33rd Annual INCOSE international symposium

hybrid event

Honolulu, HI, USA
July 15 - 20, 2023

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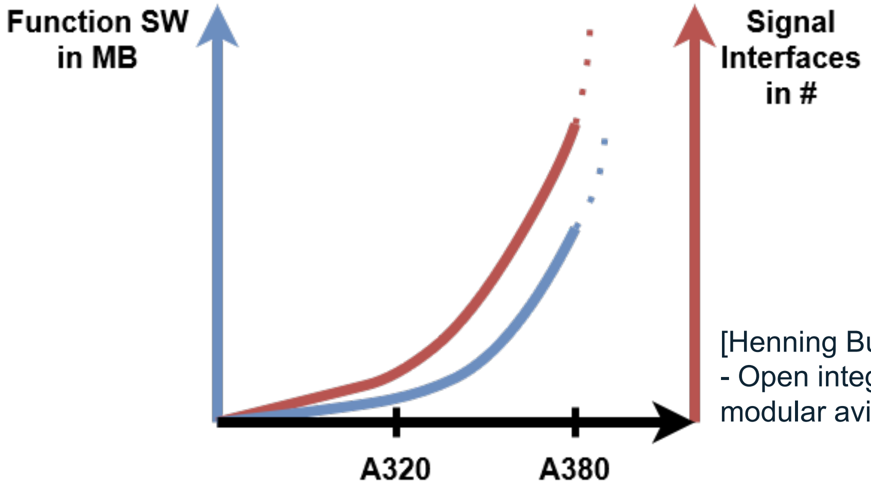
Seamless Transitions from Logical to Physical Avionics Architecture Models for Preliminary Aircraft Systems Design

TUHH

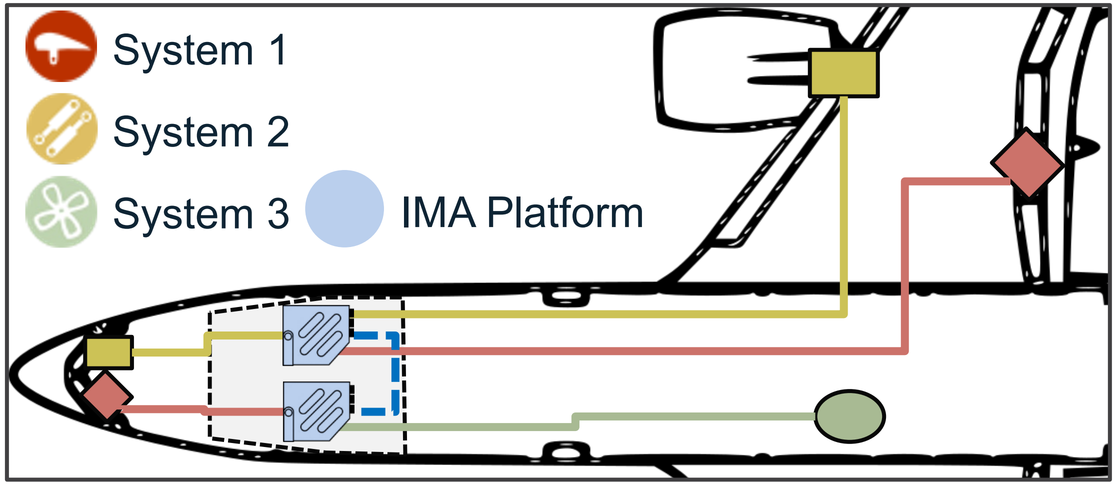
Characteristics of Avionics

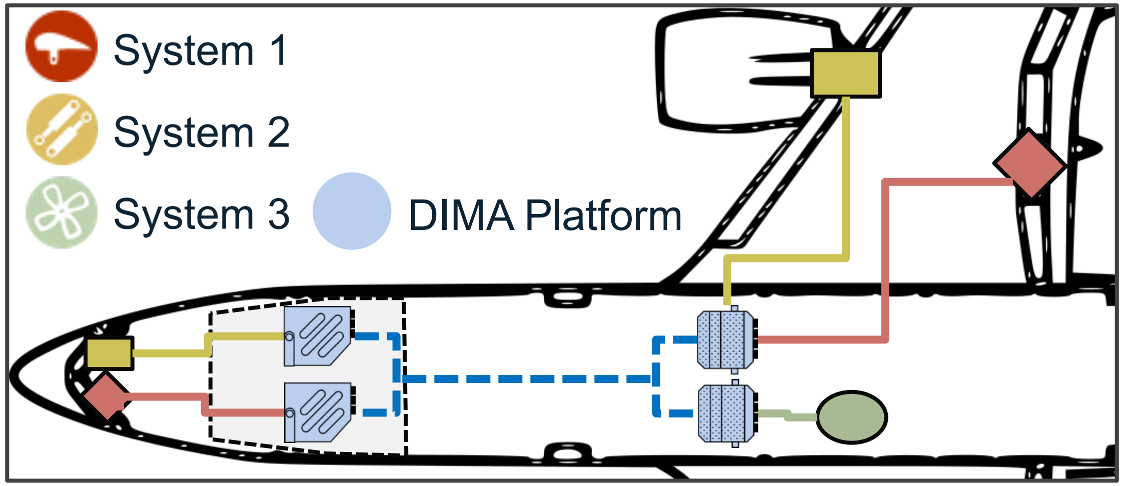
Aviation Electronics (Avionics)

- Electronic devices
- Data busses (communication network and field busses)
- ➢ Integrated Modular Avionics (IMA)
- ➢ Distributed Integrated Modular Avionics (DIMA)

