How Systems Engineering With SysML Helps in Complex Systems Design?

Dr. Saulius Pavalkis
3DS (No Magic, Inc.)

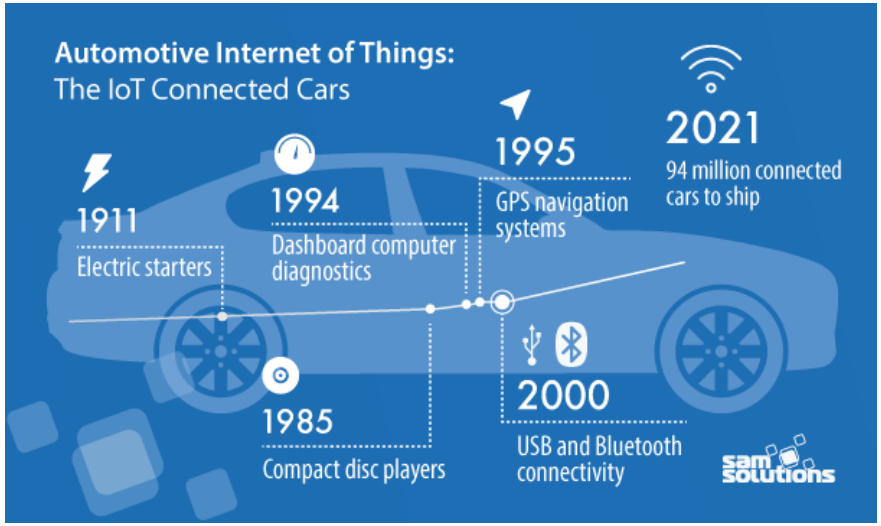
Topics

1. What Drives Complexity Of New Systems Design?
2. Systems Engineering To Manage Complexity
3. Systems Engineering Framework And Method
4. Case Study

WHAT DRIVES COMPLEXITY OF NEW SYSTEMS DESIGN?

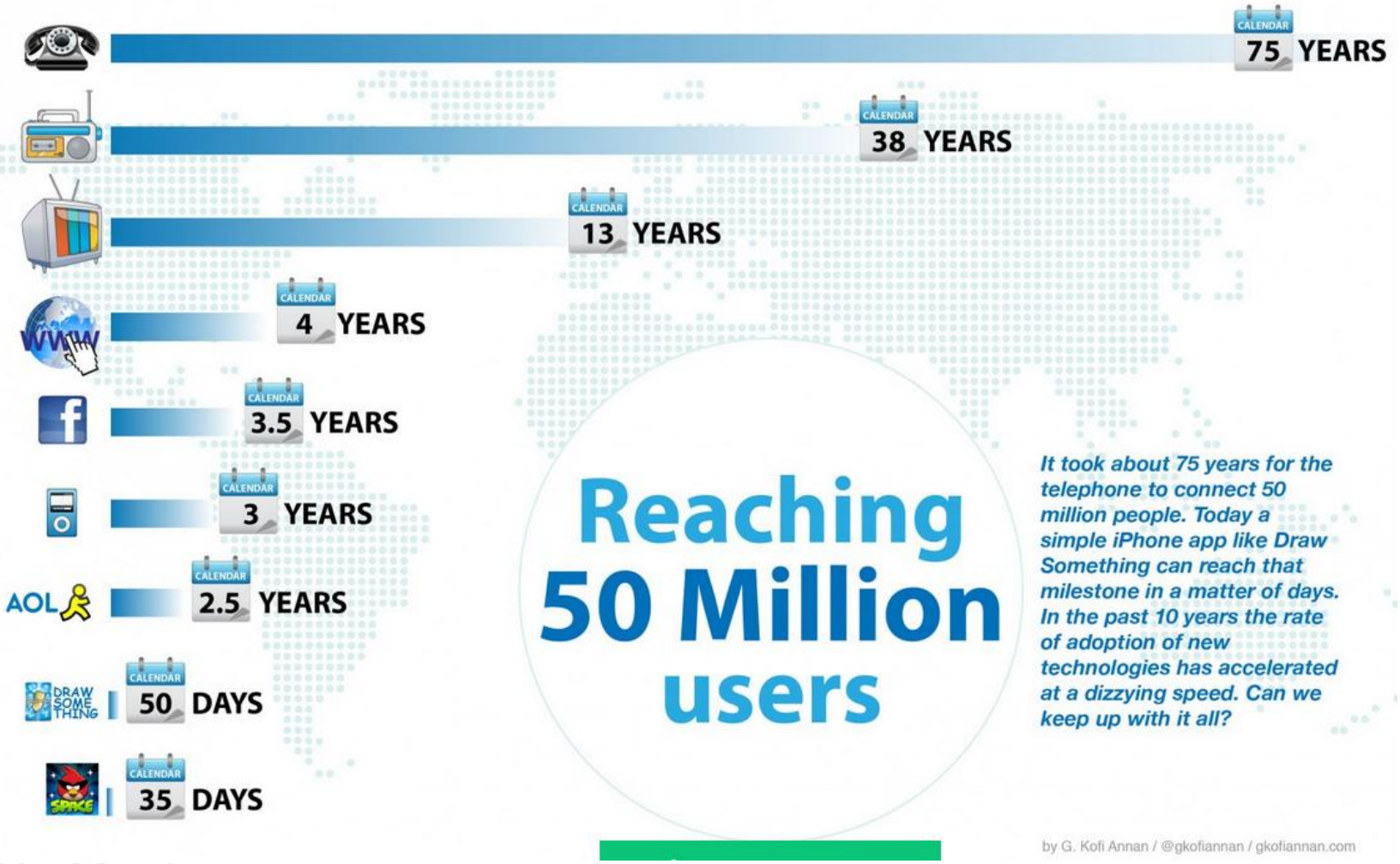
New Systems Challenges: What Drives Complexity?

- Cyber Components (Electrical, Software, Mechanical)
- Software Centric



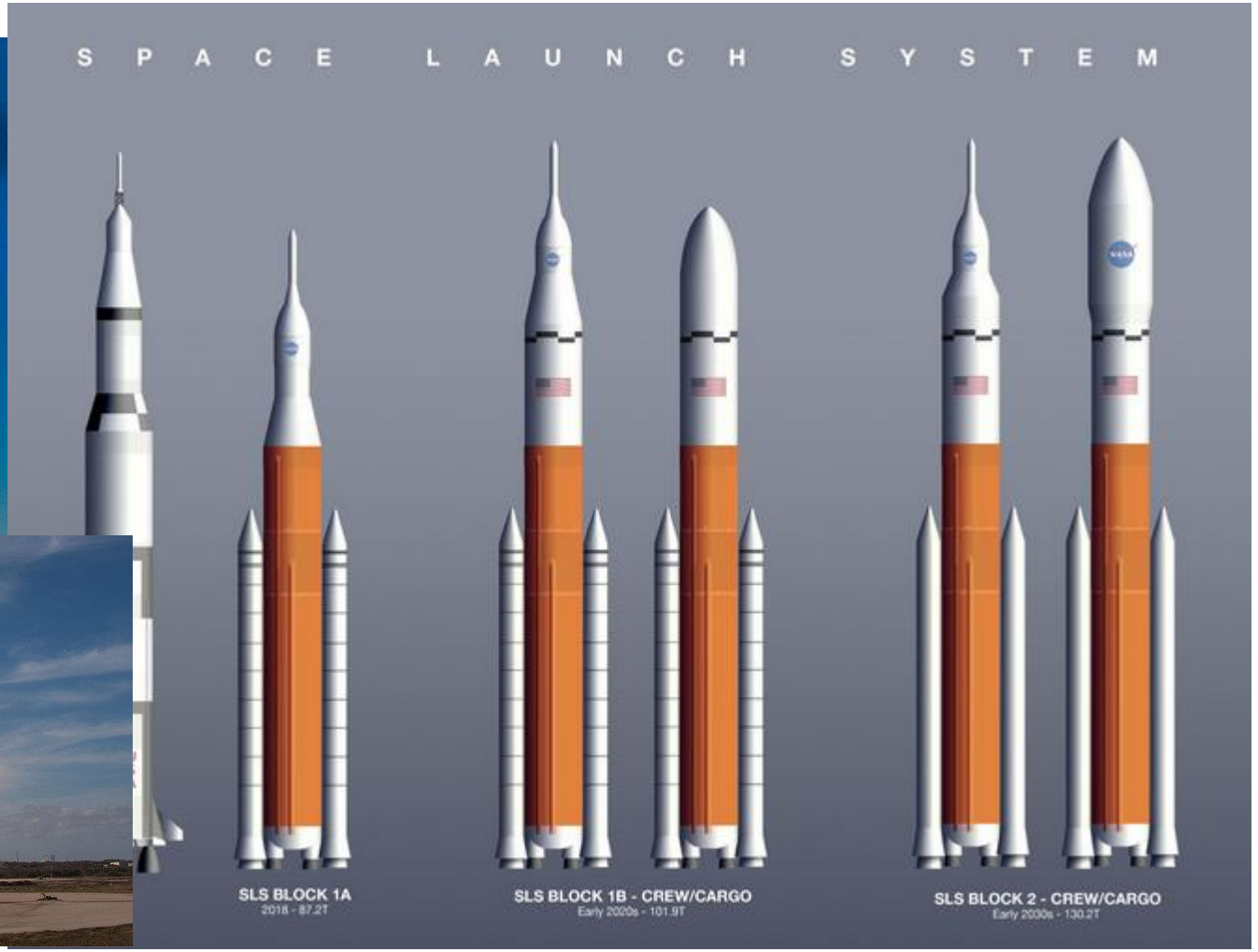
New Systems Challenges: What Drives Complexity?

- **Short Time to Market**



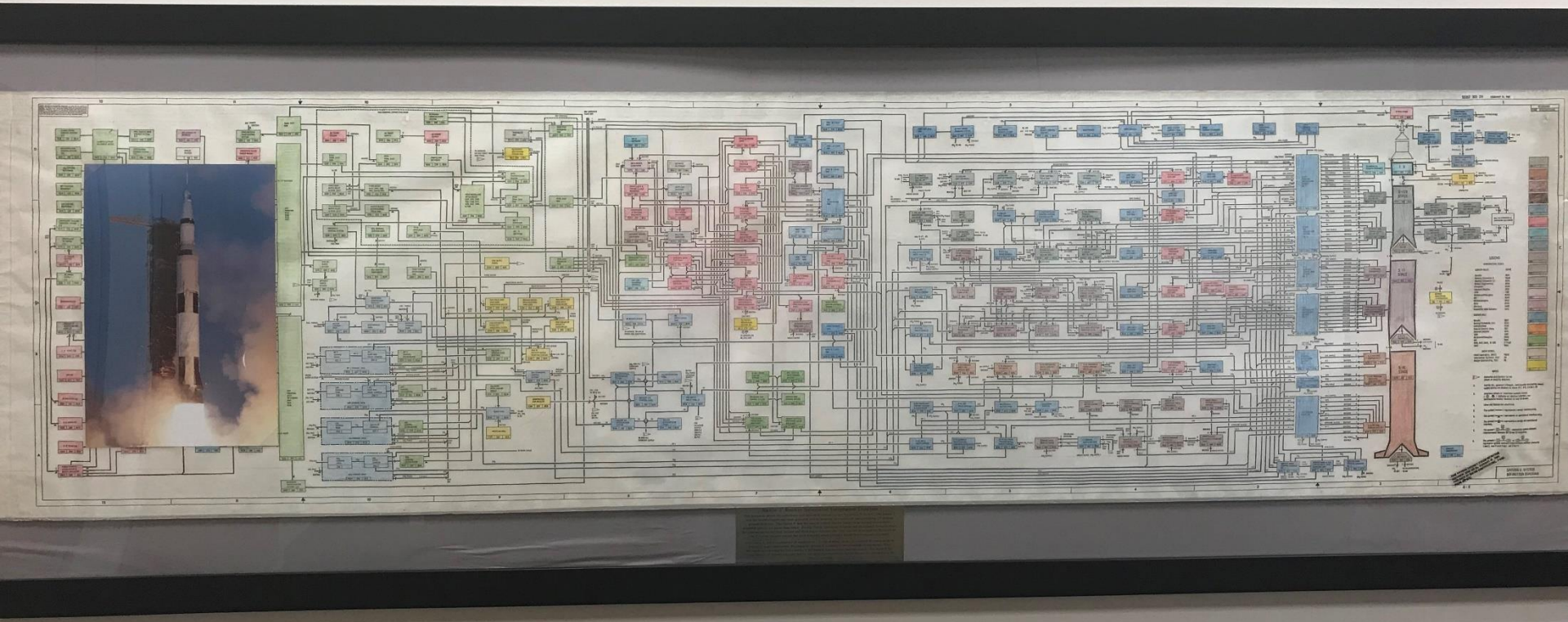
New Systems Challenges: What Drives Complexity?

