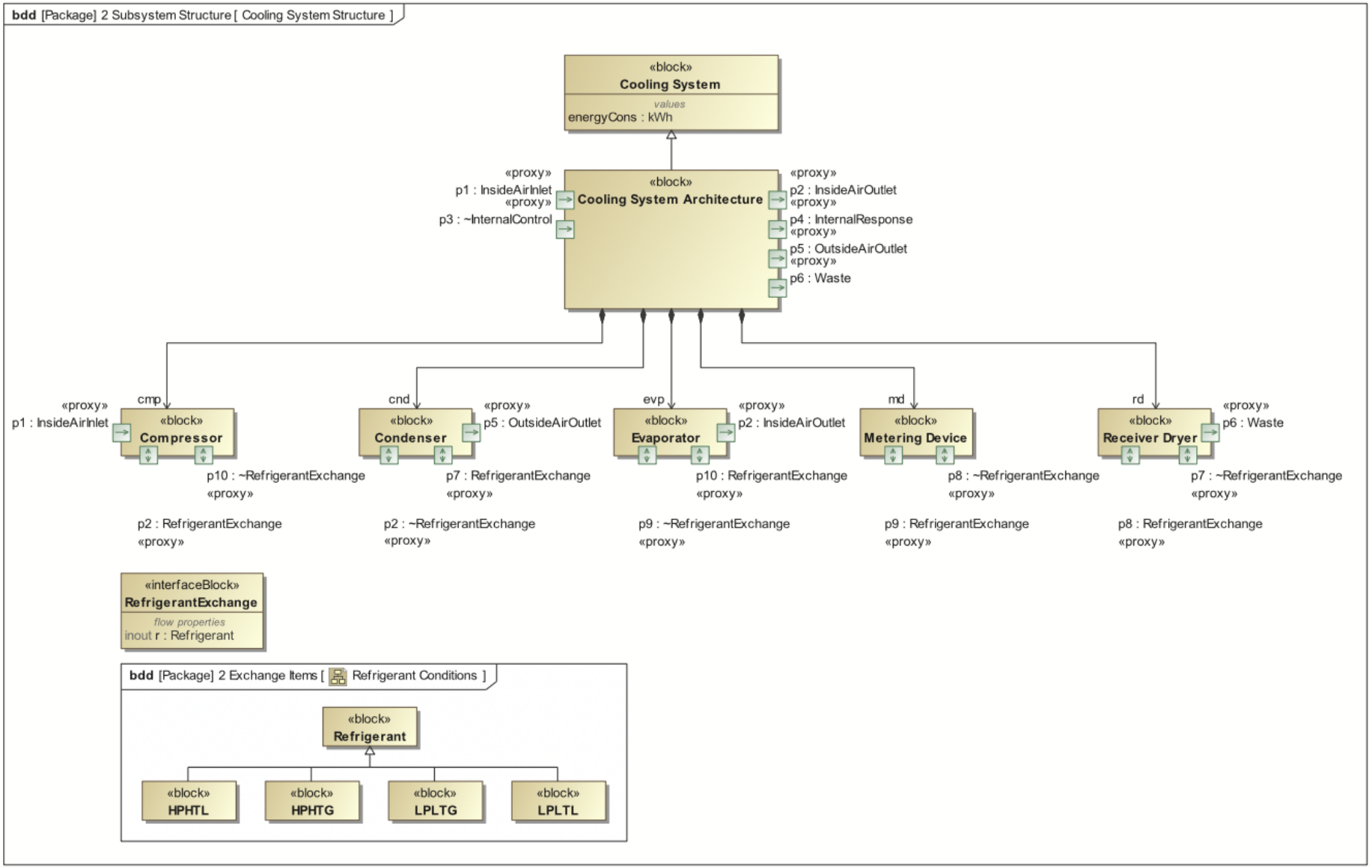
Creating Subsystem Requirements



