27th annual INCOSE international symposium

Adelaide, Australia
July 15 - 20, 2017

ENGINEERS AUSTRALIA
SESA

Robert Malone, Brittany Friedland, John Herrold and Gregory Green

The Boeing Company

Toward Systems Engineering Modeling Standards: Proposed System Architecture Core Elements and Composition

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Agenda

1. Introduction
2. System Architecture Model Engine
3. Sample Architecture Model
3. Modeling Elements and Composition
   – Requirements Architecture
   – Functional Architecture
   – Logical Architecture
   – Architecture Integration
4. Conclusion

Boeing at a Glance

- Customers and customer support in 150 countries
  - Total revenue in 2012: $81.7 billion
  - 70 percent of commercial airplane revenue from customers outside the United States
- Manufacturing, service & technology partnerships with companies around the world
  - Contracts with 22,000 suppliers and partners globally
- Research, design & technology-development centers & programs in multiple countries
- More than 170,000 Boeing employees in 50 states and 70 countries

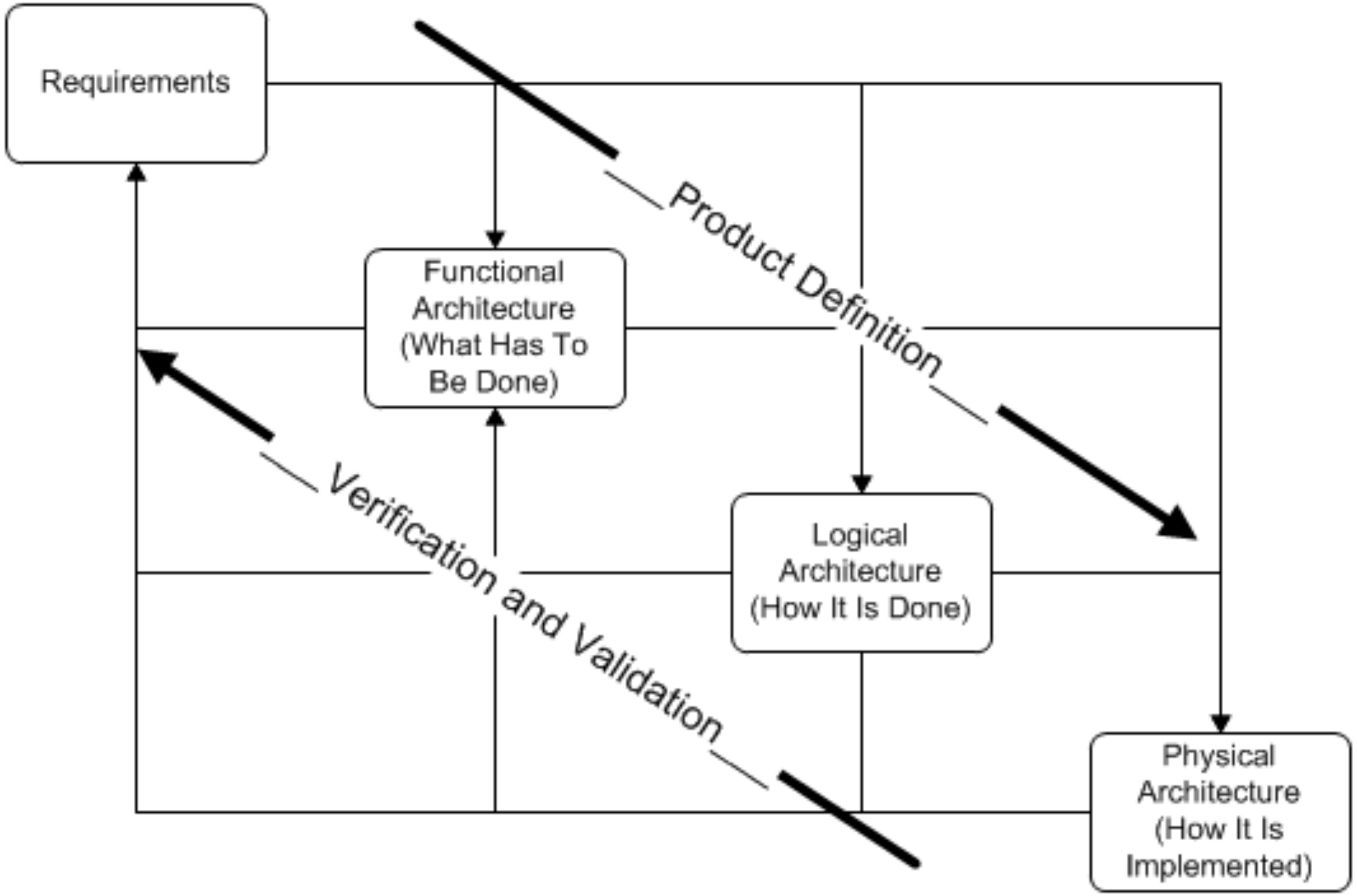
Introduction

Introduction

- Boeing derives great benefit from large scale system architecture modeling
- Boeing currently experiencing difficulty locating comprehensive tool suites and data exchange utilities
- Based on Boeing experience, industry would be well served by a modeling standard comprising a data model and accompanying composition/aggregation/ construction rules, and also data exchange and schema standards
    - Tool suites would be more capable as delivered, data exchange more straightforward (less data mapping), training reduced
- Boeing maintains an elaborate data model and constraining business rules as basis of MBSE tool suite specifications
- Presentation distills core elements of Boeing data model and business rules and proposes them as the basis of a system architecture modeling standard