- **Limited Resources**



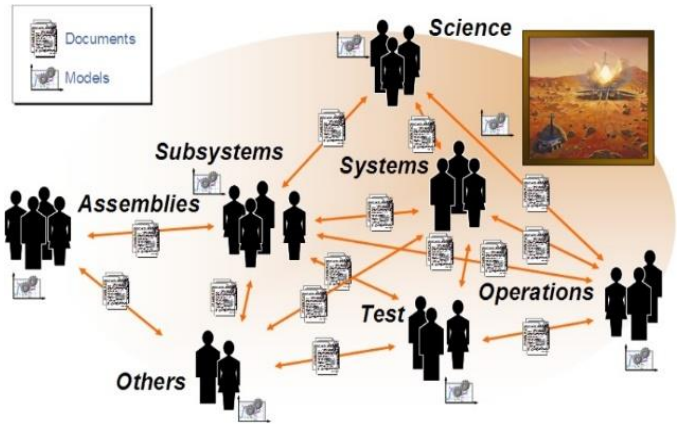
SYSTEMS ENGINEERING TO MANAGE COMPLEXITY

What is Model Based Systems Engineering (MBSE)?

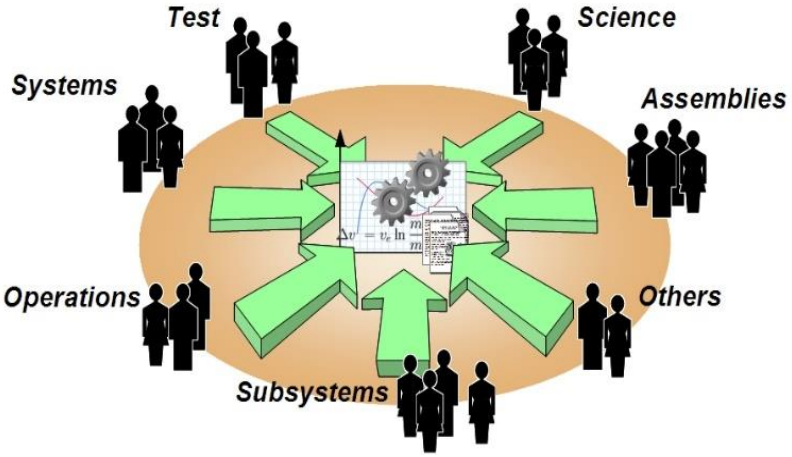


What Makes MBSE Different

- It helps avoid catastrophic mistakes by enhancing and significantly lowering the costs of feasibility studies, tradeoff analysis, and impact analysis
- The entire specification set about the system that the model captures is an interconnected network of information
- As opposed to being spread out in non-searchable and non-navigable set of documents that require dedicated staff to manage

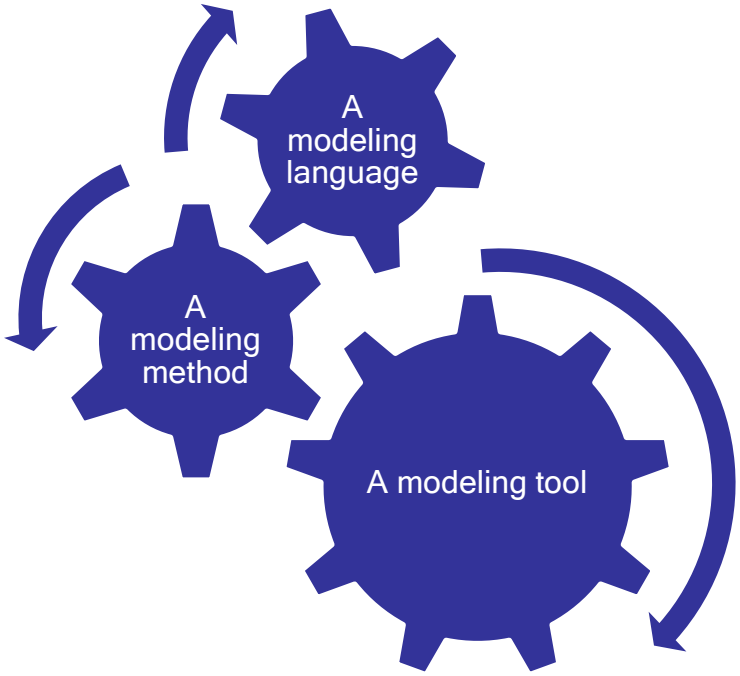


Today: Standalone models related through documents



Future: Shared system model with multiple views, and connected to discipline models

How do you do MBSE?

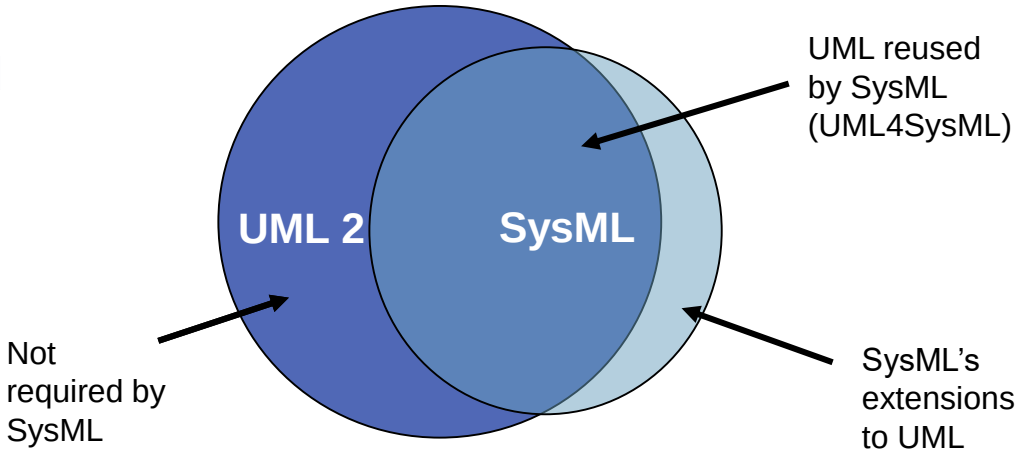


MBSE is a combination of a modeling language(s), a methodology, a modeling tool, and people that using infrastructure apply Model Driven Development in the context of a particular organization.

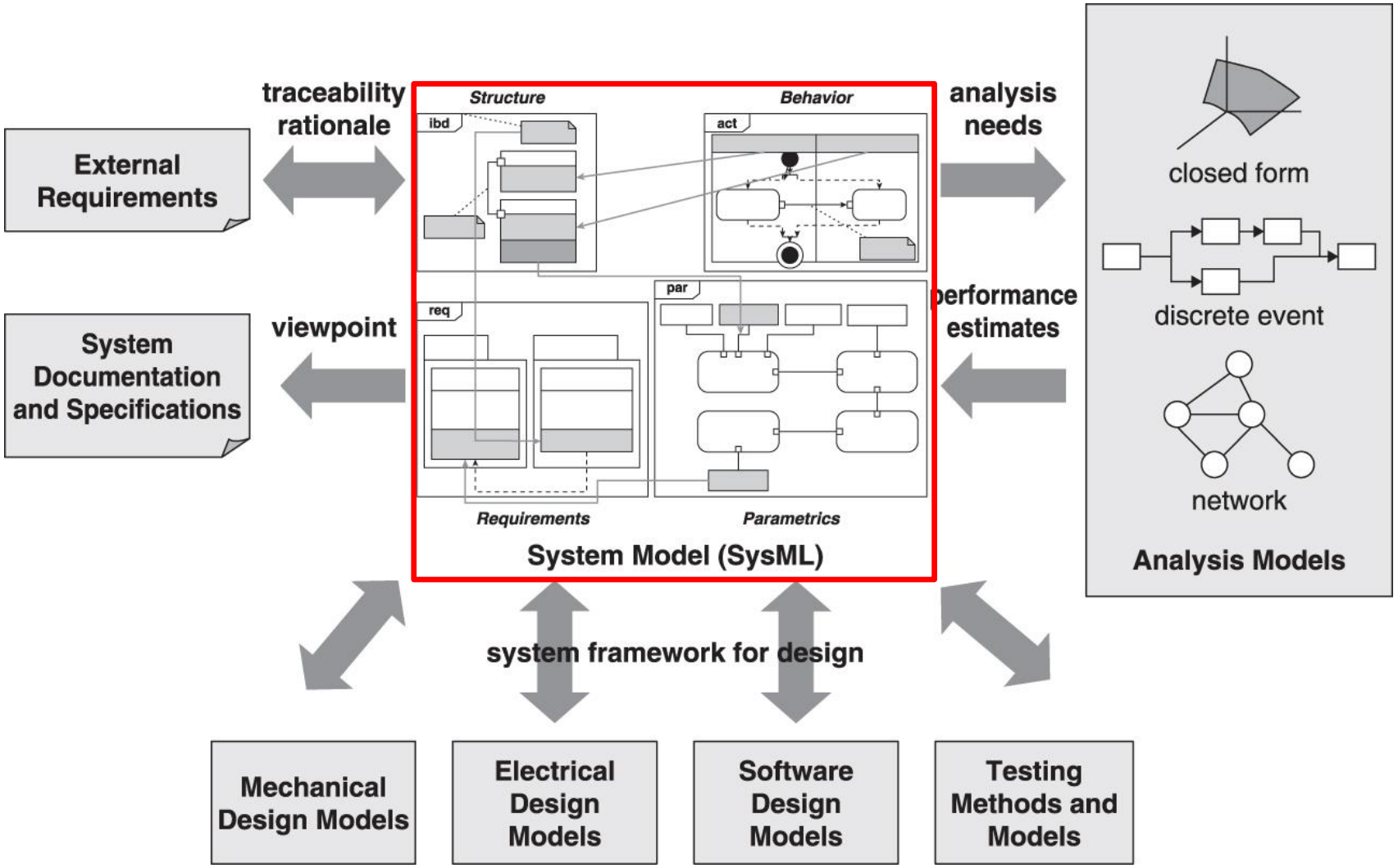
SysML Language

- Systems Modeling Language (SysML) is a graphical modeling language for specification, analysis, design, verification and validation of systems.
- Developed by OMG and INCOSE / Adopted by OMG in May 2006
- ISO Standard
- Cover the latest SysML version 1.5, active work is done on 2.0

Tutorial, specifications, papers, and vendor info can be found on the OMG SysML Website at
http://www.omgsysml.org/