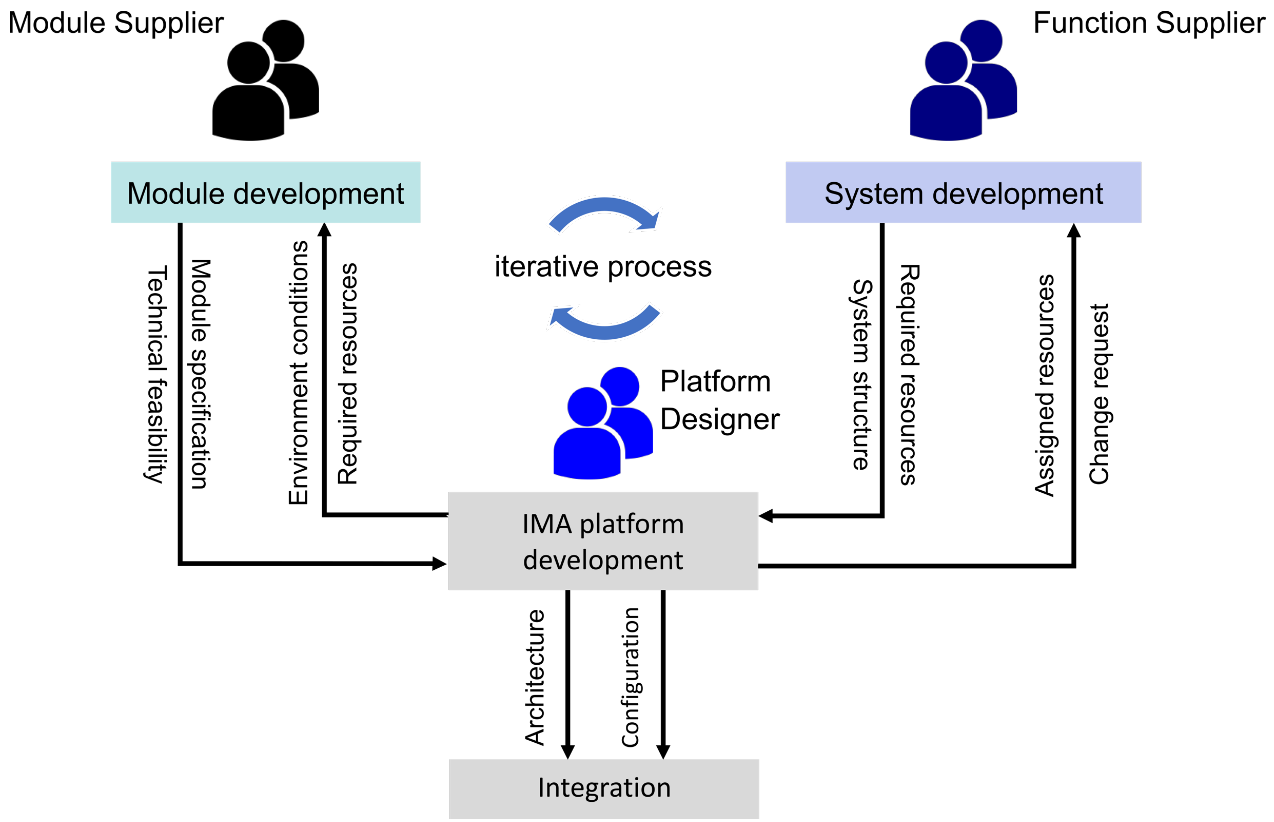


[Henning Butz (2010) - Open integrated modular avionic (IMA)]





Need for New Design Methods (I)

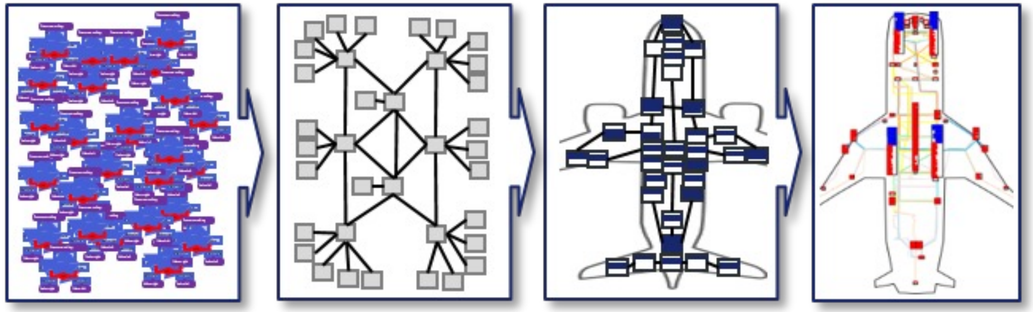


Current design process

- Many different stakeholders with interdependencies
- Unformalized data exchange
- Many design iterations
- System and platform design starts in parallel

Challenge 1: large uncertainties

Need for New Design Methods (II)



1000+ system functions | 40+ modules (different types) | 1000+ installation locations | **Sub-problem**: 175.000 var. **Complete**: > 1.000.000 var.

minimize: $f^T x$ subject to: $A_{ineq}x \leq b_{ineq}$

$$A_{eq}x = b_{eq}$$

$$x \in \{0,1\}$$

Combinatorial optimization problem

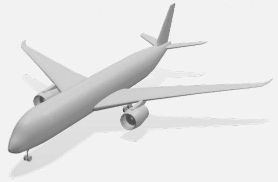
- Formal models required
  - Manual creation is error prone
  - Optimization results are only as good as problem definition, i.e. formal model
- High computation times
  - Many constraints and interdependencies
- Rising number of system functions

Challenge 2: growing complexity

Seamless Model-based Design Process

Overall Aircraft Design

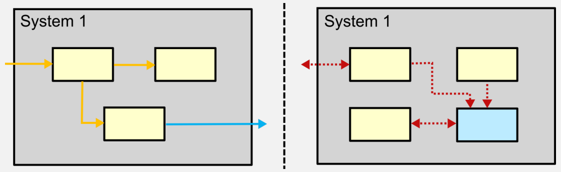
- TLARs and aircraft geometry



➢ CPACS

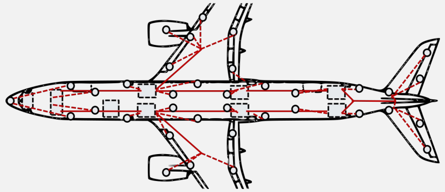
Systems Architecting

- Obtain basic system resource needs



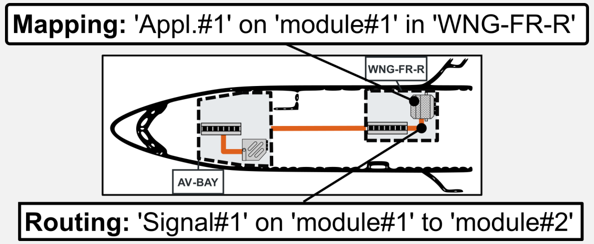
Overall Conceptual System Design

- Topology: Platform components allocation



Platform Detailed Design

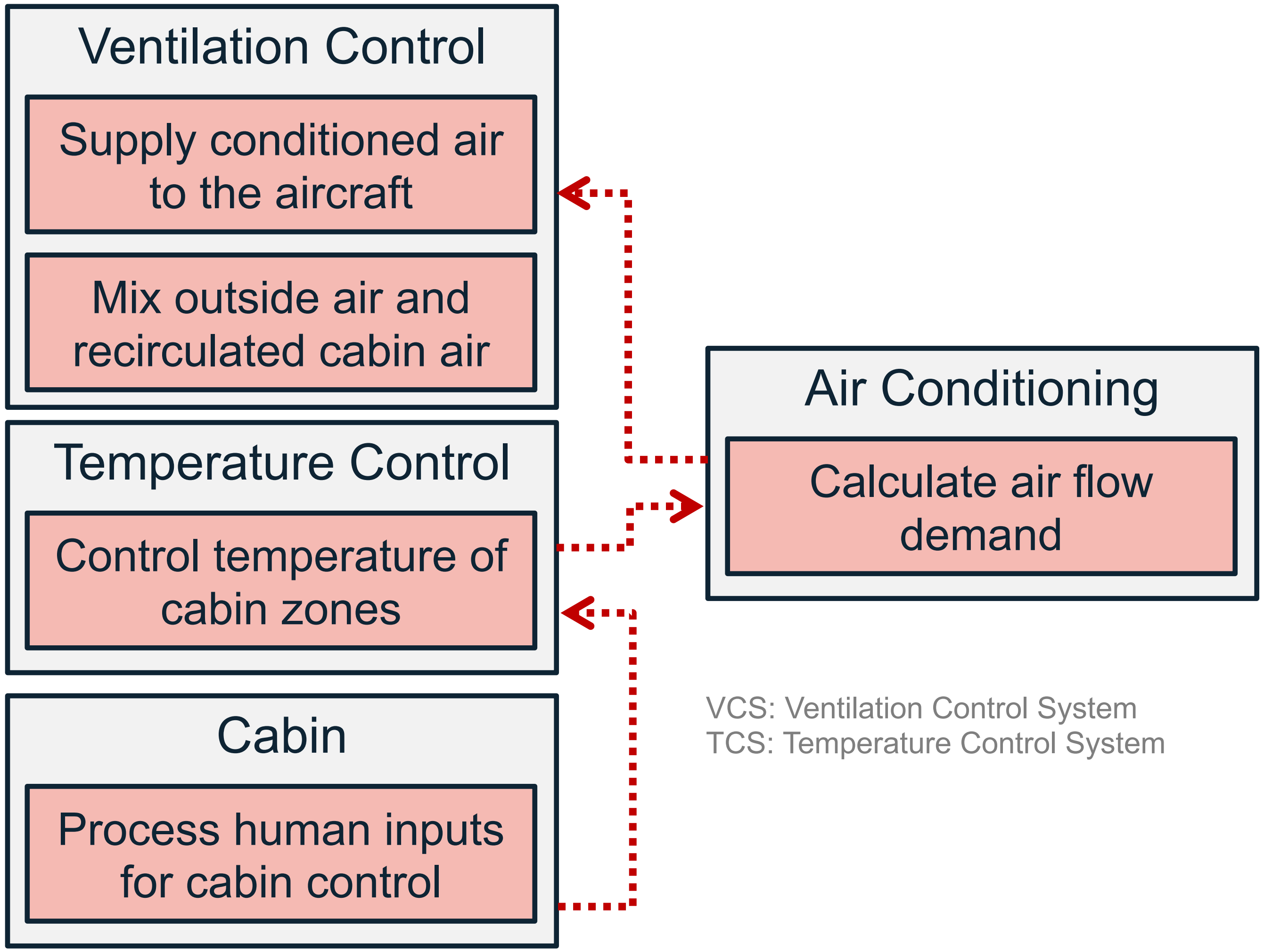
- Allocation and routing of detailed SW tasks and signals