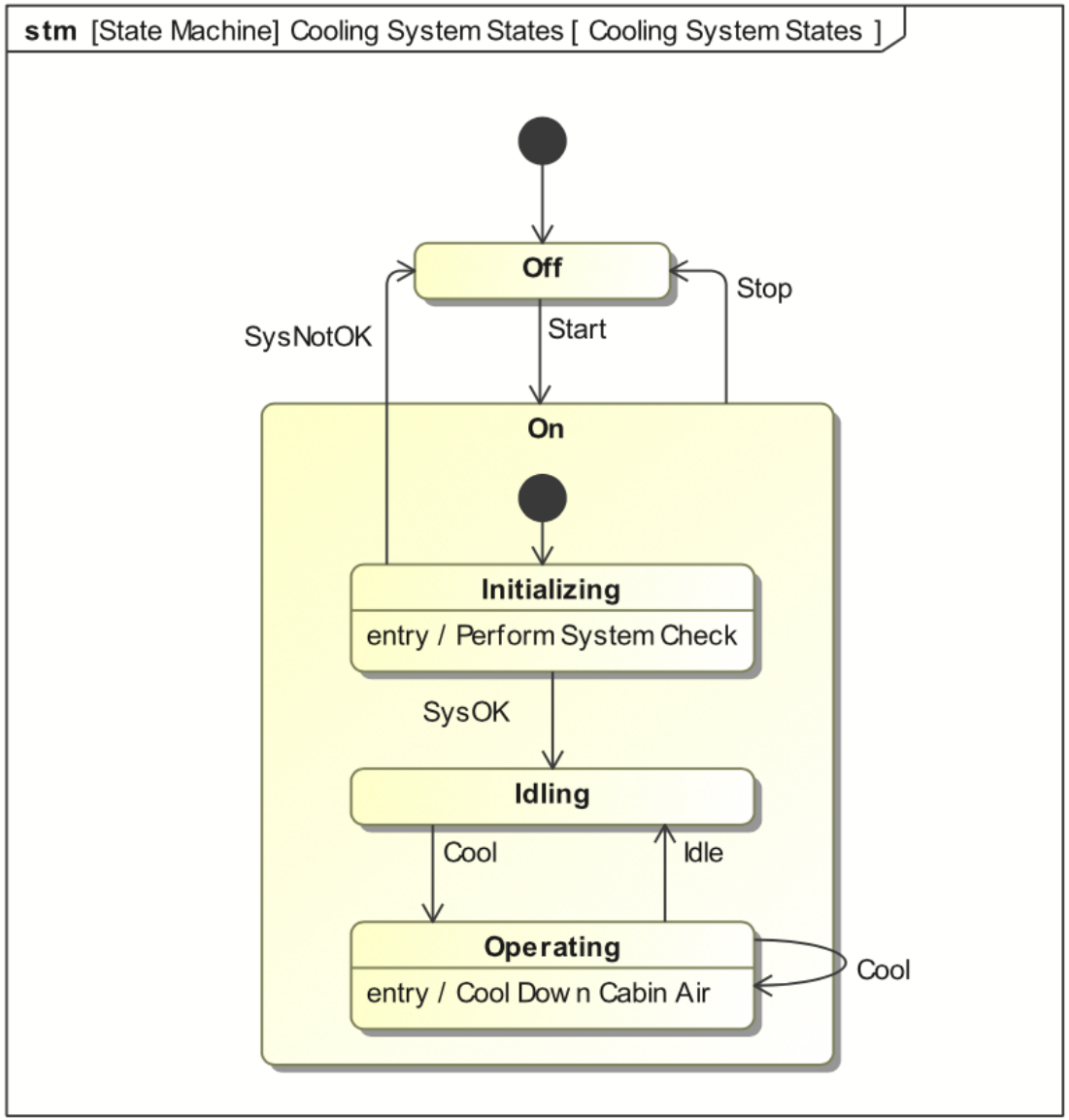
Traceability: Subsystem Requirements to System Requirements