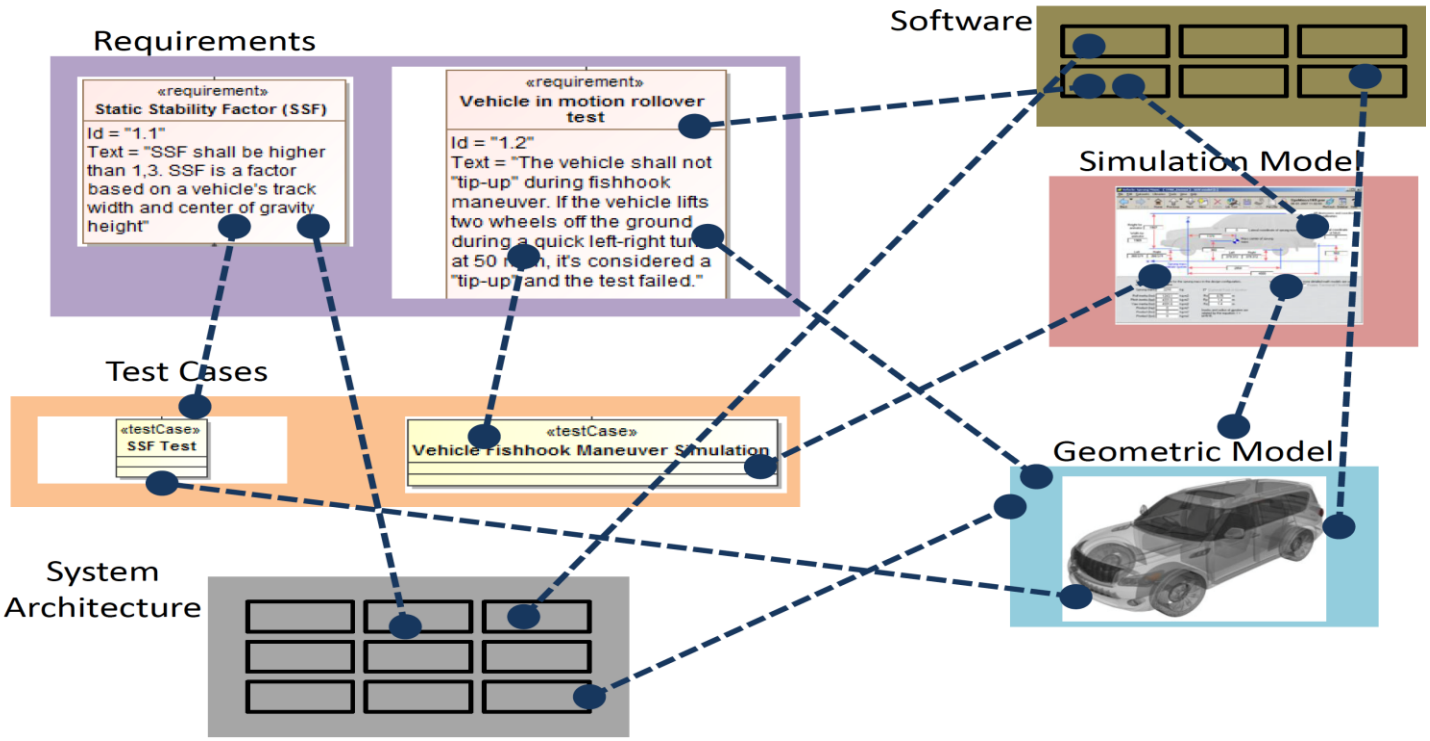


System Model as an Integration Framework



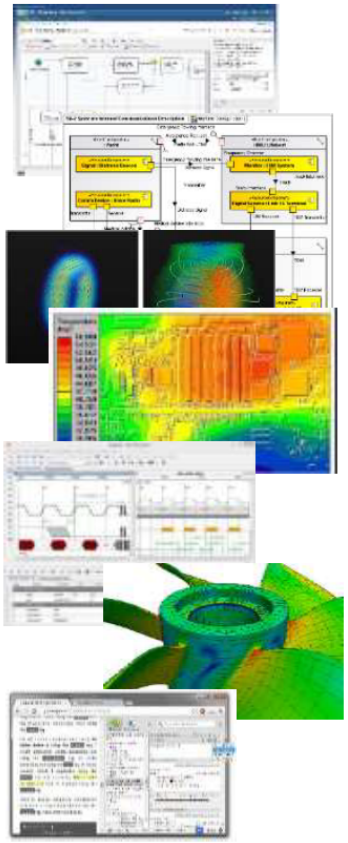
© 2012-2014 by Sanford Friedenthal

An Interconnected Network of Information

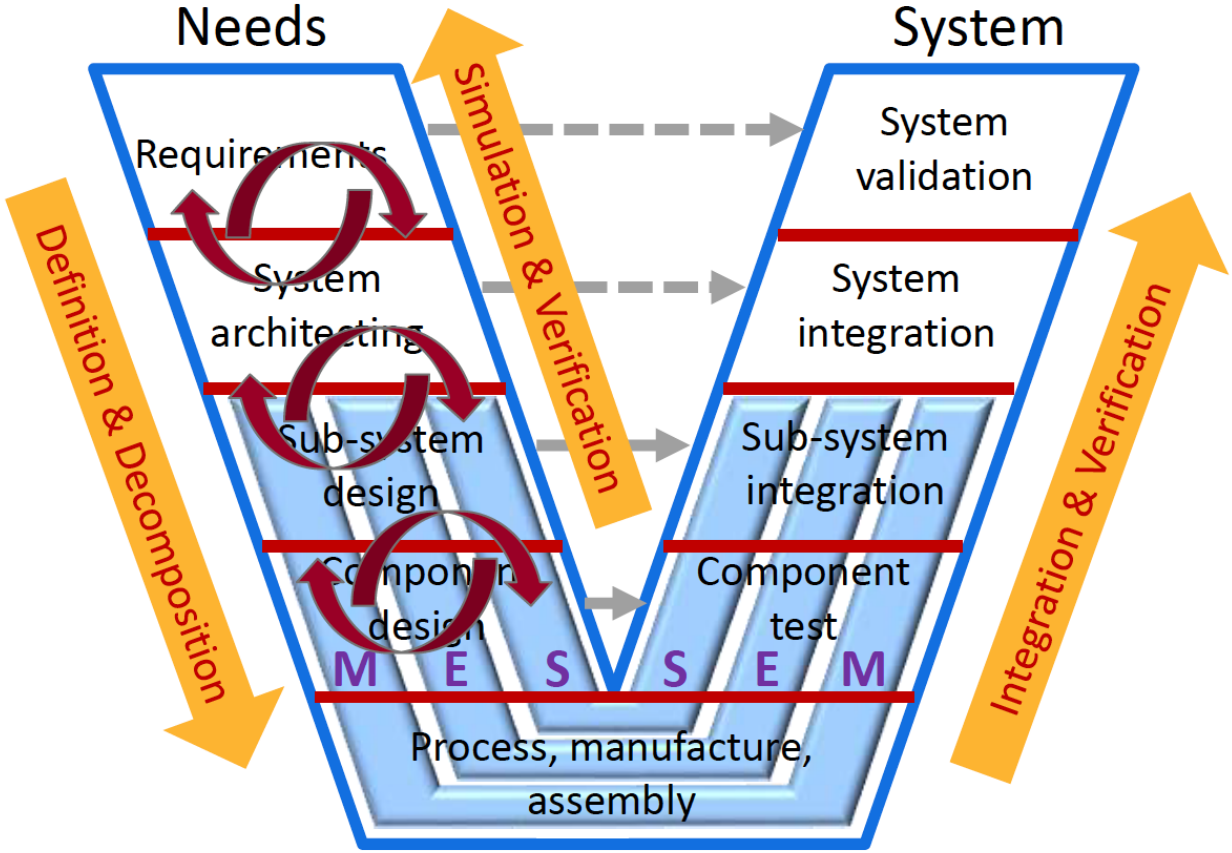


SYSTEMS ENGINEERING FRAMEWORK AND METHOD

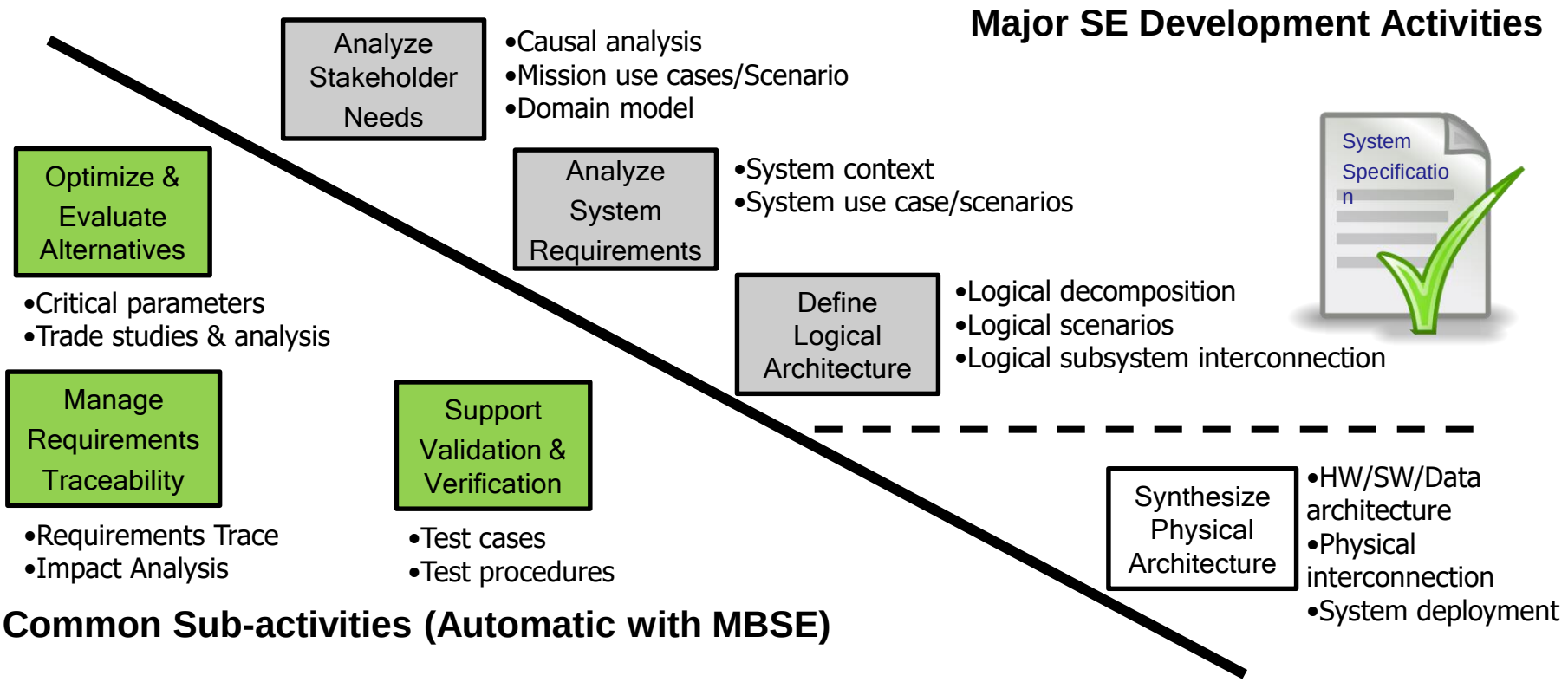
System engineering process (V process)



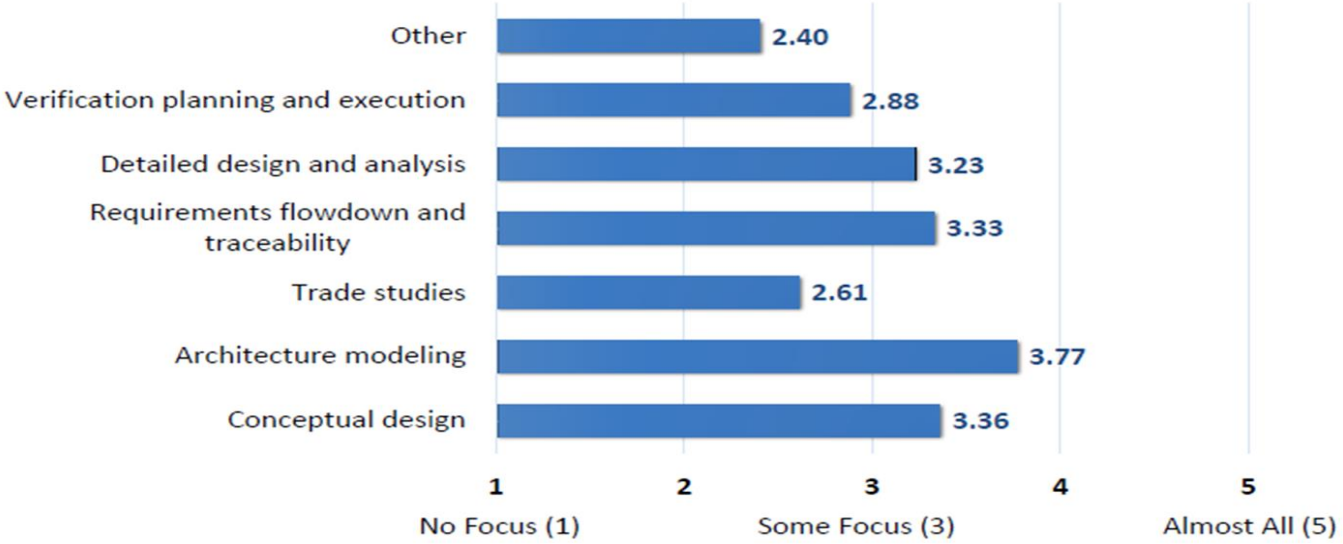
REQ model
SysML model
Simulation
AML/Software
MCAD
ECAD
Timing
Thermal
Stress
etc.



Systems Engineering Activity

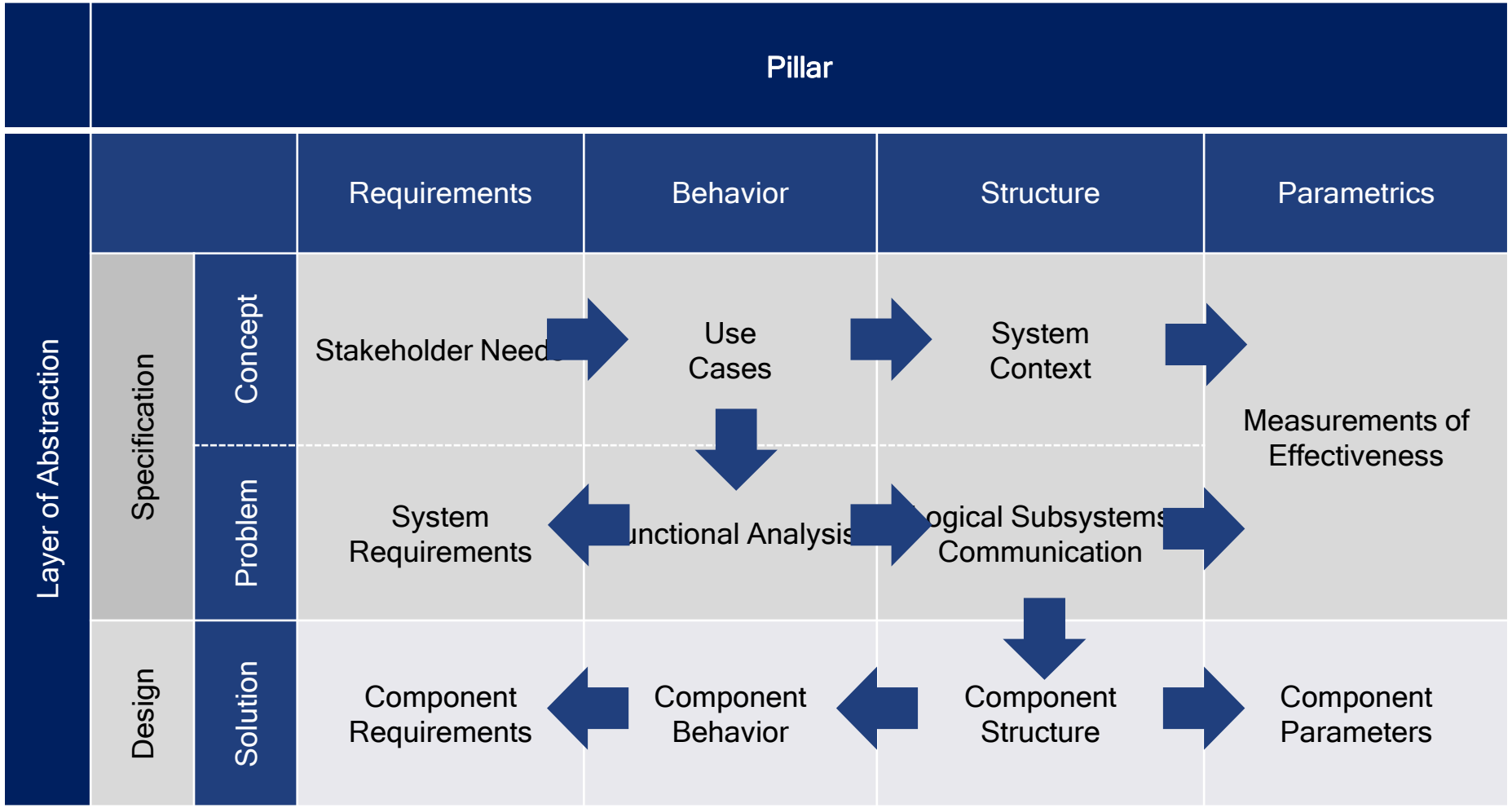


MBSE Focus SE Activities



Tower. James. 2013. " Model Based Systems Engineering 'The State of the Nation'" INCOSE UK ASEC 2013