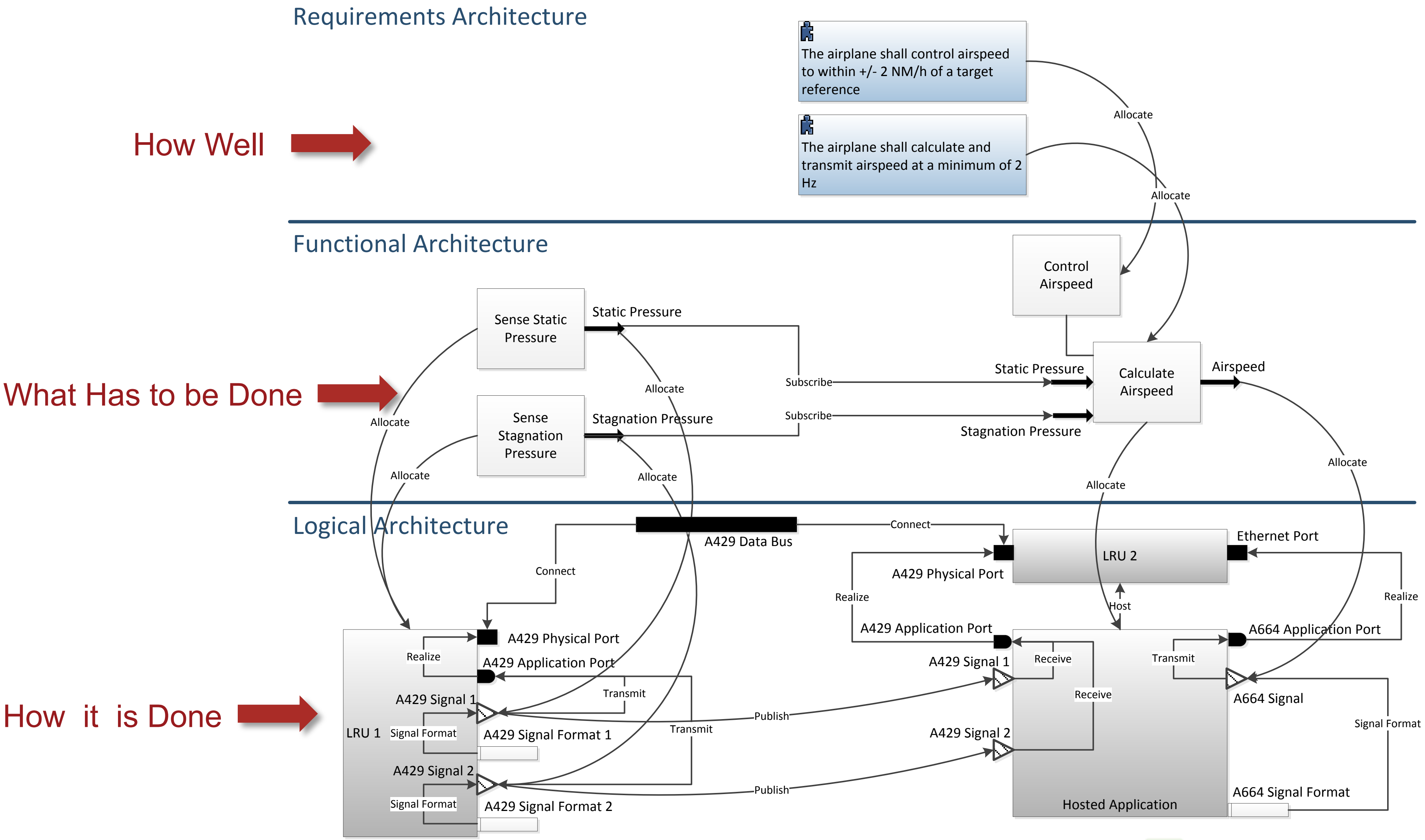
System Architecture Model Engine

System Architecture Model Engine



Sample Architecture Model

Sample Architecture Model

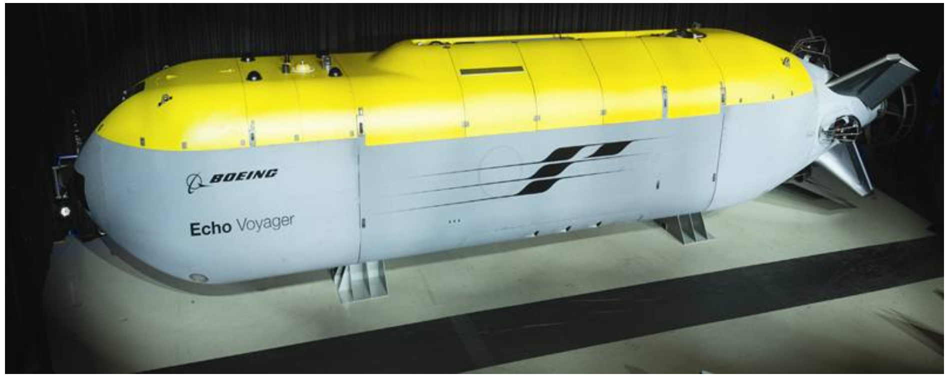


<u>Acronym and Mnemonics</u>

A429 – Aeronautical Radio, Incorporated 429 Data Protocol

A664 – Aeronautical Radio, Incorporated 664 Data Protocol

LRU – Line Replaceable Unit

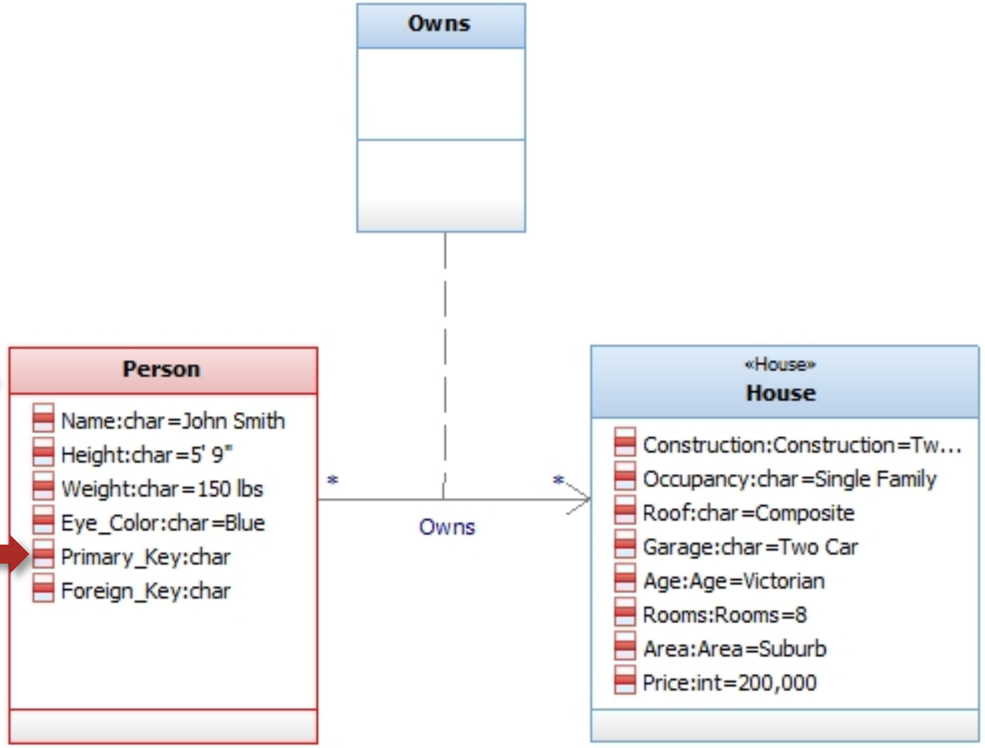


Modeling Elements and Composition

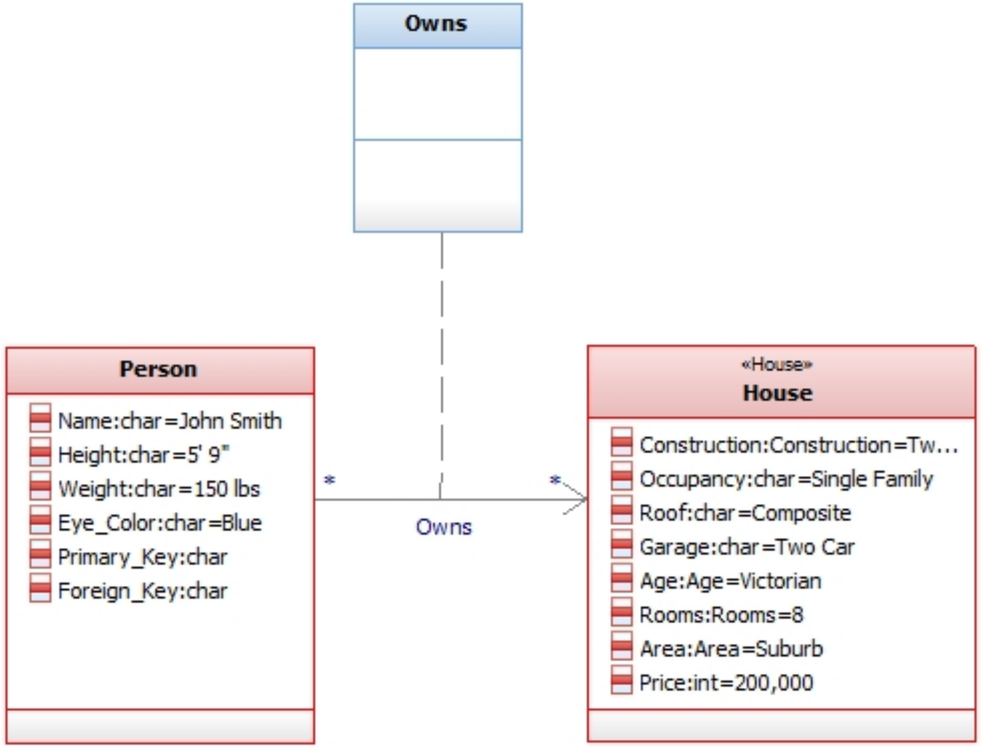
UML 2.0 Overview
Objects, Attributes, Relationships