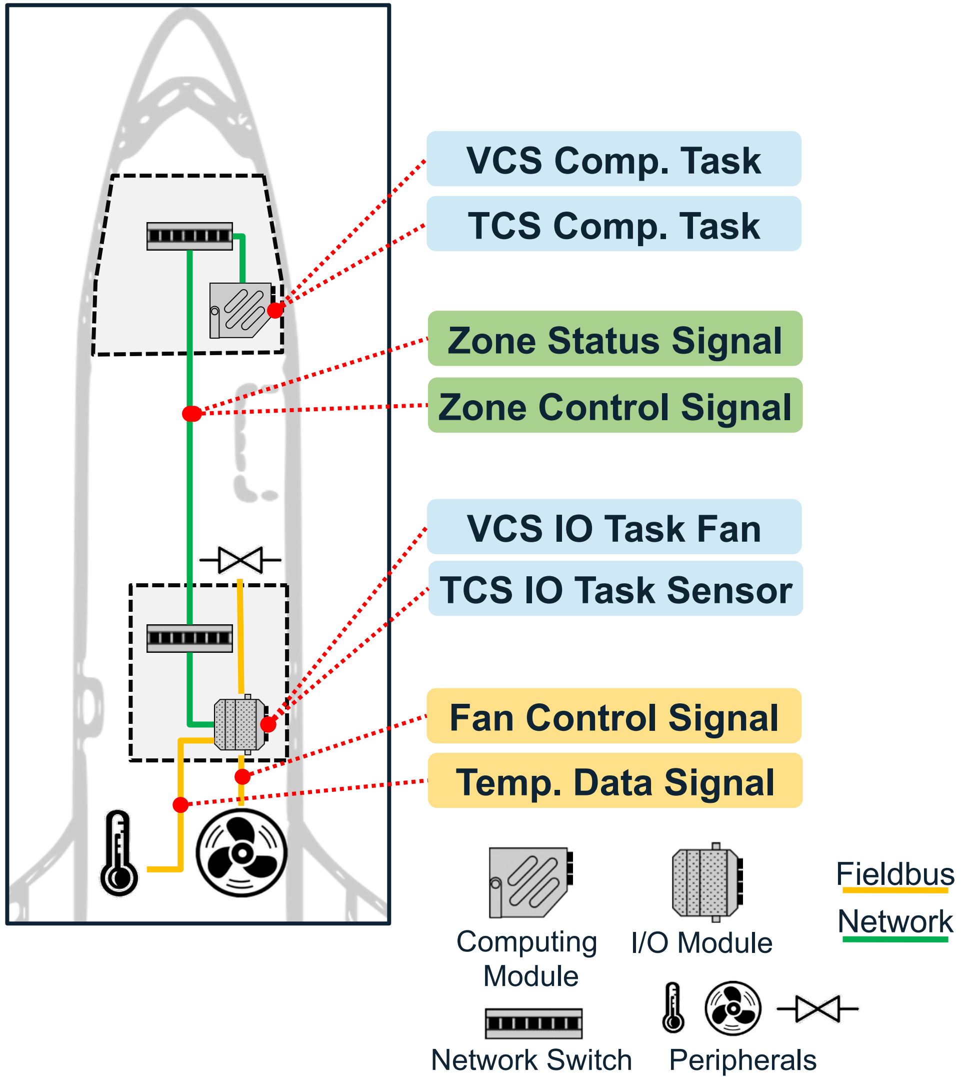
➢ OAAM

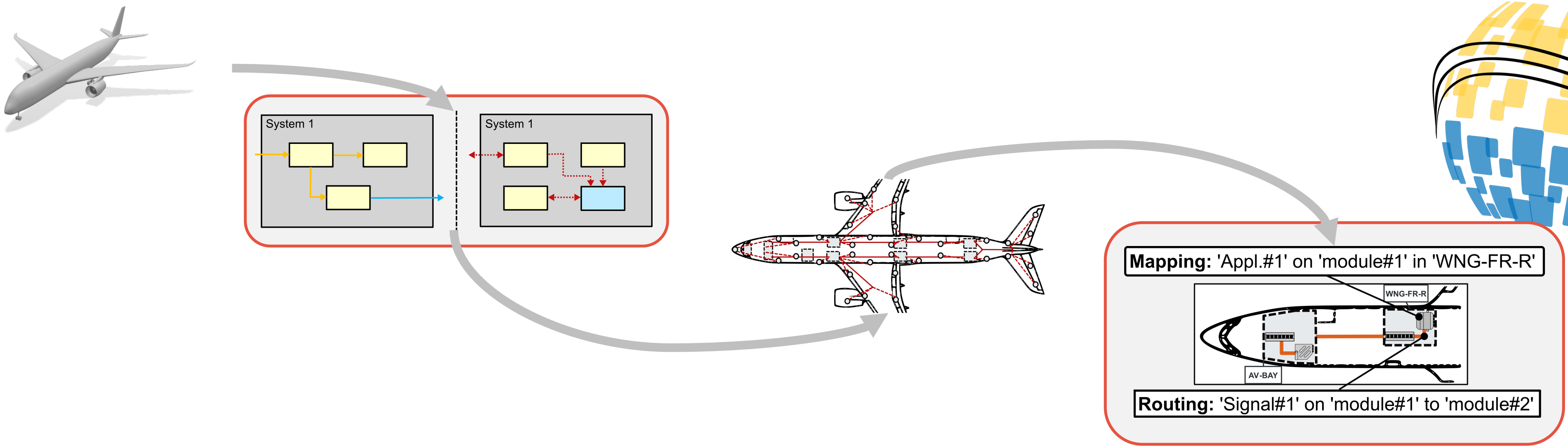
TLARs: Top Level Aircraft Requirements
CPACS: Common Parametric Aircraft Configuration Schema
OAAM: Open Avionics Architecture Model

Use Case: Environmental Control System



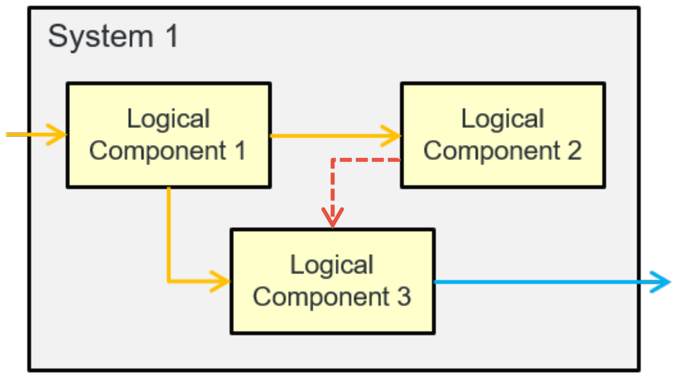
VCS: Ventilation Control System
TCS: Temperature Control System