MagicGrid


Pillar
Layer of Abstraction
Requirements
Behavior
Structure
Parametrics
Specification
Concept
Problem
Design
Solution
Stakeholder Needs
Use Cases
System Context
Measurements of Effectiveness
System Requirements
Functional Analysis
Logical Subsystems Communication
Component Requirements
Component Behavior
Component Structure
Component Parameters

CASE STUDY

Case Study of CAR Climate Control

- The CAR Climate Control case study follows the MagicGrid approach to describe the concept, problem, and Solution
- The model of the case study is based on SysML 1.4 and created with MagicDraw CASE tool

Stakeholder Needs

Layer of Abstraction		Pillar: Requirements	Pillar: Behavior	Pillar: Structure	Pillar: Parametrics
	Concept	C1 Stakeholder Needs	C2 Use Cases	C3 System Context	C4-P4 Measurements of Effectiveness
	Problem	P1 System Requirements	P2 Functional Analysis	P3 Logical Subsystems Communication	
	Solution	S1 Component Requirements	S2 Component Behavior	S3 Component Structure	S4 Component Parameters

Stakeholder Needs

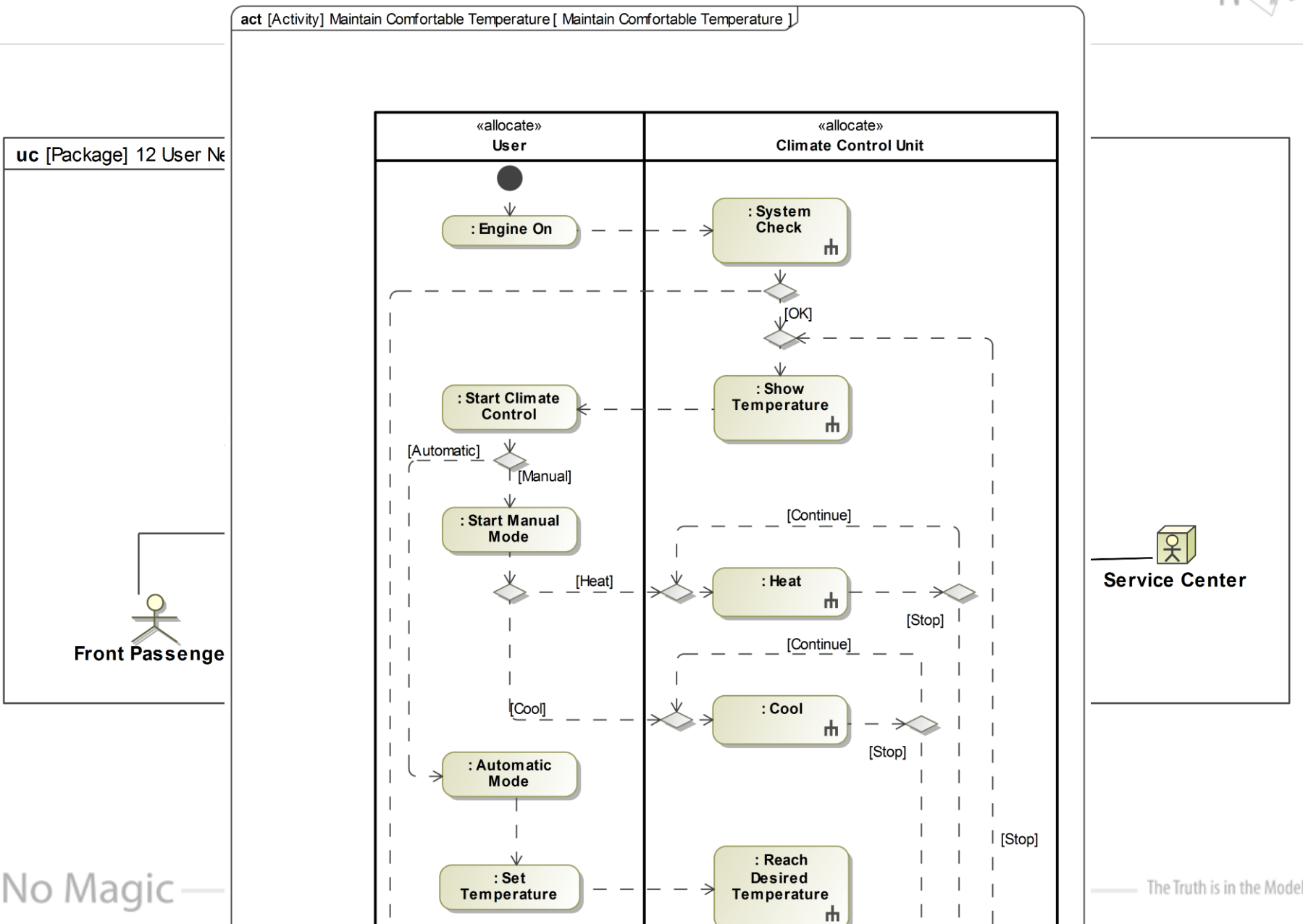
- The cell represents information gathered from all the stakeholders of the system
- It includes primary user requirements, government regulations, policies, procedures, etc.
- The later refinements in the model make these stakeholder needs structured and formalized

#	Id	Name	Text	Source
1	STN1	STN1 Vehicle Parameters	CAR AC will be used for average midsize vehicle	Marketing dep.
2	STN2	STN2 Climate Control Mass	Mass of unit shall not be bigger than 5 percent of total car mass	Design dep.
3	STN3	STN3 Driver and Passenger Needs	Unit shall be accommodate different driver and frond passenger climate needs	Marketing dep.
4	STN4	STN4 Set Temperature	Possible to set and maintain wanted cabin temperature	Design dep.
5	STN5	STN5 Heat and Cool Modes	Shall be able to heat and cool	Design dep.
6	STN6	STN6 Working Climate Control	The Climate Control Unit shall work whenever client wants	Marketing dep.
7	STN7	STN7 Maintenance	The Climate Control Unit maintenance shall be done in terms which are in market average range	Design dep.
8	STN8	STN8 Noise Level	Climate control unit in max mode shall not be louder than engine	Standard regulation
9	STN9	STN9 Development	Unit development time shall not be more than one year of team working hours after proje start	Design dep.
10	STN10	STN10 Price	Price of the unit shall not be bigger than 2 percent of total car cost	Marketing dep.
11	STN11	STN11 Connected system	Service center shall get information if CAR AC parameters are out of norm	Marketing dep.

Use Cases

Layer of Abstraction		Pillar			
		Requirements	Behavior	Structure	Parametrics
Concept		C1 Stakeholder Needs	C2 Use Cases	C3 System Context	C4-P4 Measurements of Effectiveness
Problem		P1 System Requirements	P2 Functional Analysis	P3 Logical Subsystems Communication	
Solution		S1 Component Requirements	S2 Component Behavior	S3 Component Structure	S4 Component Parameters

Use Cases

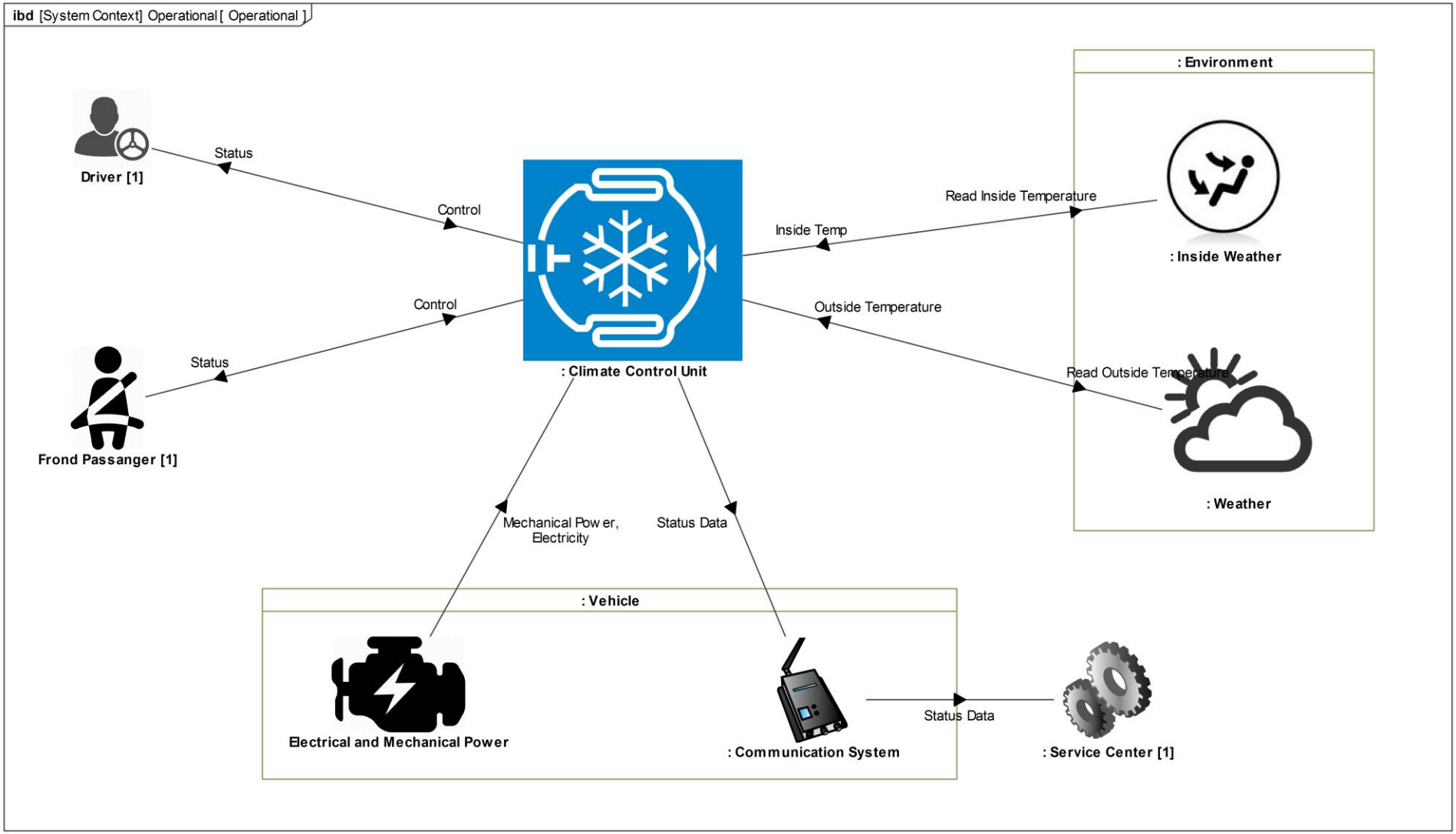

uc [Package] 12 User Ne
Front Passenge
Service Center
act [Activity] Maintain Comfortable Temperature [Maintain Comfortable Temperature]
«allocate»
User
«allocate»
Climate Control Unit
: Engine On
: System Check
[OK]
: Start Climate Control
: Show Temperature
[Automatic]
[Manual]
: Start Manual Mode
[Continue]
[Heat]
: Heat
[Stop]
[Continue]
[Cool]
: Cool
[Stop]
: Automatic Mode
[Stop]
: Set Temperature
: Reach Desired Temperature

System Context

Layer of Abstraction		Pillar			
		Requirements	Behavior	Structure	Parametrics
Concept		C1 Stakeholder Needs →	C2 Use Cases →	C3 System Context	C4-P4 Measurements of Effectiveness
Problem		P1 System Requirements	P2 Functional Analysis	P3 Logical Subsystems Communication	
Solution		S1 Component Requirements	S2 Component Behavior	S3 Component Structure	S4 Component Parameters