Subsystem Structure



Subsystem Behaviour



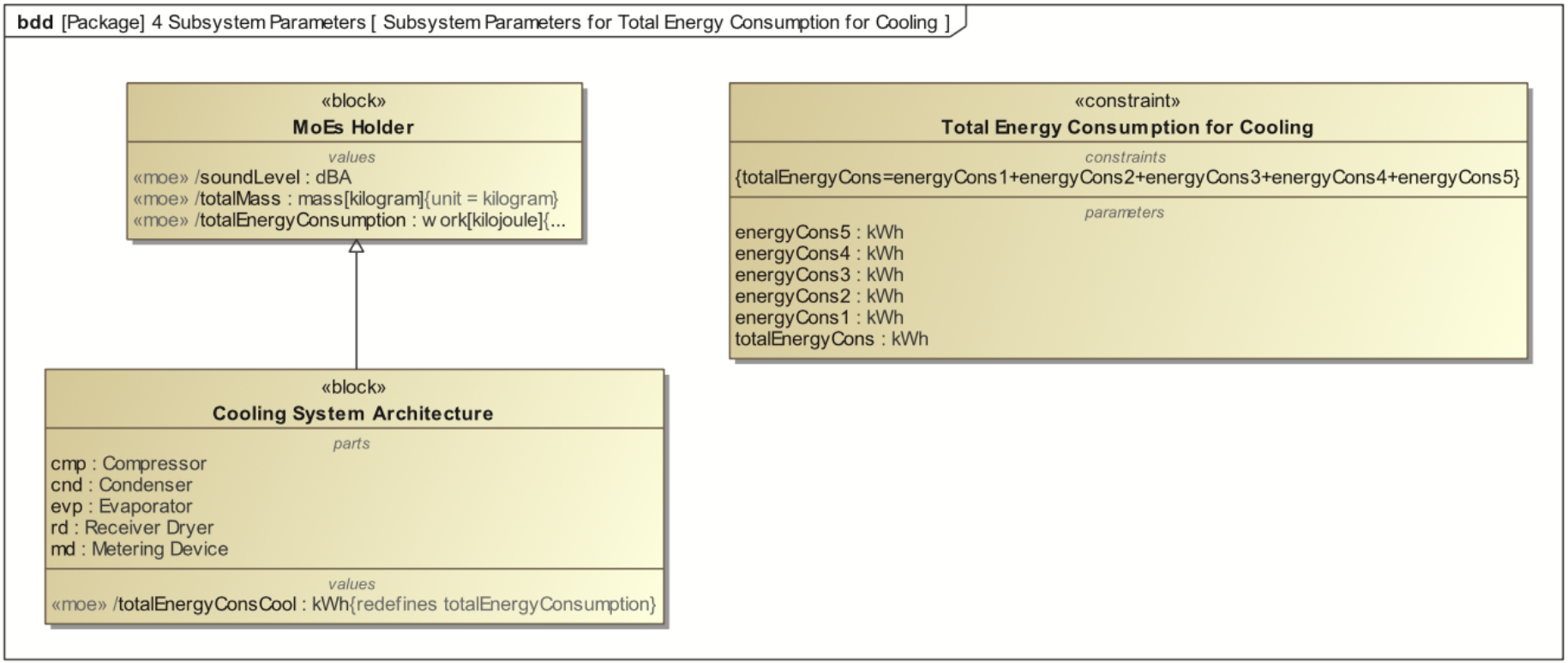
Subsystem Parameters (1/3)

Subsystem parameters:

- Capture quantitative characteristics of the relevant subsystem
- Are used to calculate MoEs