Objects: useful data categories

Attributes: information defining and describing item in the category

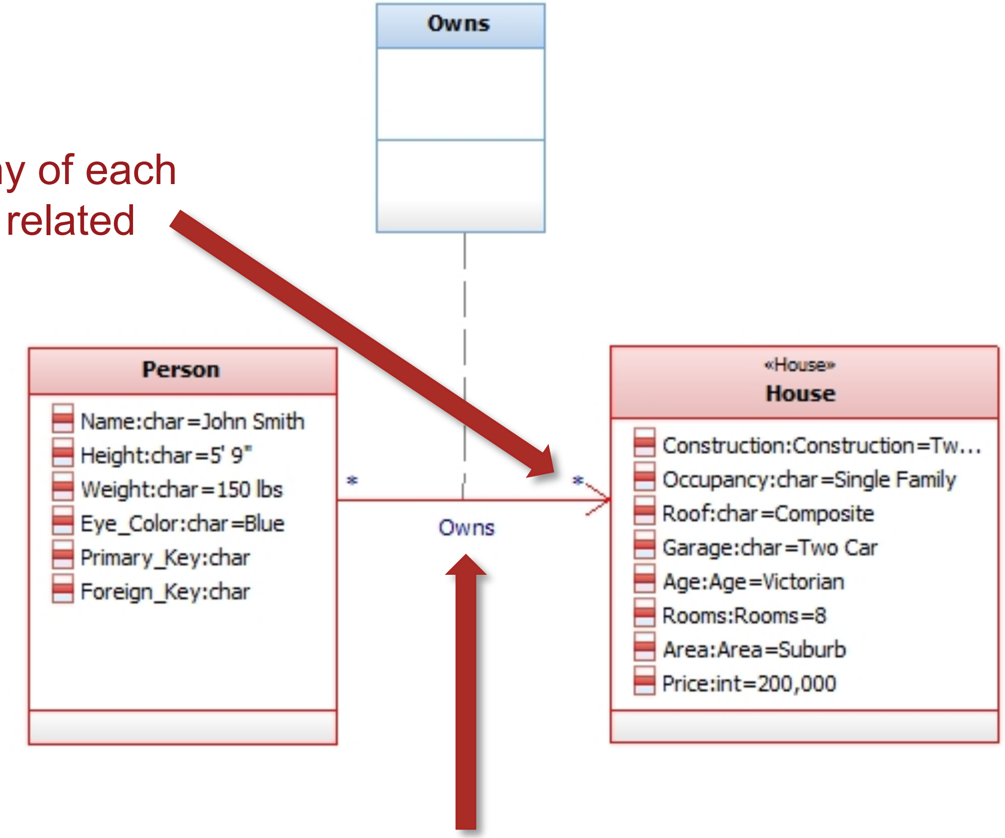


UML 2.0 Overview
Objects, Attributes, Relationships



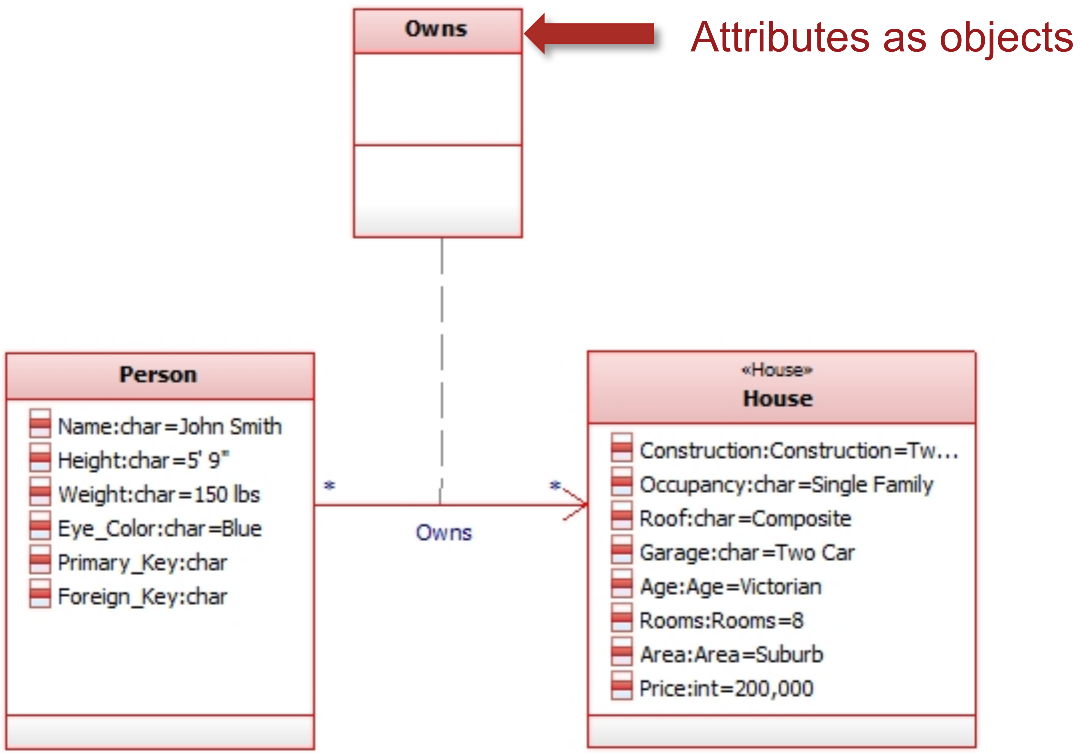
UML 2.0 Overview
Objects, Attributes, Relationships