© 2016 No Magic, Inc. Exclusively for No Magic Use

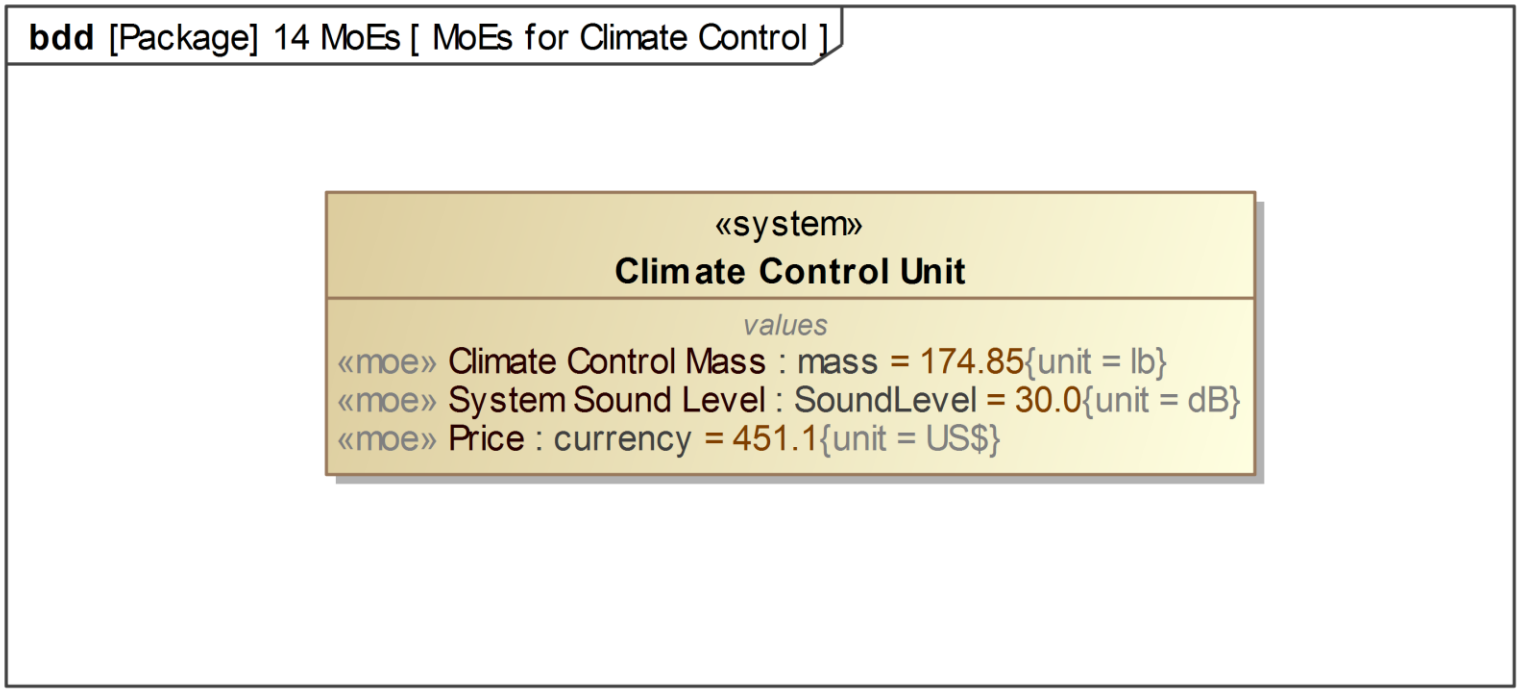
System Context



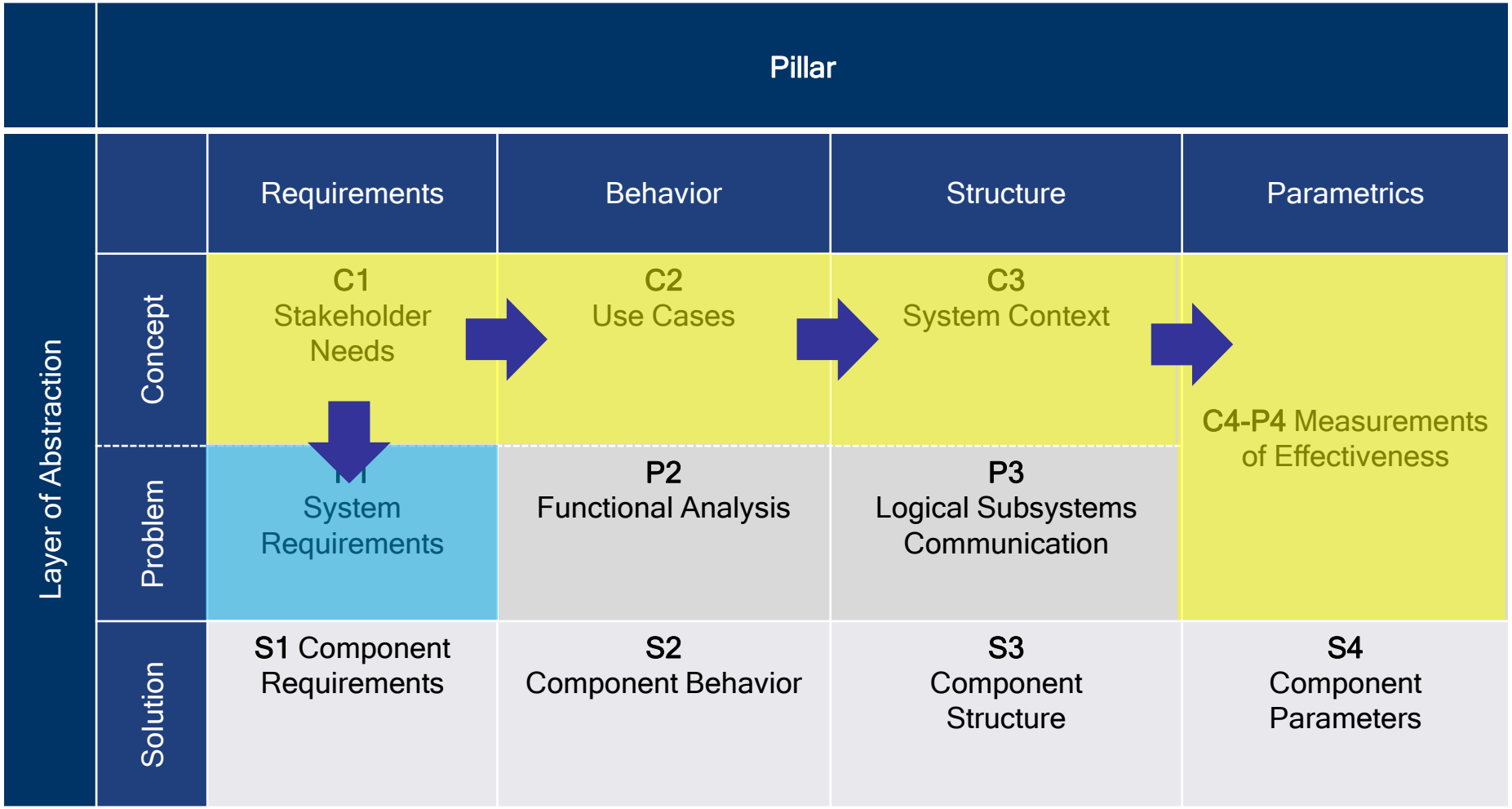
Measurements of Effectiveness (MoEs)

Layer of Abstraction		Pillar: Requirements	Pillar: Behavior	Pillar: Structure	Pillar: Parametrics
Concept		C1 Stakeholder Needs →	C2 Use Cases →	C3 System Context →	C4-P4 Measurements of Effectiveness
Problem		**P1** System Requirements	**P2** Functional Analysis	**P3** Logical Subsystems Communication	
Solution		**S1** Component Requirements	**S2** Component Behavior	**S3** Component Structure	**S4** Component Parameters

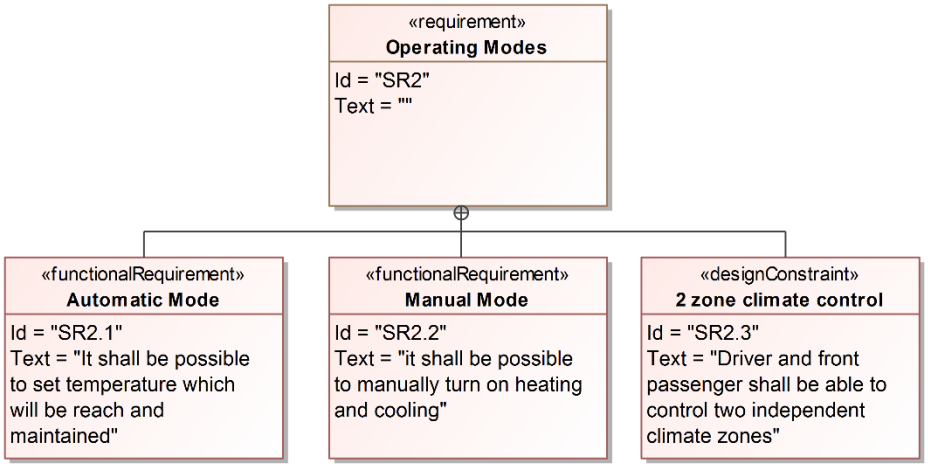
Measurements of Effectiveness (MoEs)