Application of Seamless Model-based Design Process

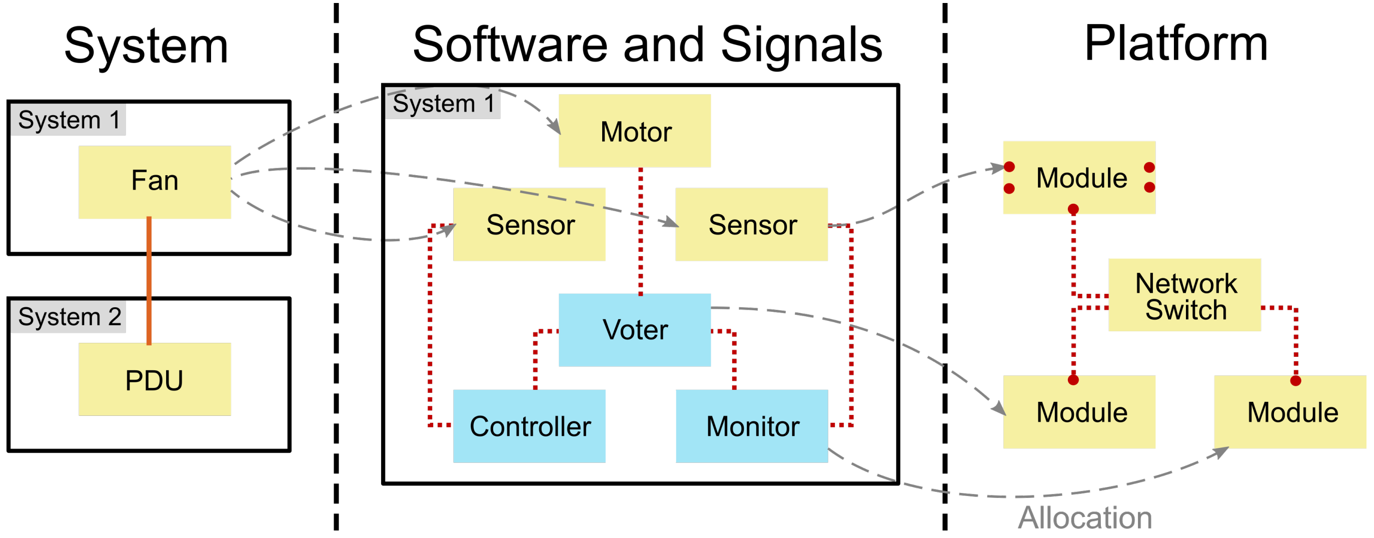
Logical Modeling - Concept



Executable avionics specification model

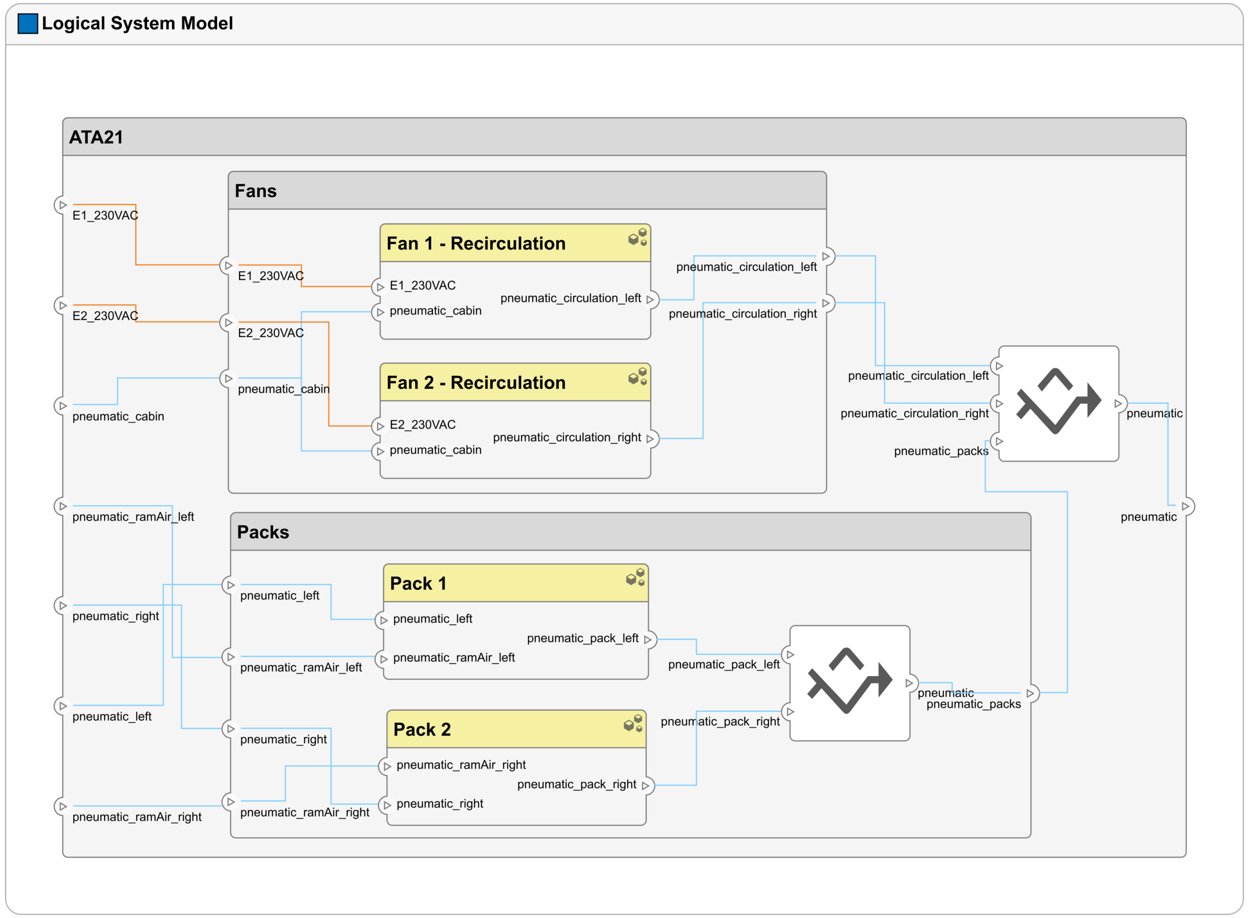
- Capturing of system requirements for avionics platform design

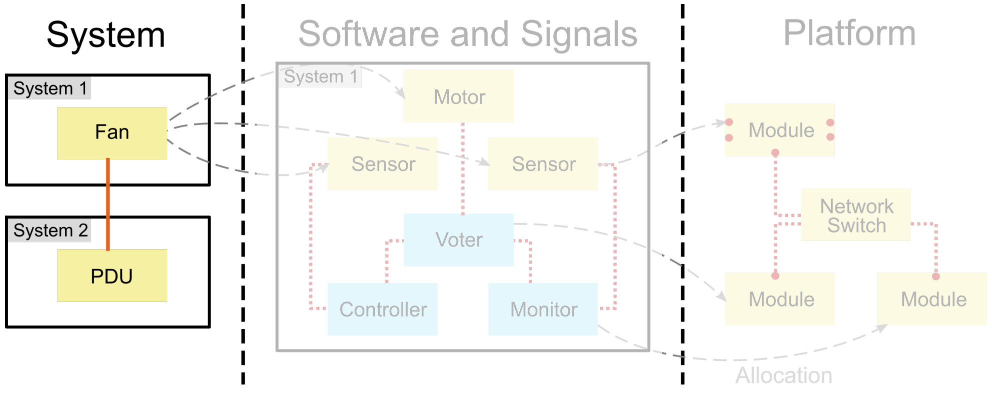
➤ Three layered logical modeling approach