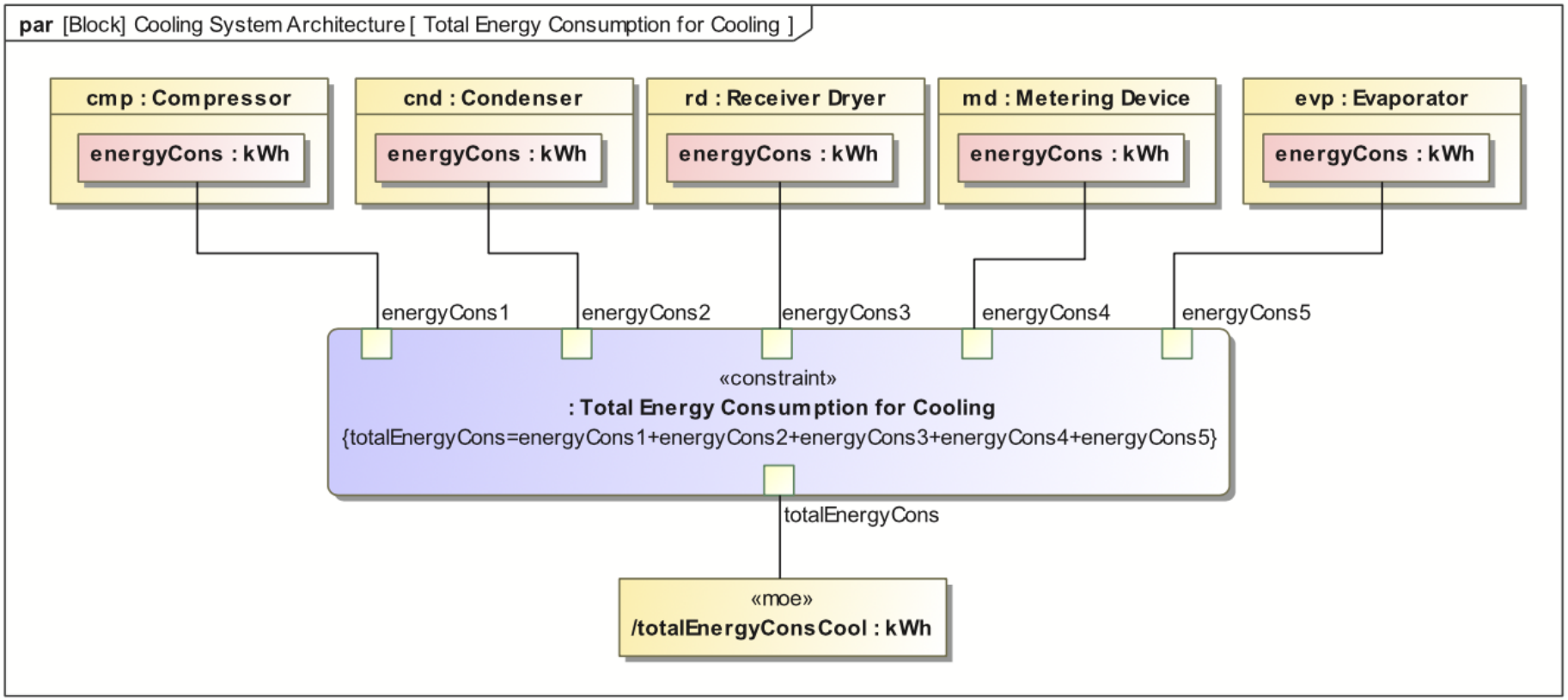
Approach:

- Inheriting from reusable sets of MoEs or, instead, specifying from the scratch
- Capturing parameters as, for instance, Constraint Expression(s)



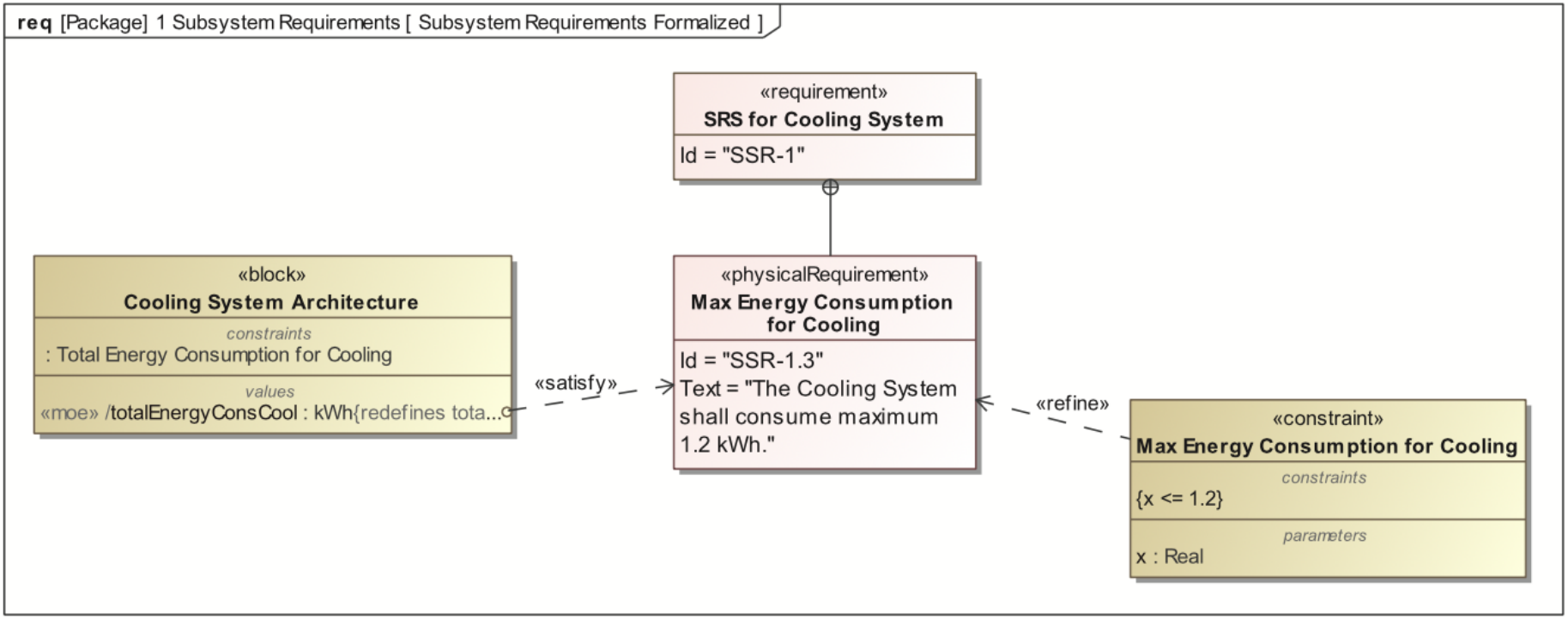
Subsystem Parameters (2/3)