System Requirements

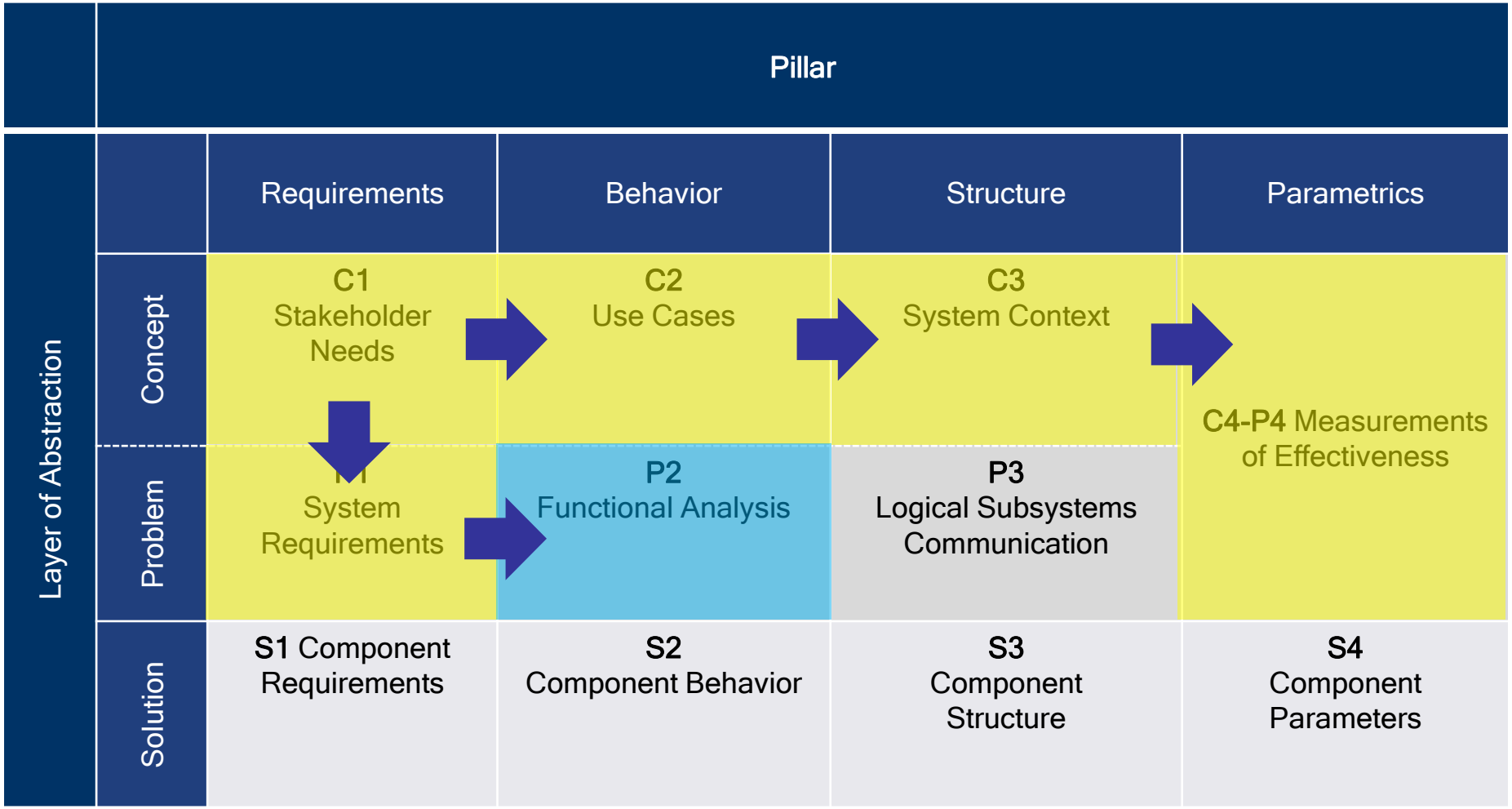


System Requirements

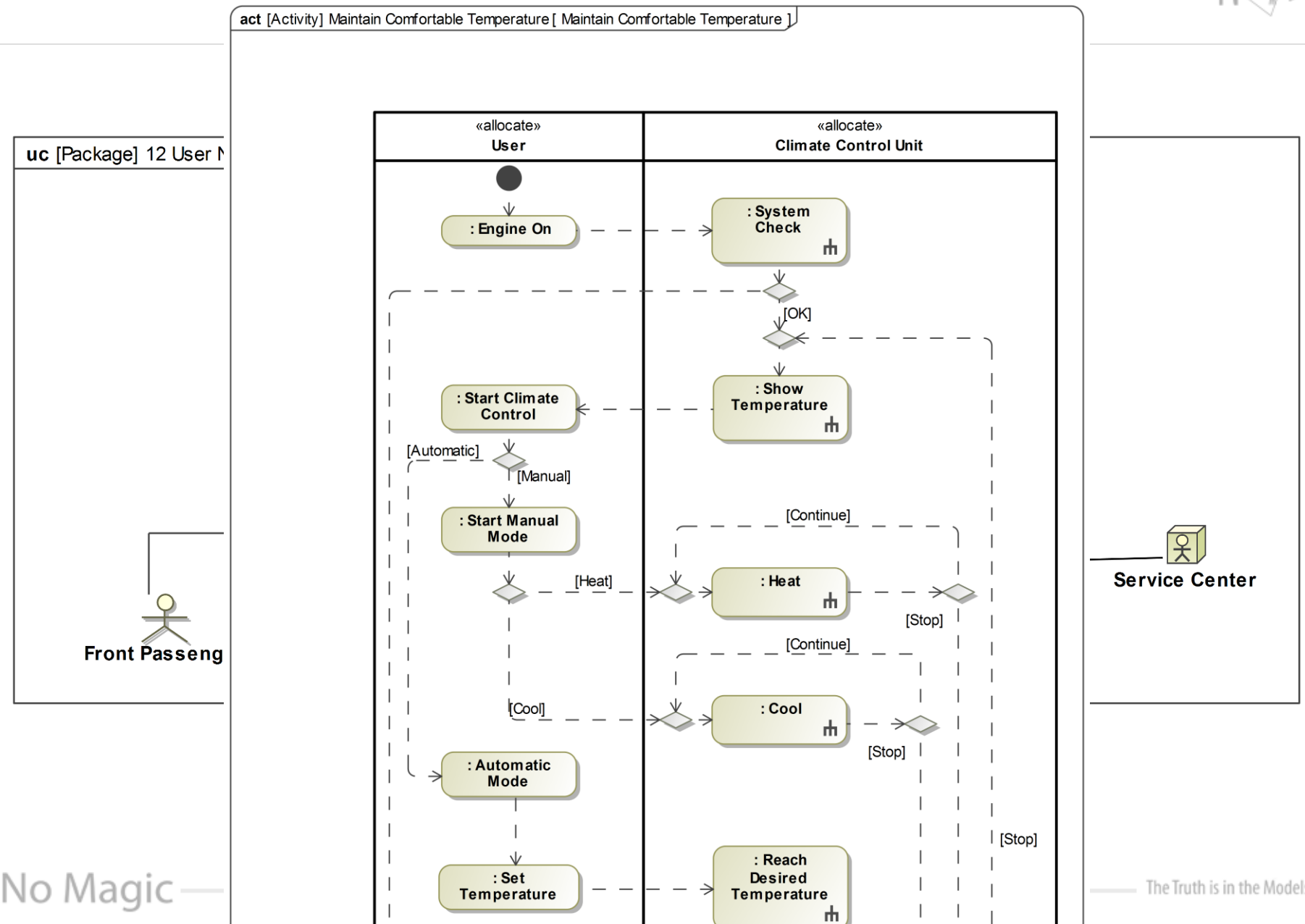


#	Name	Text	Derived From
1	R SR2 Operating Modes		
2	F SR2.1 Automatic Mode	It shall be possible to set temperature which will be reach and maintained	F STN4 Set Temperature
3	F SR2.2 Manual Mode	it shall be possible to manually turn on heating and	F STN5 Heat and Cool Modes
4	D SR2.3 2 zone climate control	Driver and front passenger shall be able to control two independent climate zones	D STN3 2 zone Climate Control