PDU: Power Distribution Unit

Logical Modeling – Use Case

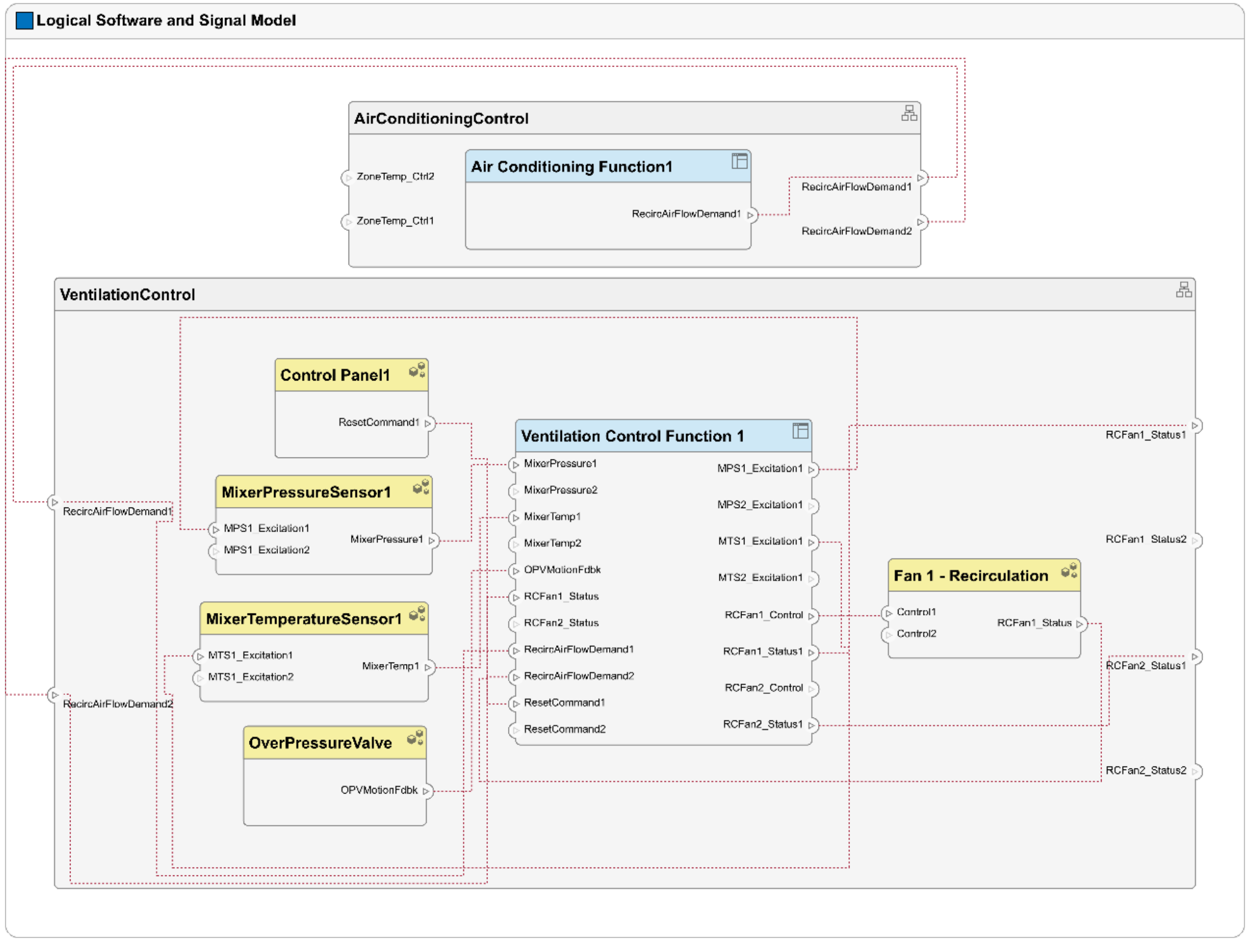


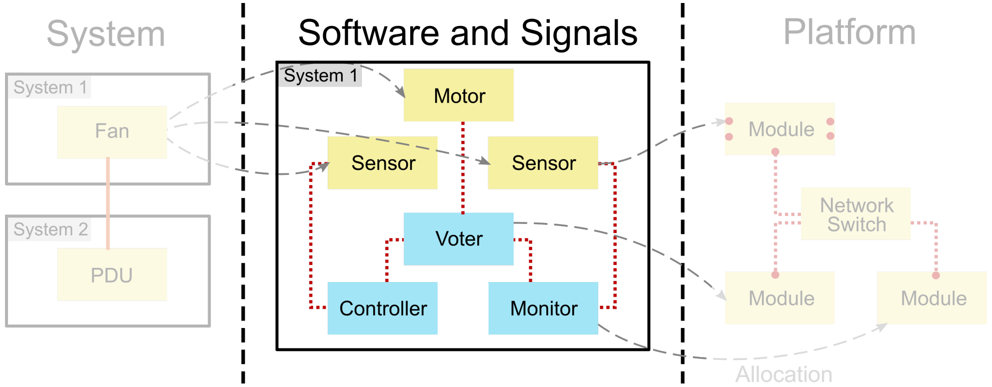


System function perspective

- Limits information to data necessary for system design
- ➢ Reduced complexity

Logical Modeling – Use Case

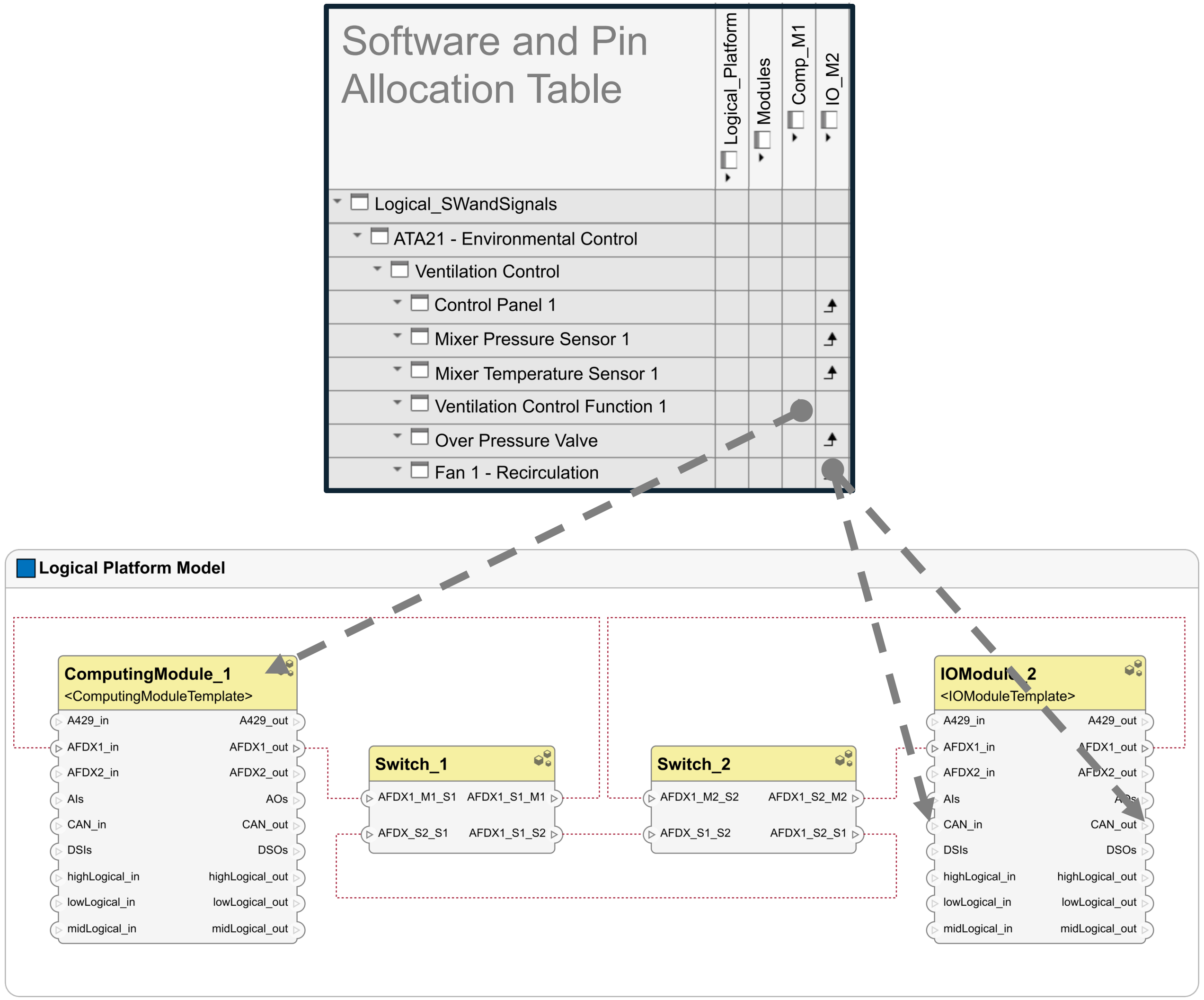


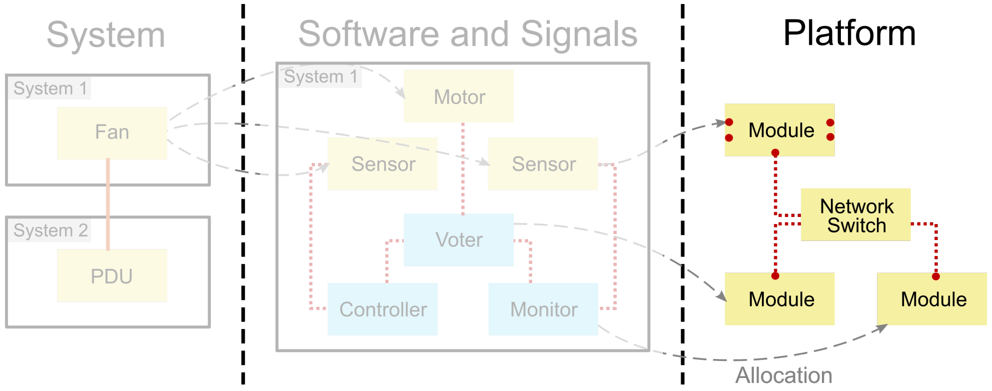


Data-centric perspective

- Model-based estimation of platform requirements
- Executable specification model to enable automated validation of requirements, e.g. signal redundancy

Logical Modeling – Use Case





Logical-Functional Mapping

- Determination of platform concept
  - Technology selection
  - Module numbers
  - Logical platform connections