Cardinality: how many of each object type can be related

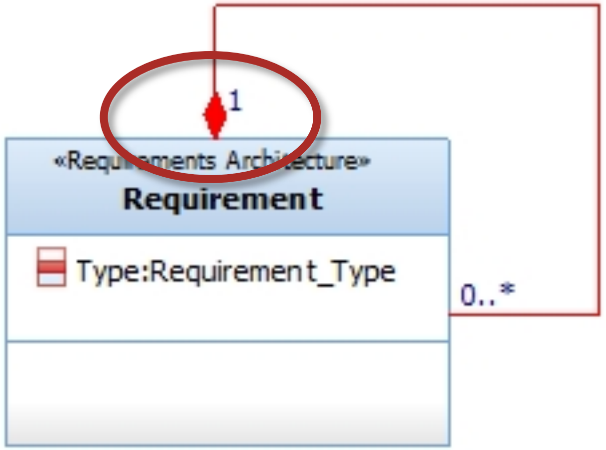


Relationships: links relating objects in context

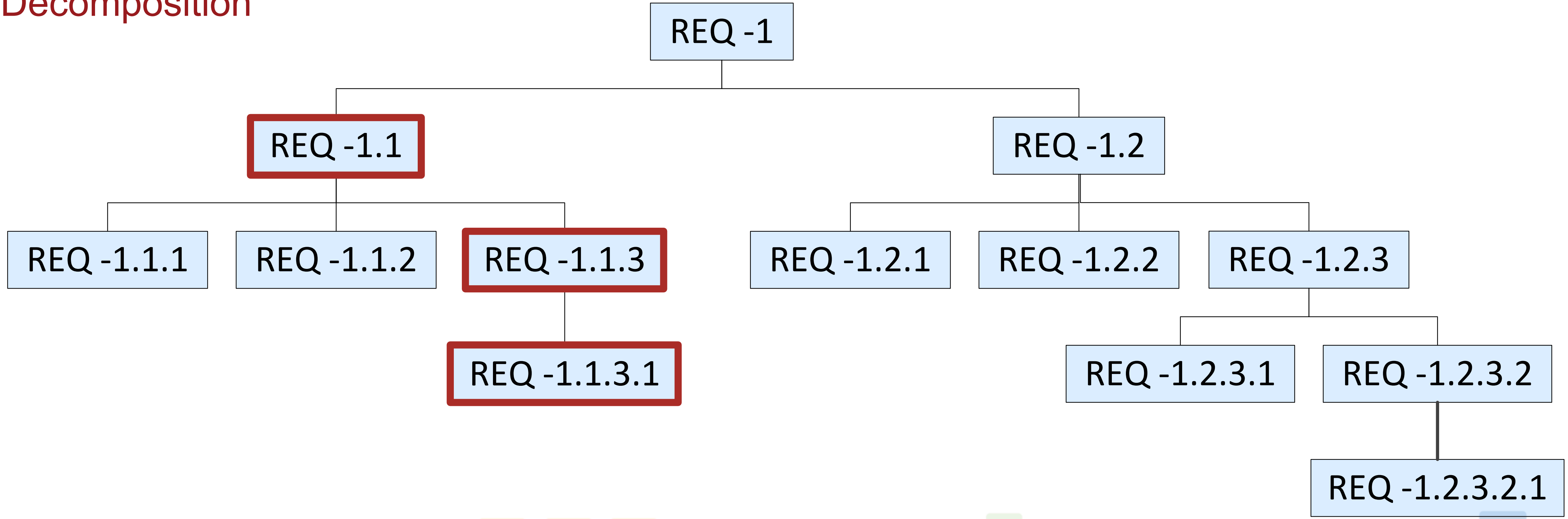
UML 2.0 Overview
Objects, Attributes, Relationships