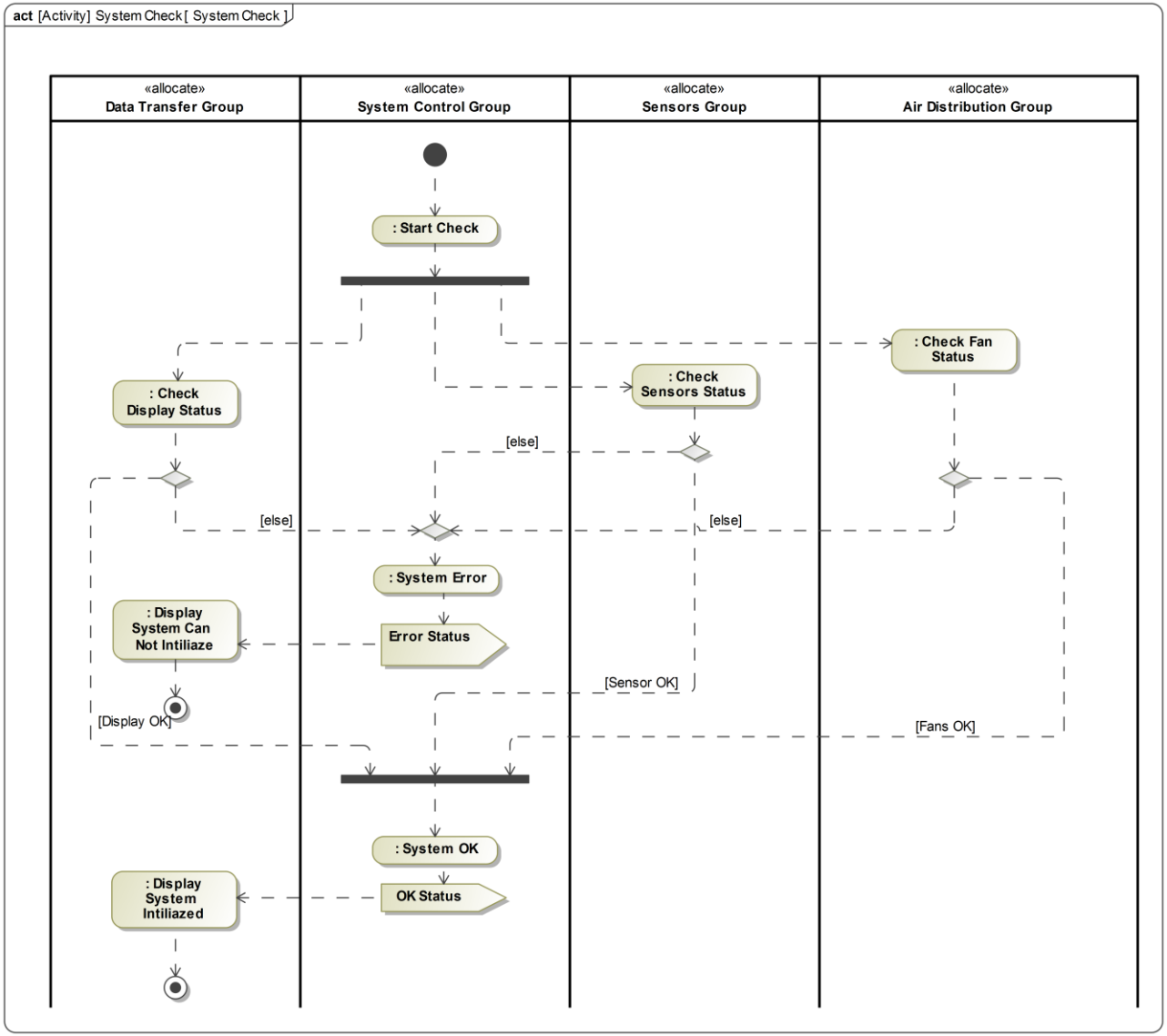
Functional Analysis



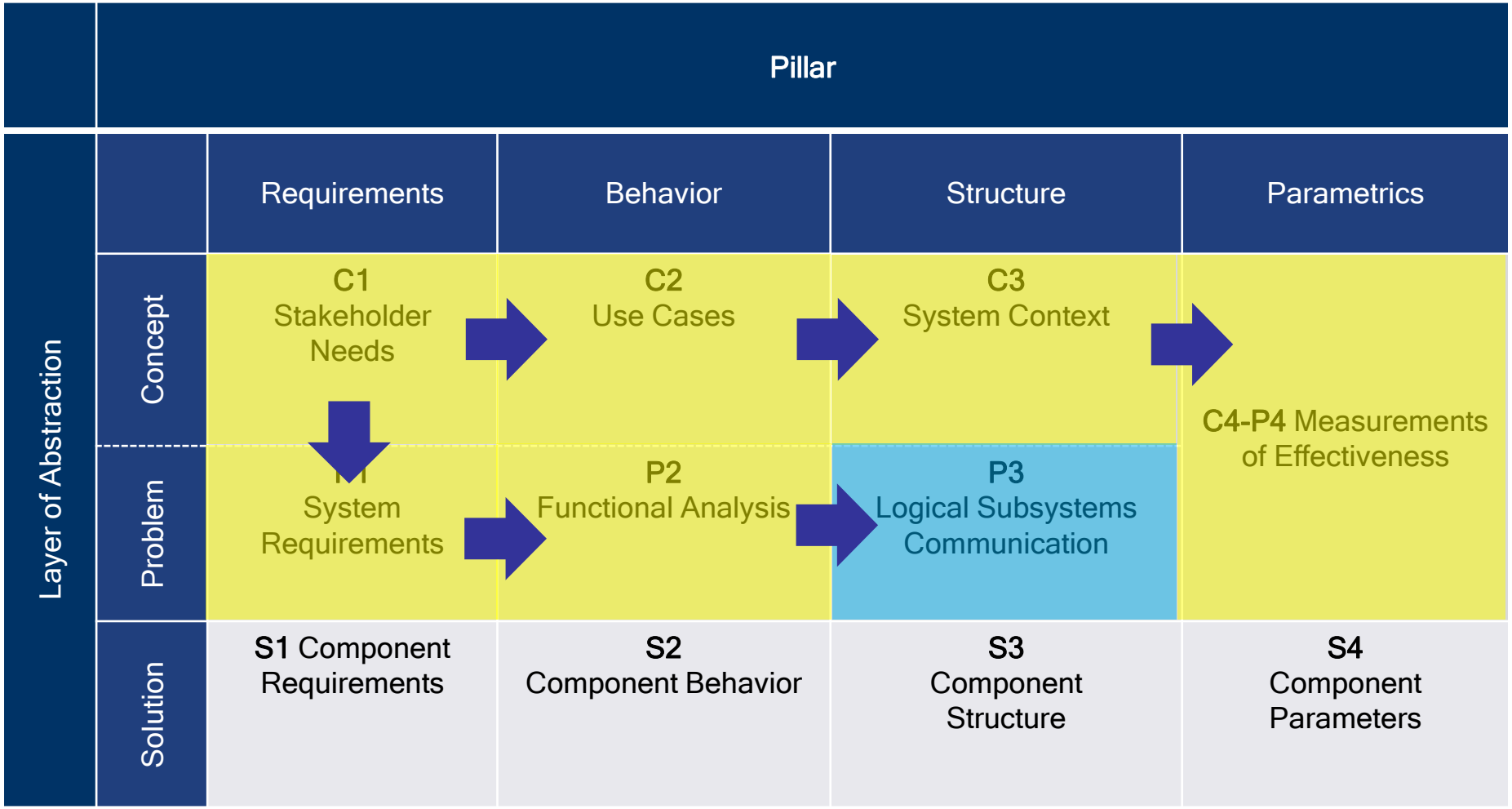
Functional Analysis



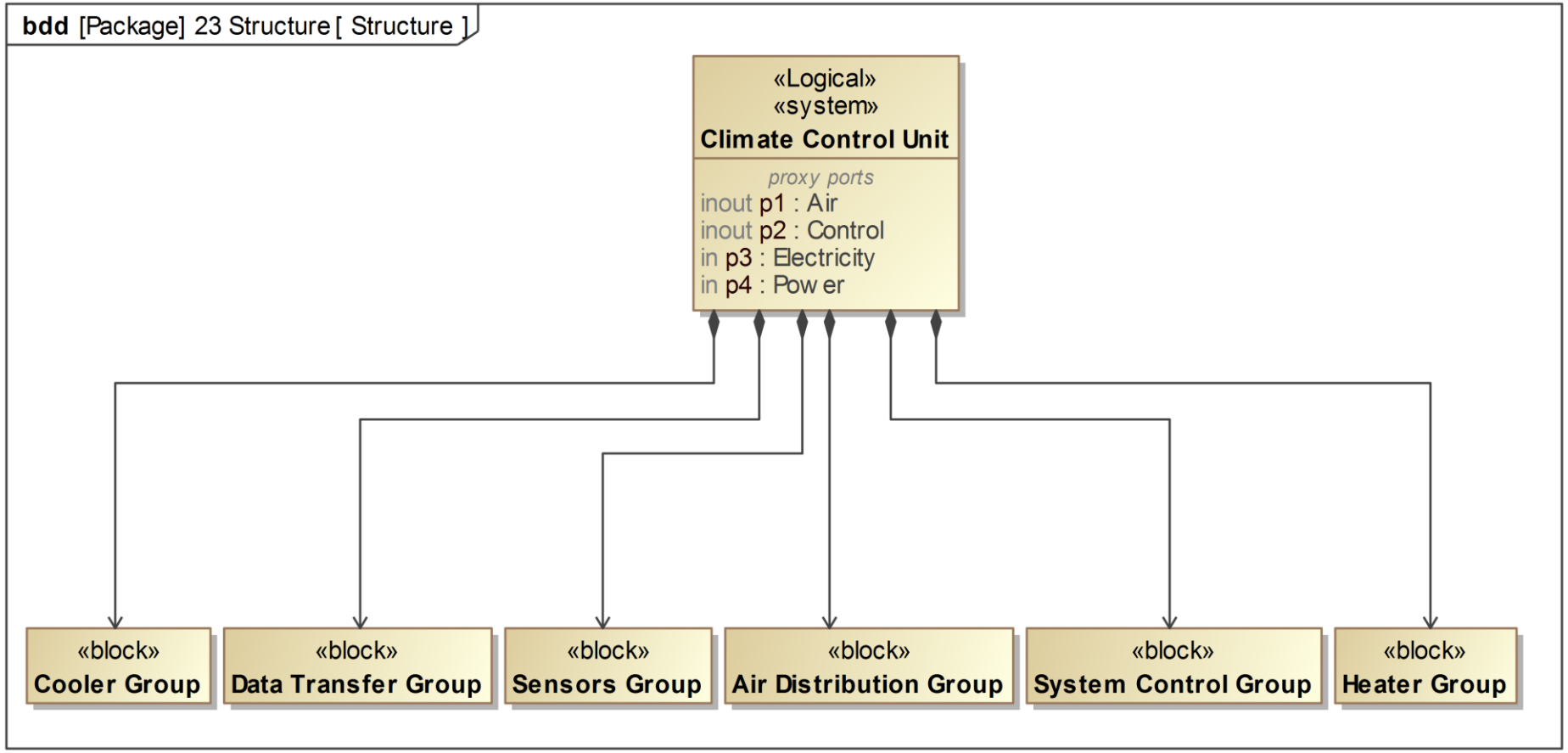
Functional Analysis



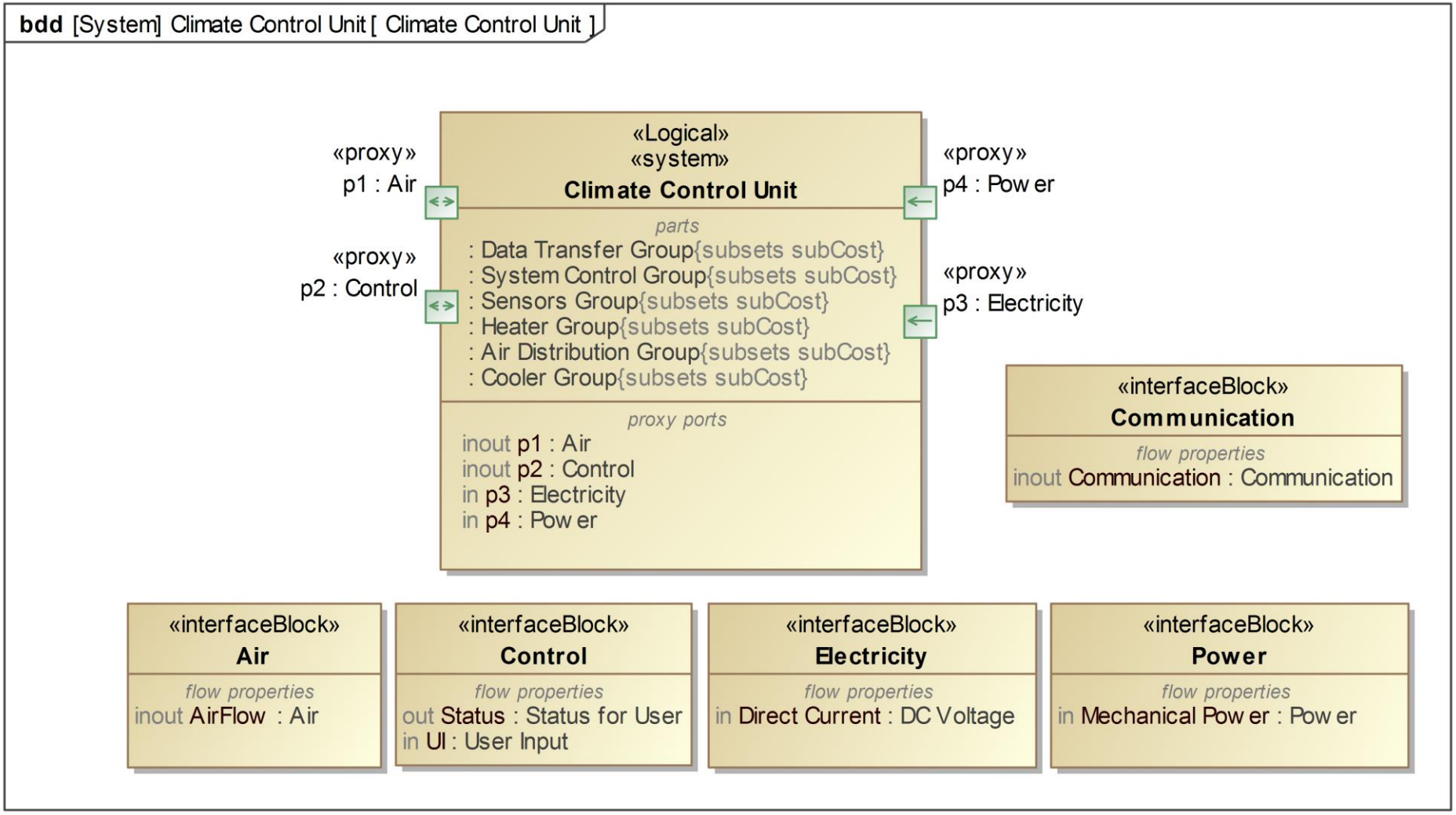
Logical Subsystems Communication



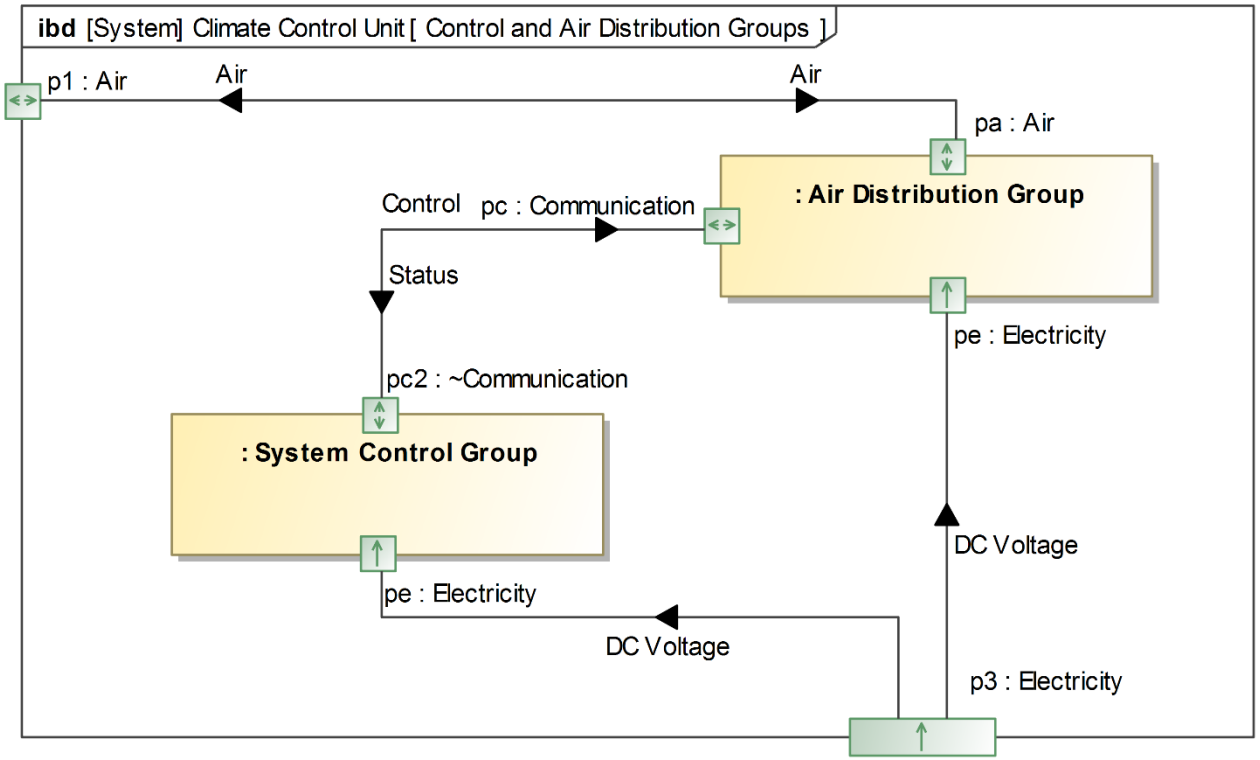
Structure - Product Tree



Interfaces

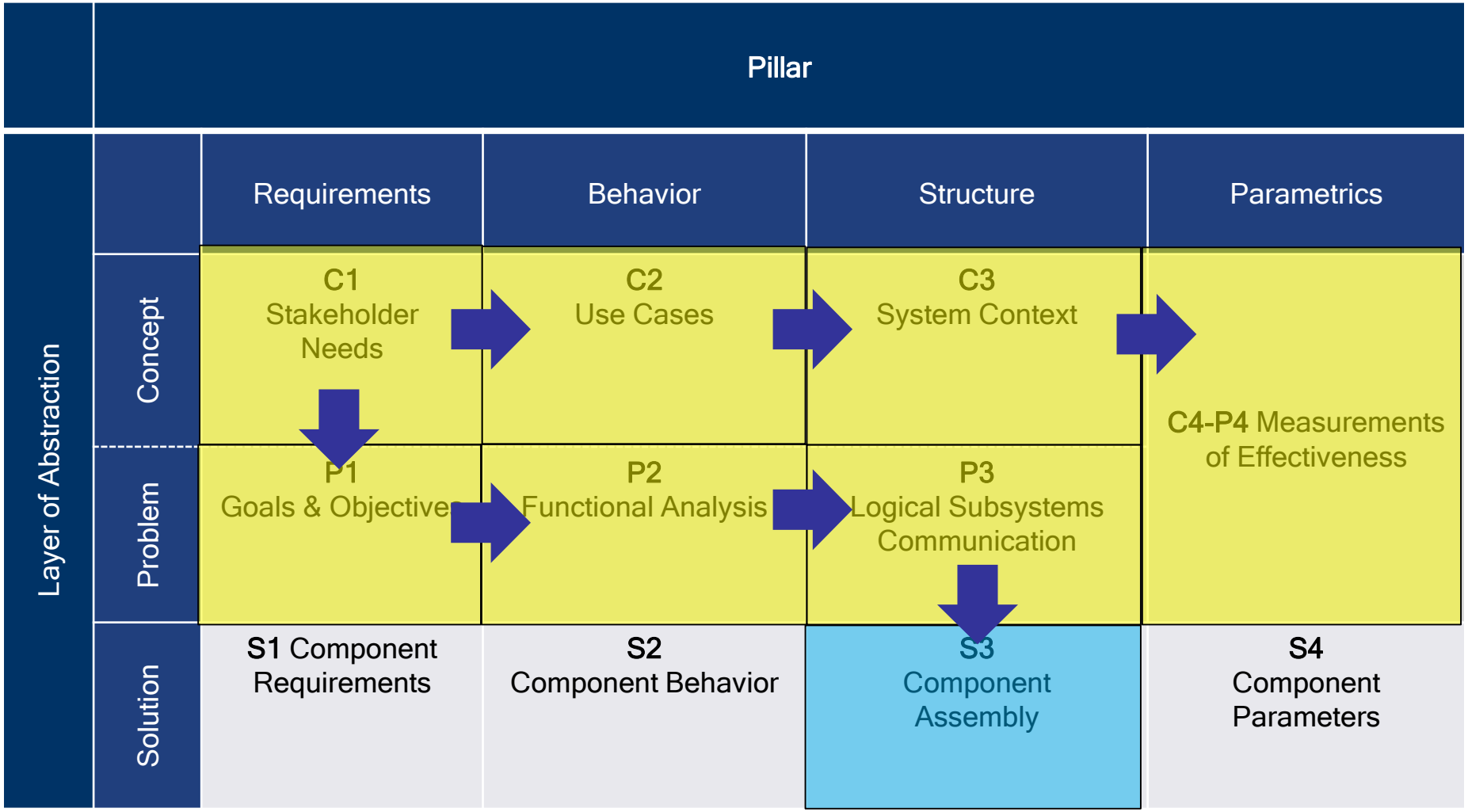

bdd [System] Climate Control Unit [Climate Control Unit]
«proxy»
p1 : Air
«proxy»
p2 : Control
«Logical»
«system»
Climate Control Unit
parts
: Data Transfer Group{subsets subCost}
: System Control Group{subsets subCost}
: Sensors Group{subsets subCost}
: Heater Group{subsets subCost}
: Air Distribution Group{subsets subCost}
: Cooler Group{subsets subCost}
proxy ports
inout p1 : Air
inout p2 : Control
in p3 : Electricity
in p4 : Power
«proxy»
p4 : Power
«proxy»
p3 : Electricity
«interfaceBlock»
Communication
flow properties
inout Communication : Communication
«interfaceBlock»
Air
flow properties
inout AirFlow : Air
«interfaceBlock»
Control
flow properties
out Status : Status for User
in UI : User Input
«interfaceBlock»
Electricity
flow properties
in Direct Current : DC Voltage
«interfaceBlock»
Power
flow properties
in Mechanical Power : Power