- Detailing a Constraint Expression



Subsystem Parameters (3/3)

- Representing the **satisfy** and the **refine relationships**



Traceability: Subsystem Elements to Subsystem Requirements

Legend

↗ Satisfy

Cooling System Architecture

[Cooling System States]

On

	Off		Idling	Initializing	Perform System Check	:Perform System Check	Operating	Cool Down Cabin Air	:Cool Down Cabin Air	/totalEnergyConsCool : kWh	cmp : Compressor	cnd : Condenser	evp : Evaporator	in p1 : InsideAirInlet	in p3 : ~InternalControl	md : Metering Device	out p2 : InsideAirOutlet	out p4 : InternalResponse	out p5 : OutsideAirOutlet	out p6 : Waste	rd : Receiver Dryer
SSR-1 SRS for Cooling System																					
SSR-1.1 Cooling Approach	5										↙	↙	↙			↙					↙
SSR-1.1.1 Air for Cooling	2													↙			↙				
SSR-1.1.2 Hot Air Removal	1																		↙		
SSR-1.1.3 Waste Removal	1																			↙	
SSR-1.2 Cooling System Working States	2	2	↙	↙																	
SSR-1.2.1 Internal Communication	2														↙			↙			
SSR-1.2.2 Initialization	2	2			2		↙	1	↙												
SSR-1.2.3 Idling	1	1			1	↙															
SSR-1.2.4 Operating	2	2			2					↙	1	↙									
SSR-1.3 Max Energy Consumption for Cooling	1											↙									

Outline

1. Prerequisites
2. Description / Tasks
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   - White-box Perspective
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   - System Level
   - Subsystem Level
   - Safety and Reliability
5. Deadlines

Exploring Safety and Reliability (1/3)

Safety - IEC 61508:2010 EEPE safety-related systems

Safety is freedom from unacceptable risk.

Reliability - ISO/IEC 2382:2015 Information Technology

Reliability is the ability of a functional unit to perform a required function under given conditions for a given time interval.

- Recalling some safety and reliability requirements

#	Name	Text
12	R SN-1.3 Safety & Reliability	
13	R SN-1.3.1 Heat air to the desired temperature in 5 minutes	Heat air to the desired temperature in 5 minutes.
14	R SN-1.3.2 Harm to passenger	
15	R SN-1.3.2.1 Resistance to fire	Climate control unit will not cause fire on its own and will not add to fire started from other causes.
16	R SN-1.3.2.2 Biofouling	Passengers of a car should not be exposed to any toxic materials accumulated in climate control unit.