UML 2.0 Overview
Composition



Decomposition



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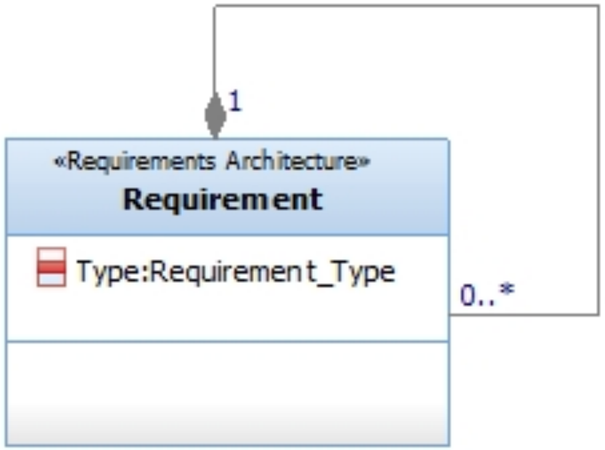
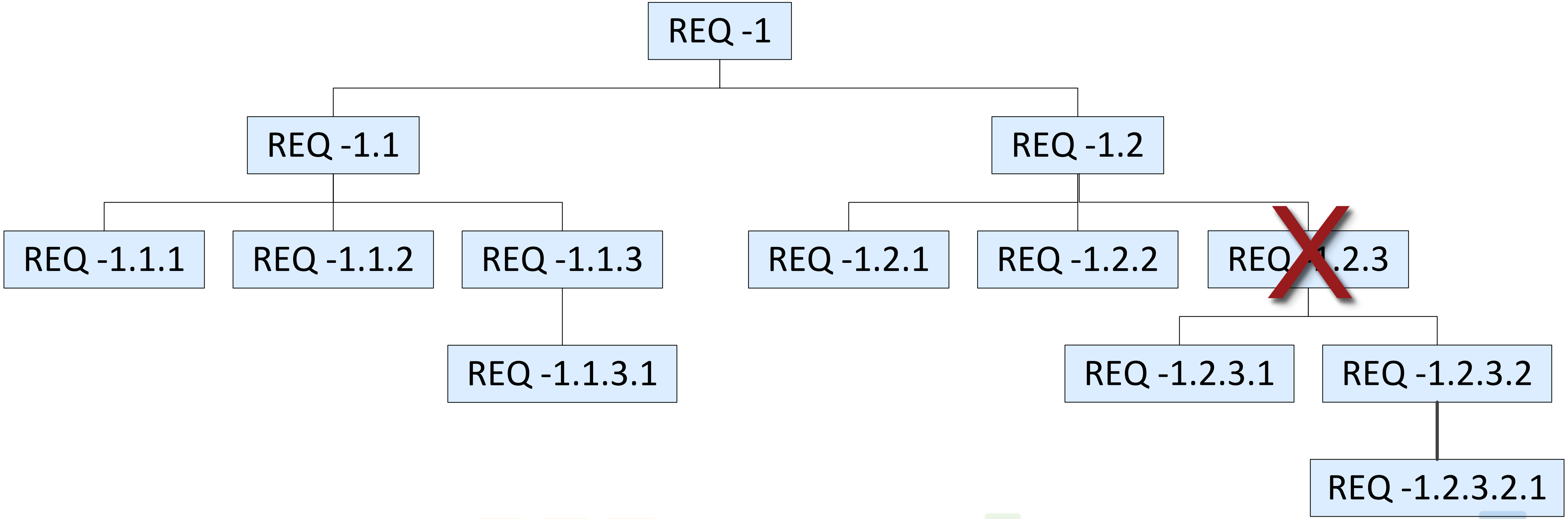
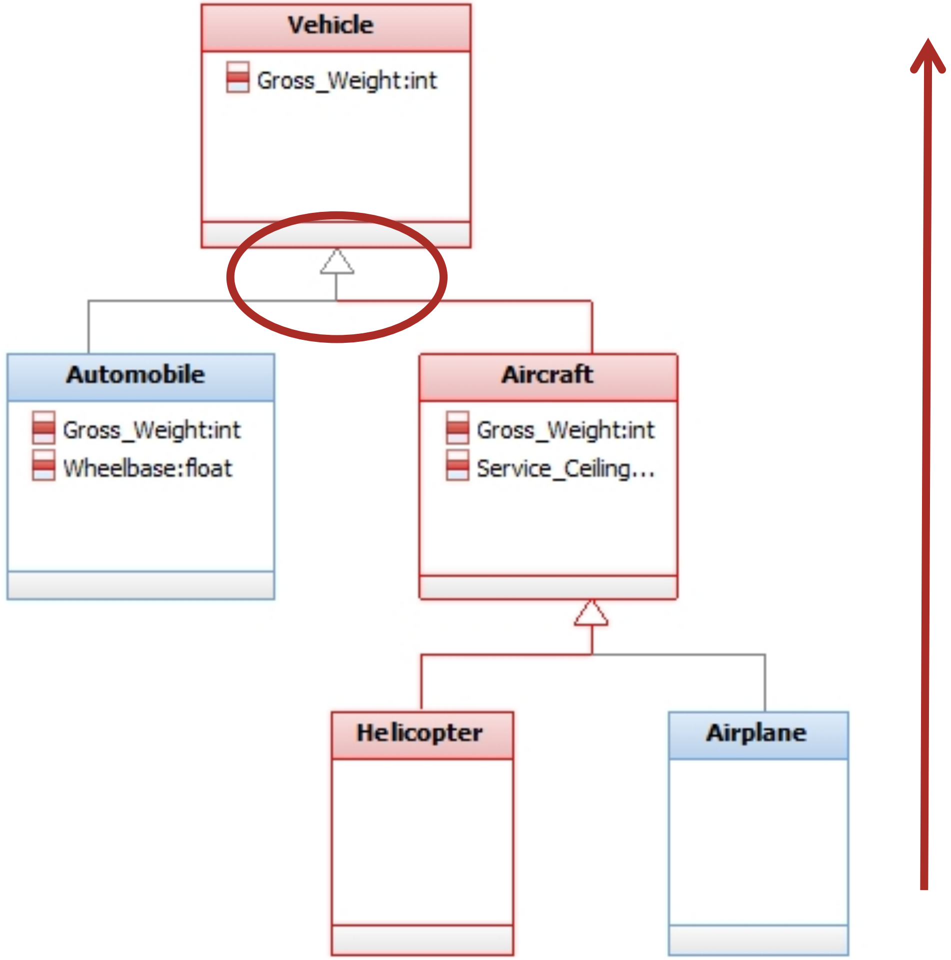