Logical Modeling - Handling Uncertainty

Knowledge-based resource estimation matrix

- For systems without an available logical software and signal model
- Intervals for worst and best case architecture

Subsystem/ Function	Resource Type	Peripheral Type	Multiplier	Port Complexity	Computational Demand	Redundancy Pattern
Temperature Control	Comp.	-	-	-	low	simplex
Temperature Control	IO	Temp. sensor	7	medium	-	simplex
Temperature Control	IO	Valve actuator	7	low	-	simplex
Cabin	IO	LRU	-	high	-	simplex

LRU: Line Replaceable Unit
SWC: Software Component

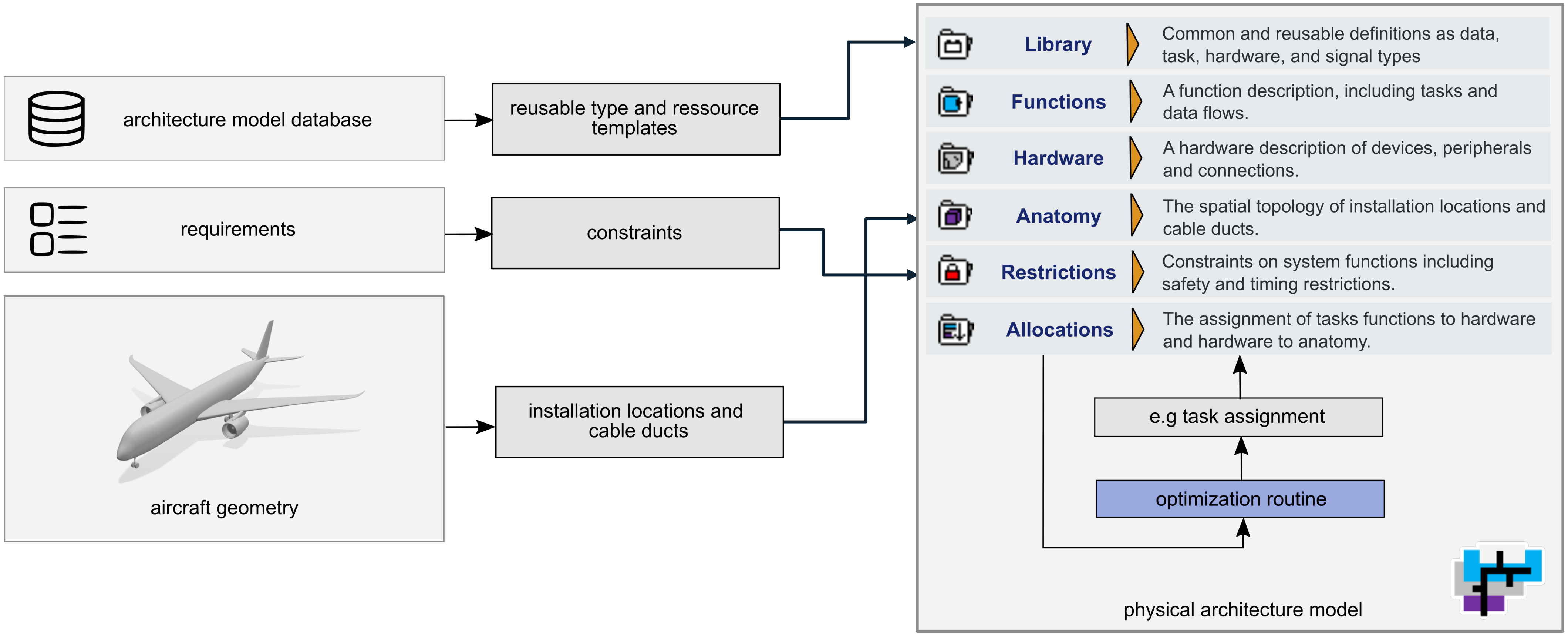
Additional tuning parameter (e.g. 7 Cabin Zones)

Intervals of SW component size (e.g. low: 10-20% of CPU capacity)