Exploring Safety and Reliability (2/3)

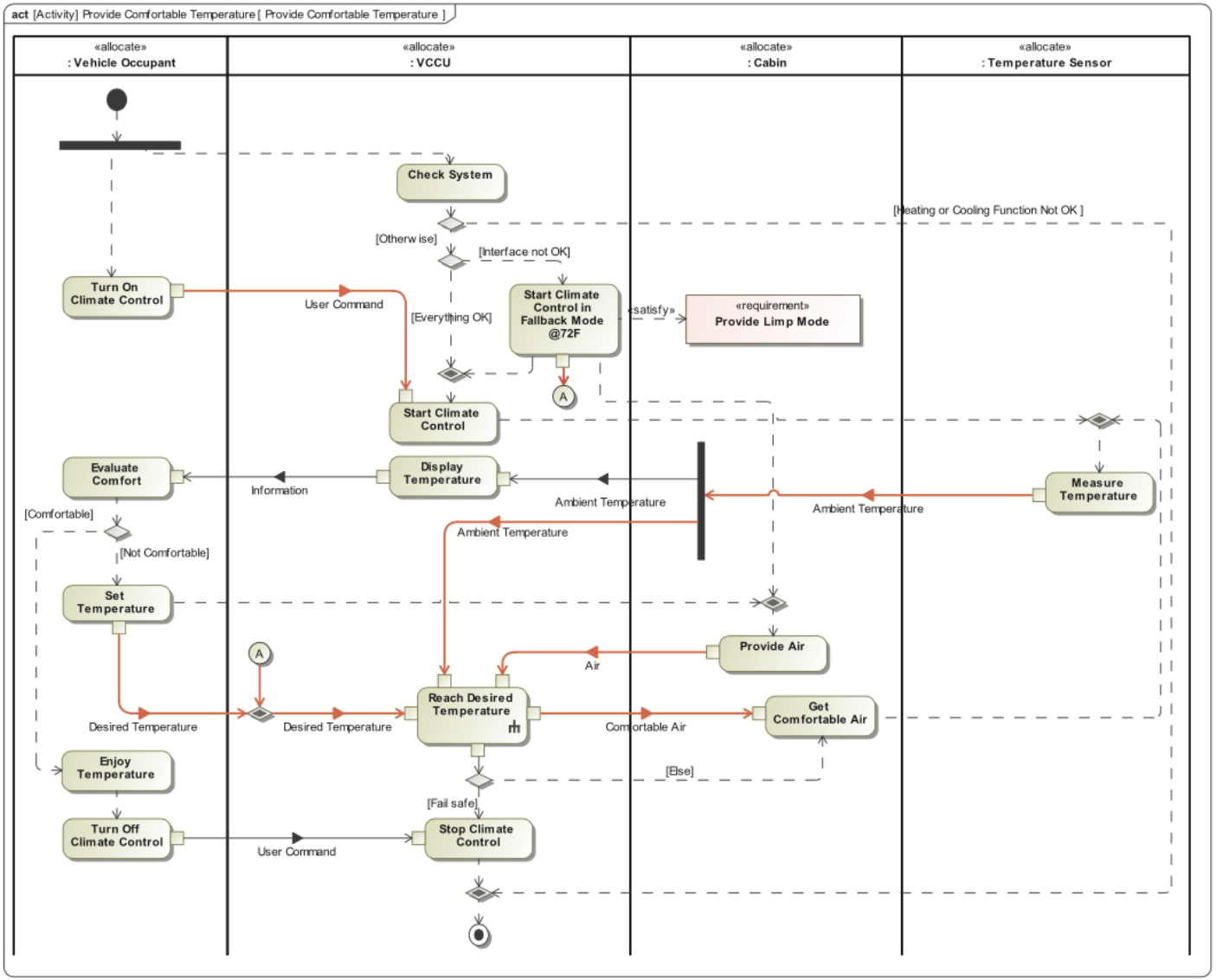
- Refining and/or Adding requirements due to safety and reliability