UML 2.0 Overview
Generalization (Subtypes)

- Generalization is a mechanism for grouping similar objects



Generalization

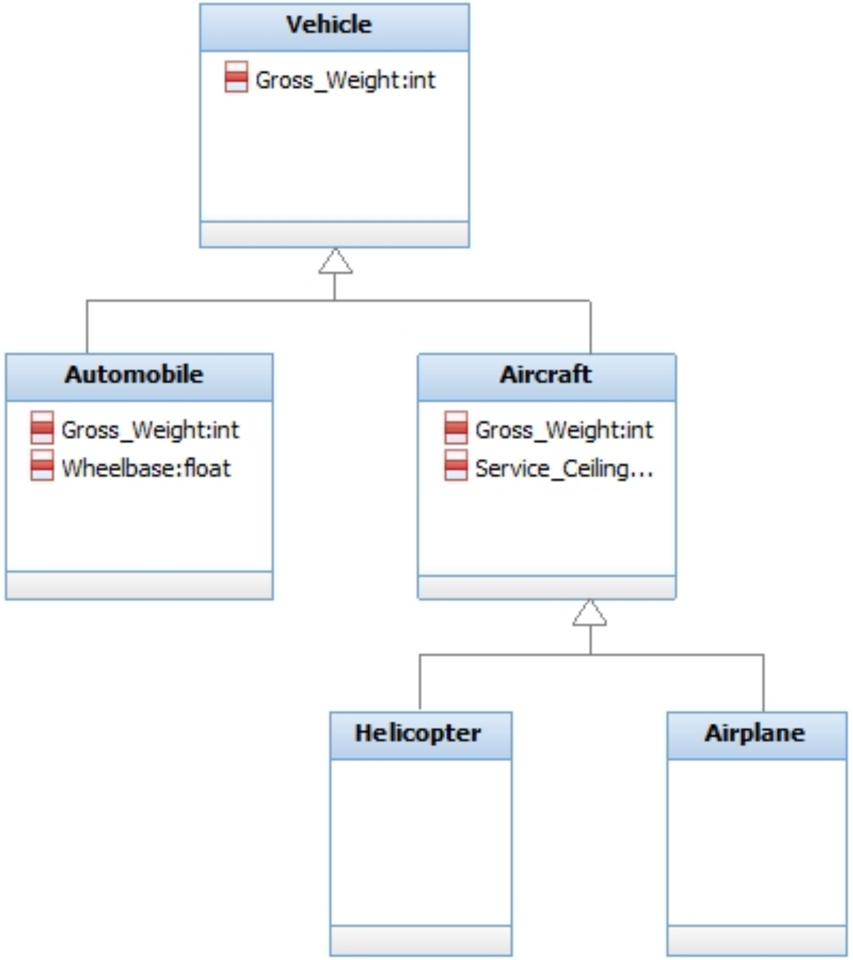
Helicopter generalizes to **Aircraft** generalizes to **Vehicle**