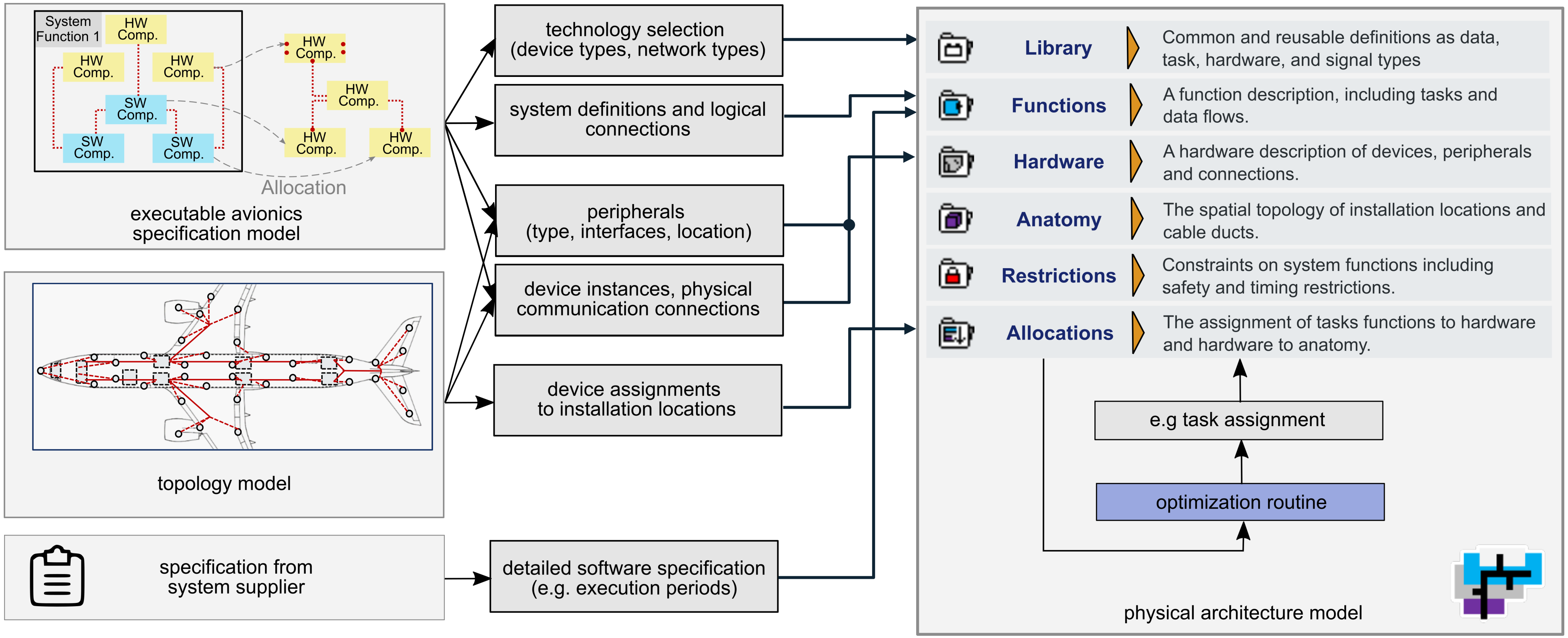
Intervals of physical pins (e.g. low: 1 pin, high: 4-9 pins or special connector)