#	Id	Name	Item	Cause Of Failure	Failure Mode	Local Effect Of Failure	Final Effect Of Failure	Refines	Mitigation
1	F-1	VCCU on fire due to internal fault	: VCCU		VCCU severely overheated	Fire spreads to other systems Emit smoke VCCU not operational Loss of containment	Burns from fire Poisoning from smoke Direct death from fire Accident while driving	SN-1.3.2.1 Resistance to fire	1 Use Flame-Resistent Materials
2	F-2	Allergies	: VCCU	Direct contact of a passenger with toxic materials accumulated in climate control unit.	VCCU unit cannot be operated by a passenger	Emit allergens	Discomfort while operating VCCU Allergic reactions affecting skin or pulmonary system	SN-1.3.2.2 Biofouling	2 Air Filters
3	F-3	Insufficient heating	: VCCU	Insufficient heating power Big difference between ambient and desired temperature	Reduction of function	VCCU not being able to reach required temperature in time	Passengers in unconmfortable temperature due to insufficient heating	SN-1.3.1 Heat air to the desired temperature in 5 minutes	3 Provide Auxiliary Heating

#	Id	Name	Item	Subsystem	Source	Target	Cause Of Failure	Failure Mode	Local Effect Of Failure	Final Effect Of Failure	Refines	Mitigation
1	F-4	Overheating or undercooling when it cannot be turned on	: VCCU	Object Flow[output -> input]	:Turn On Climate Control	:Check System	VCCU does not accept the command to start	Loss of function	VCCU not operational	Passangers overheated or undercooled	Provide Comfortable Temperature	4 Provide Limp Mode
2	F-5	Overheating or undercooling when it does not accept or receive set temperature	: VCCU	Object Flow[-> Desired Temperature]	:Set Temperature	:Reach Desired Temperature	VCCU does not accept or receive set temperature	Loss of function	VCCU not operational	Passangers overheated or undercooled	Provide Comfortable Temperature	4 Provide Limp Mode
3	F-6	Overheating or undercooling when it does not accept or receive ambient temperature measurement	: VCCU	Object Flow[-> Ambient Temperature]	:Measure Temperature	:Reach Desired Temperature	VCCU does not accept or receive ambient temperature measurement	Loss of function	VCCU not operational	Passangers overheated or undercooled	Provide Comfortable Temperature	5 Shut Down the System in Fail-Safe Manner when Unable to Read or Accept Ambient Temperature
4	F-7	Overheating or undercooling when it cannot suck air from cabin	: VCCU	Object Flow[output -> Air]	:Provide Air	:Reach Desired Temperature	VCCU cannot suck air from cabin	Loss of function	VCCU not operational	Passangers overheated or undercooled	Provide Comfortable Temperature	6 Shut Down the System in Fail-Safe Manner when Unable to Suck Air from Cabin
5	F-8	Overheating or undercooling when it cannot blow conditioned air into cabin	: VCCU	Object Flow[Comfortable Air -> input]	:Reach Desired Temperature	:Get Comfortable Air	VCCU cannot blow conditioned air into cabin	Loss of function	VCCU not operational	Passangers overheated or undercooled	Provide Comfortable Temperature	7 Shut Down the System in Fail-Safe Manner when Unable to Blow Conditioned Air into Cabin

Exploring Safety and Reliability (3/3)

- Refining artifacts to handle safety and reliability...



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Project Assignment(s) Deadline(s)

Project assignments are drawn up to be developed by students in a sequential order, i.e., first students develop assignment P1, then assignment P2 and so on...

The foreseen project assignments schedule is depicted in the following table:

Part	Assignment	Release Date	Deadline
1	P1	2024/09/23 (W2)	2024/11/03 (W7)
	P2	2024/09/30 (W3)	2024/11/03 (W7)
	P3	2024/10/14 (W5)	2024/11/03 (W7)
	P4	2024/10/28 (W7)	2024/11/03 (W7)
2	P5	2024/11/04 (W8)	2024/11/24 (W10)

Unless stated otherwise, these deadlines must be honoured.

References & Bibliography I

[1] Aistė Aleksandravičienė and Aurelijus Morkevičius. *MagicGrid Book of Knowledge, A Practical Guide to Systems Modeling using MagicGrid from Dassault Systemes*. 2nd. Vitae Litera, 2021. ISBN: 978-609-454-554-2.

[2] Alexandre Bragança. *Lectures Handouts on Requirements and Model-driven Engineering (RAMDE) 2023/24*. 2023.

Q&A

Questions?

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Thank You!