UML 2.0 Overview
Generalization (Subtypes)

- Generalization is a mechanism for grouping similar objects

Subtype

All attributes of the general object are inherited by the sub-typed objects



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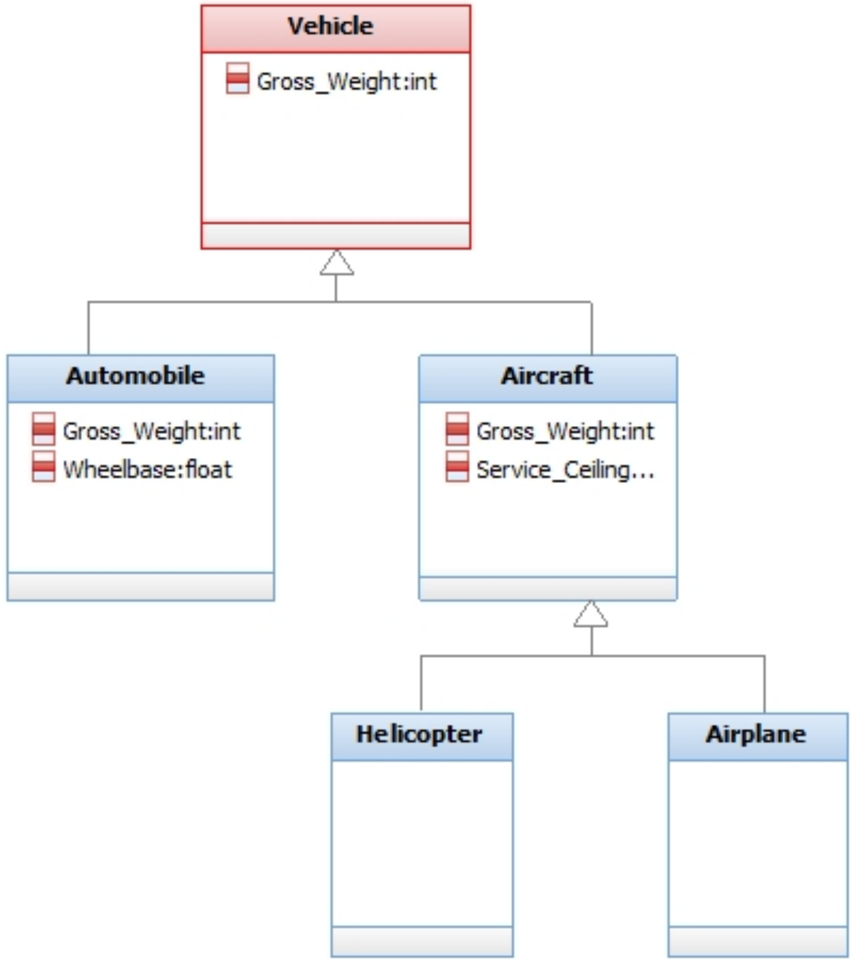

UML 2.0 Overview
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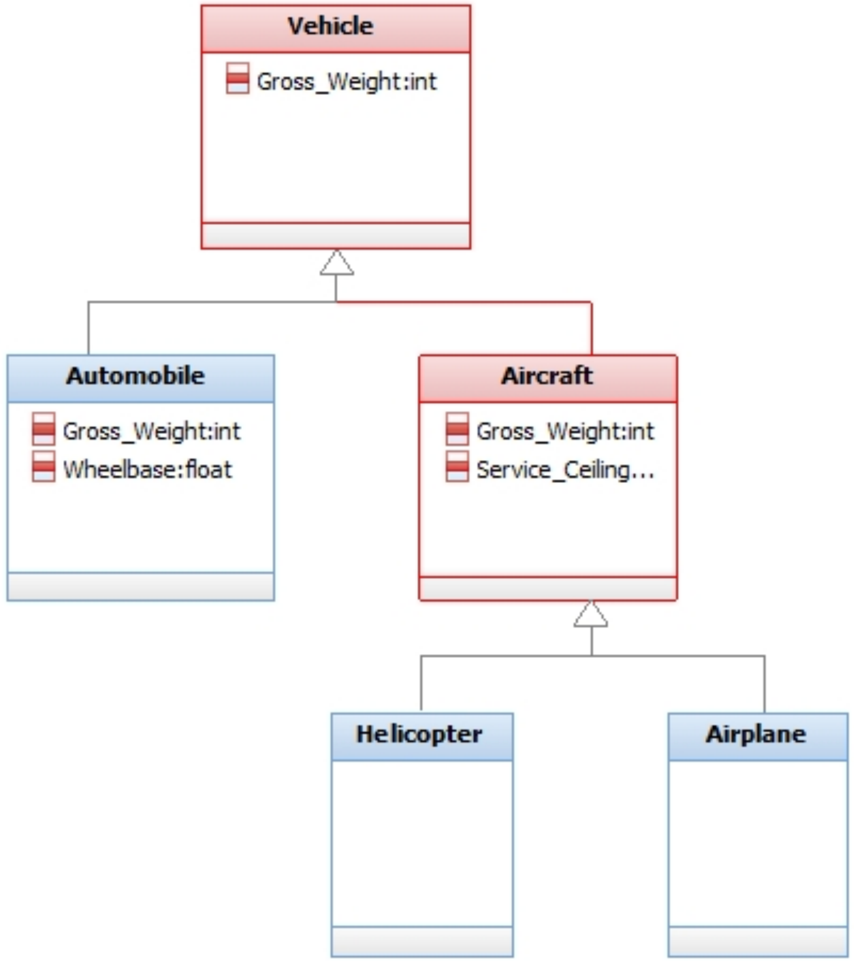
Aircraft is a subtype of Vehicle