e.g. triplex 3 x Peripherals, 9 x Peripheral Wires, 3 x SWCs + Voter SWC

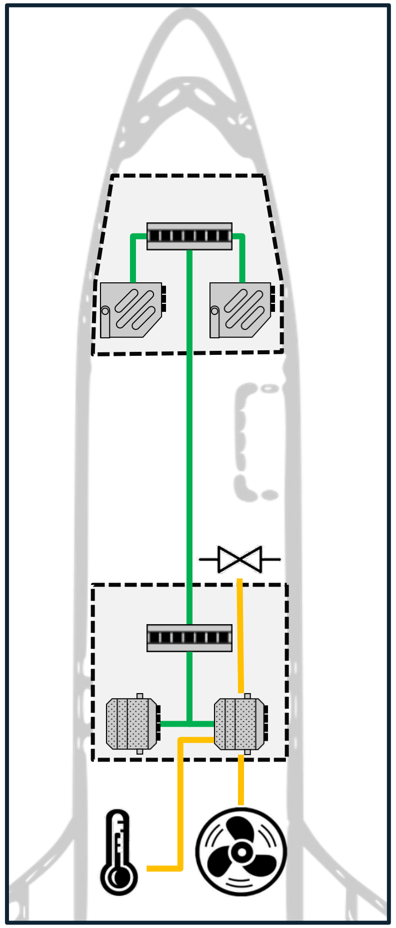
Physical Architecture Model – Concept



Physical Architecture Model – Concept

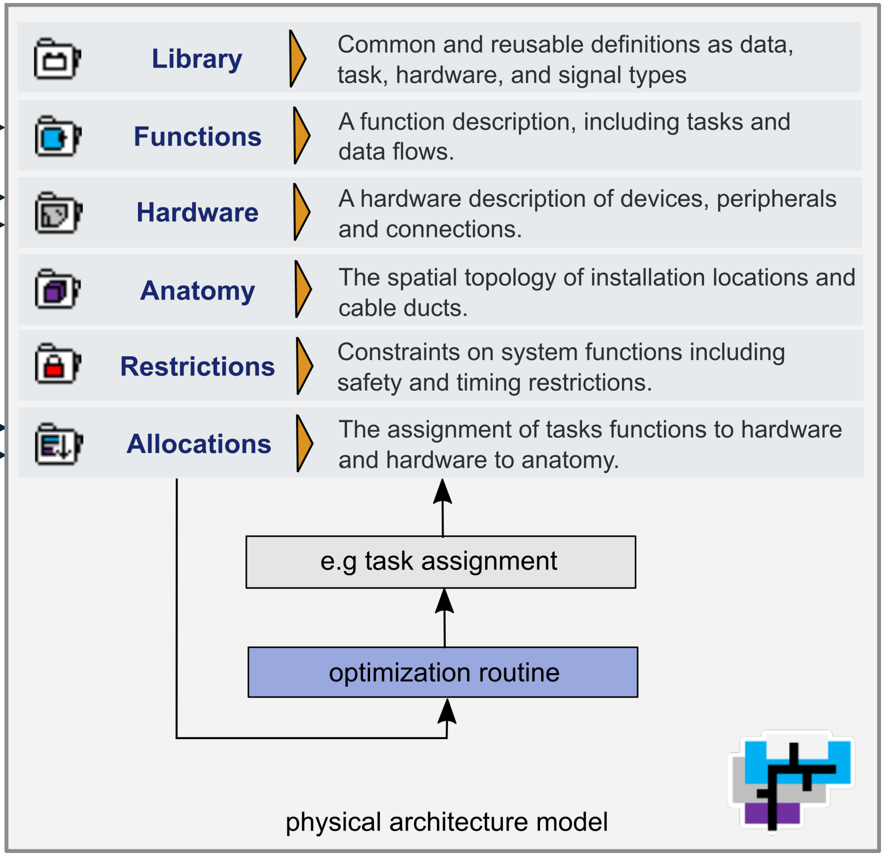


Results from Model Transitions

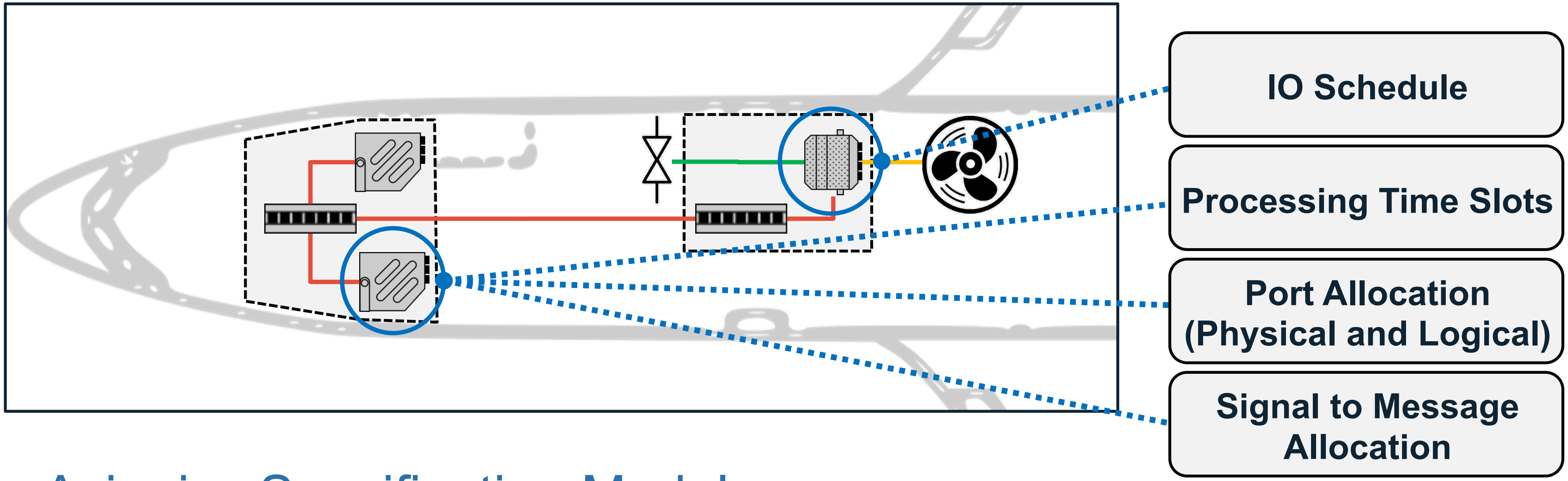


Element generation

- 29 SW tasks and 75 signals
  - 234 model elements and element references
- 24 peripheral components
  - 72 model elements and element references
- 8 IMA devices (modules and network switches) and 10 connections
  - 24 model elements



Detailing of Physical Architecture



Avionics Specification Model

- Generation of simulation models
- Generation of configuration templates

Summary

Formalized interfaces

- Coupling of overall aircraft design with detailed avionics platform design

Early estimation of platform requirements

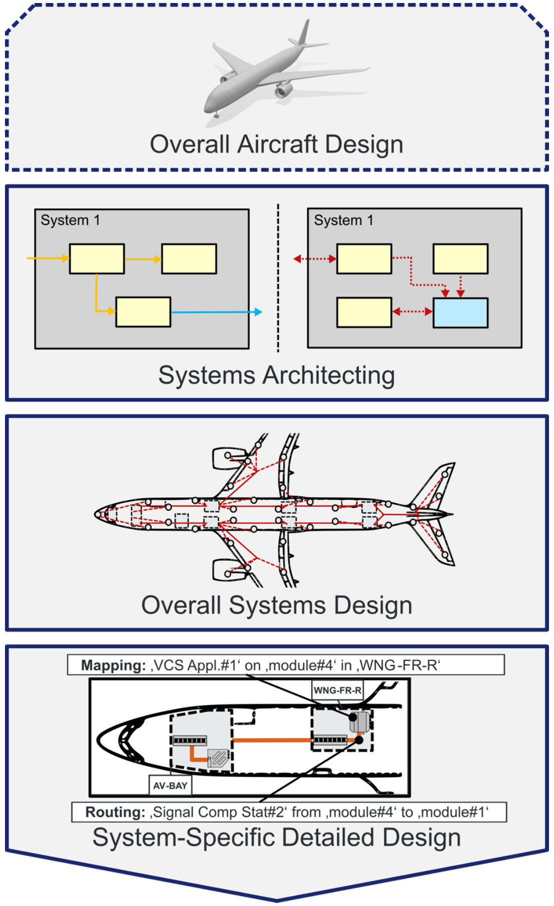
- Usage of parametric design pattern

Reduced design space

- Most promising systems architectures and platform concepts for detailed design studies

Machine-readable and formal architecture models

- Enable early and continuous model-based validation
- Reusability of architectural artifacts



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Thank you for your attention!

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Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

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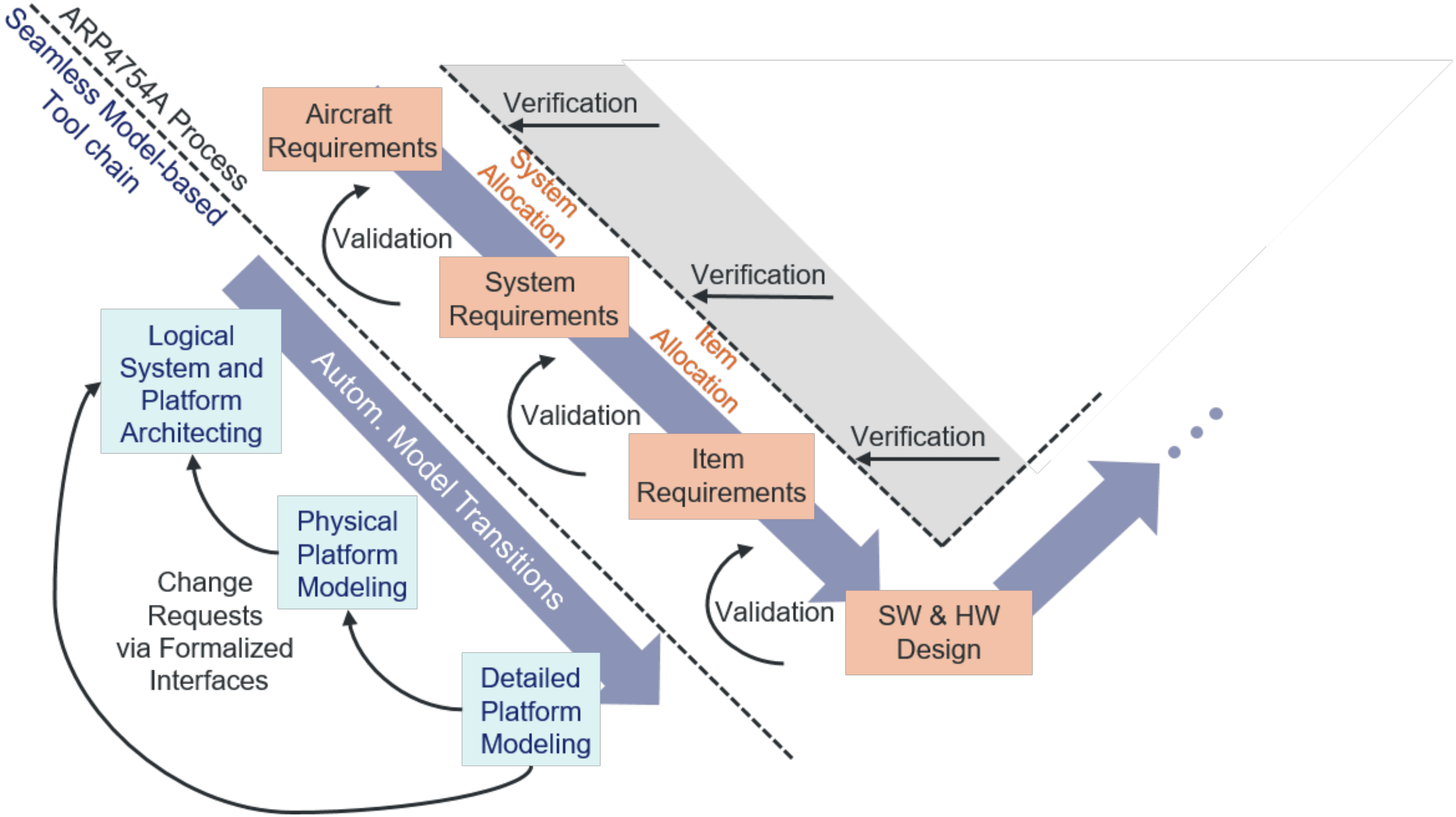
Embedding into ARP4754



Topology Design Pattern