Logical Subsystems Communication

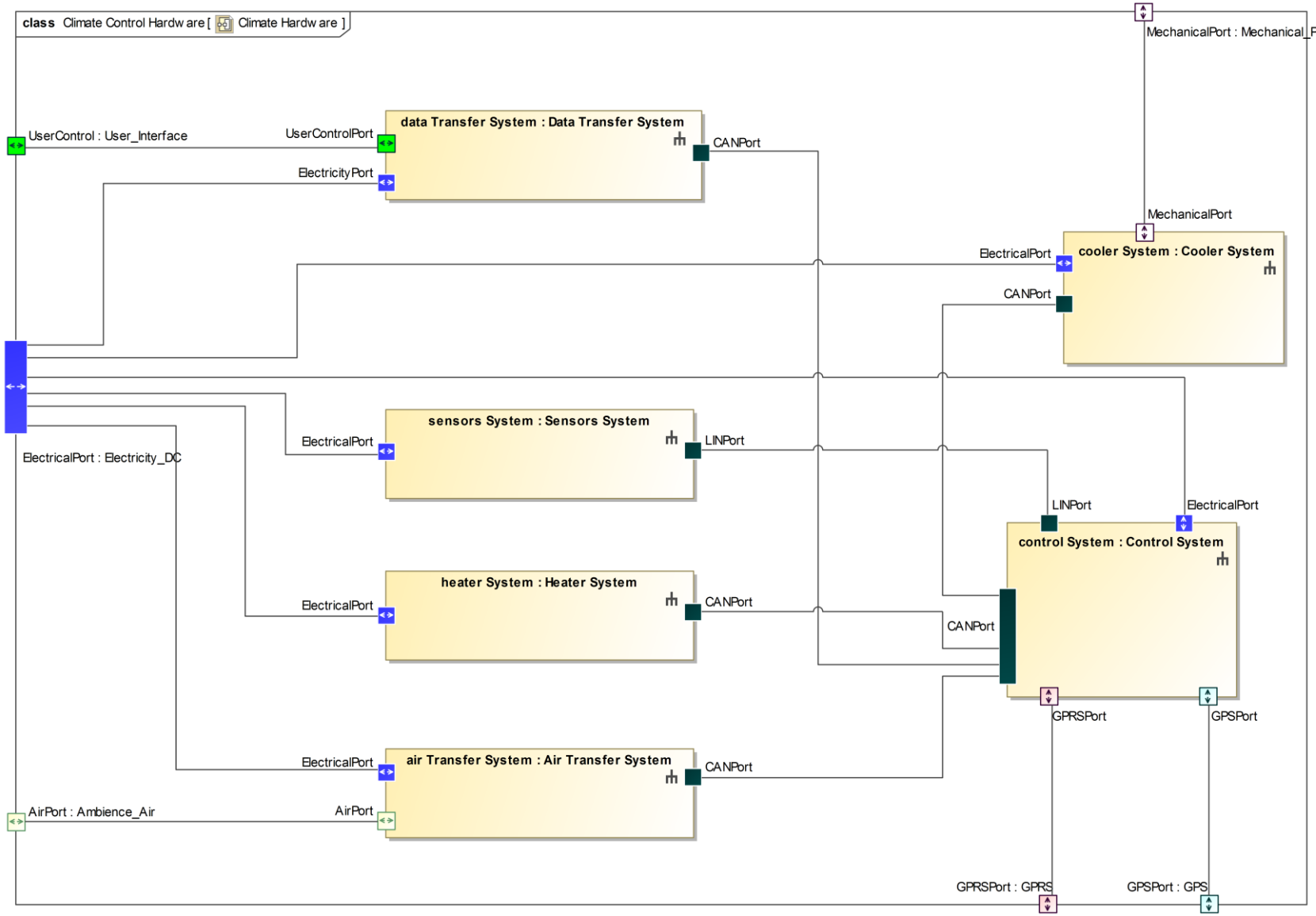


#	~ ^	Port Name	Port Type	Type Features	Direction	Documentation
1		p3	Electricity	F in Direct Current : DC Voltage	in	
2		p4	Power	F in Mechanical Power : Power	in	
3		p1	Air	F inout AirFlow : Air	inout	
4		p2	Control	F in UI : User Input F out Status : Status for User	inout	

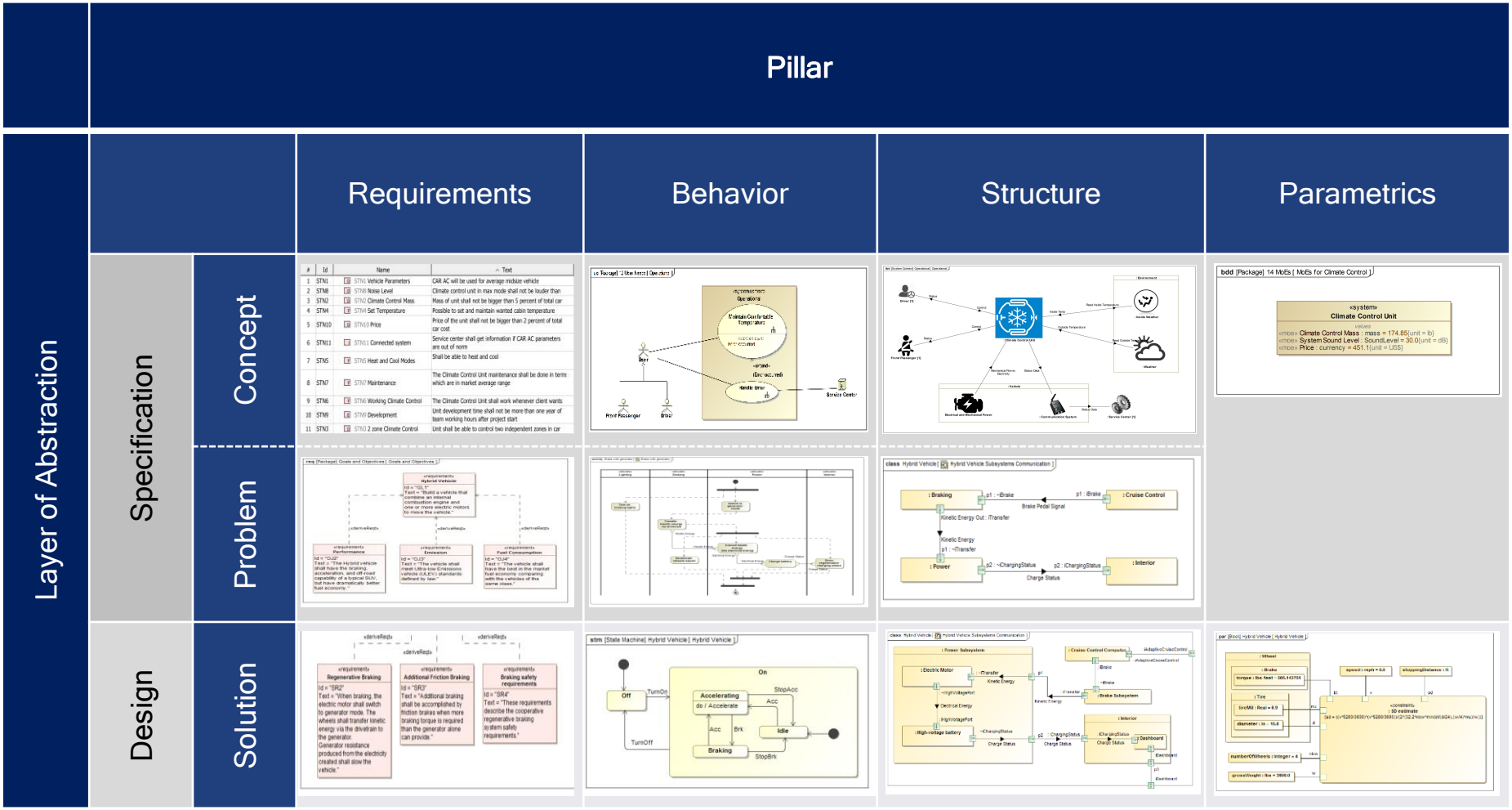
Component Assembly



Component Assembly

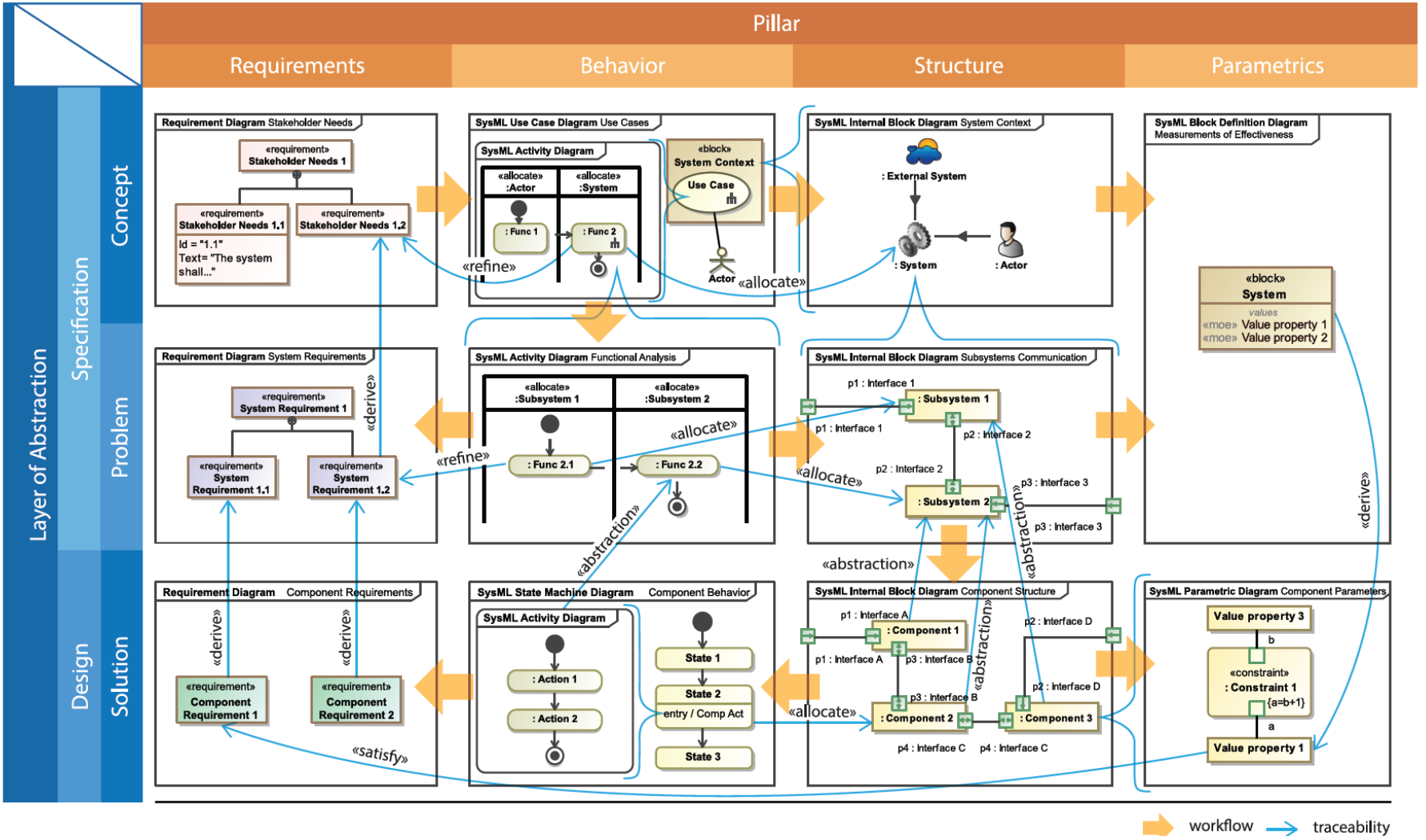


MagicGrid


Pillar
Layer of Abstraction
Requirements
Behavior
Structure
Parametrics
Specification
Concept
Problem
Design
Solution

Enable Traceability - Digital Thread

MagicGrid™ Framework



Conclusions

- Systems engineering support complex multidisciplinary systems design.
- Because of formalization and transparency MBSE with SysML and method / framework support complex systems design automation and integration.
- Requirements are no longer abstract text paragraphs. Now they are formalized with models which allows efficient traceability and optimization between stakeholder needs to electrical, software and mechanical components even at the most complex systems.

Saulius.Pavalkis@3DS.com

THANK YOU!