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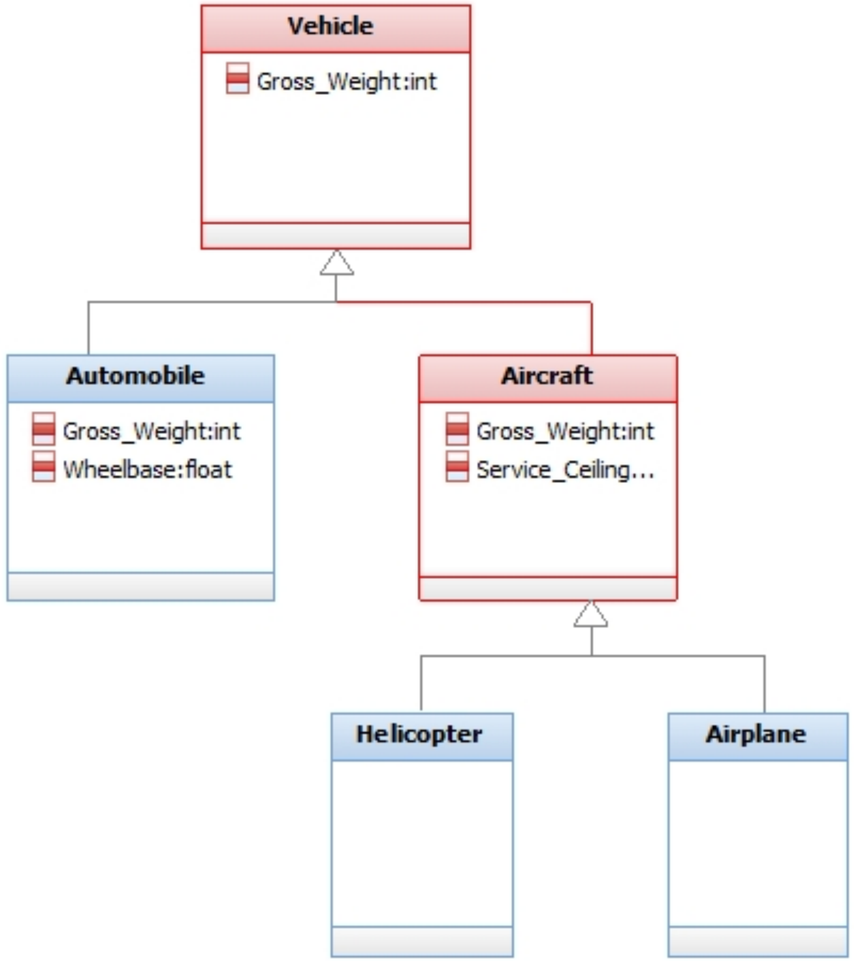


UML 2.0 Overview
Generalization (Subtypes)

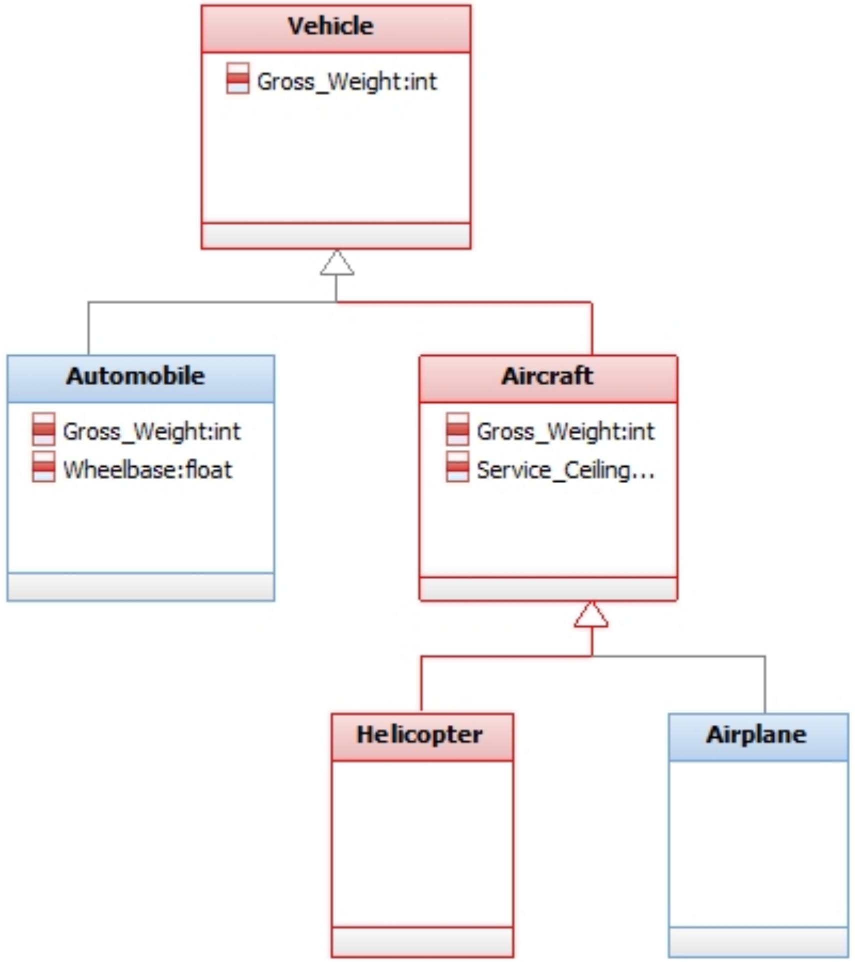
- Generalization is a mechanism for grouping similar objects

Subtype

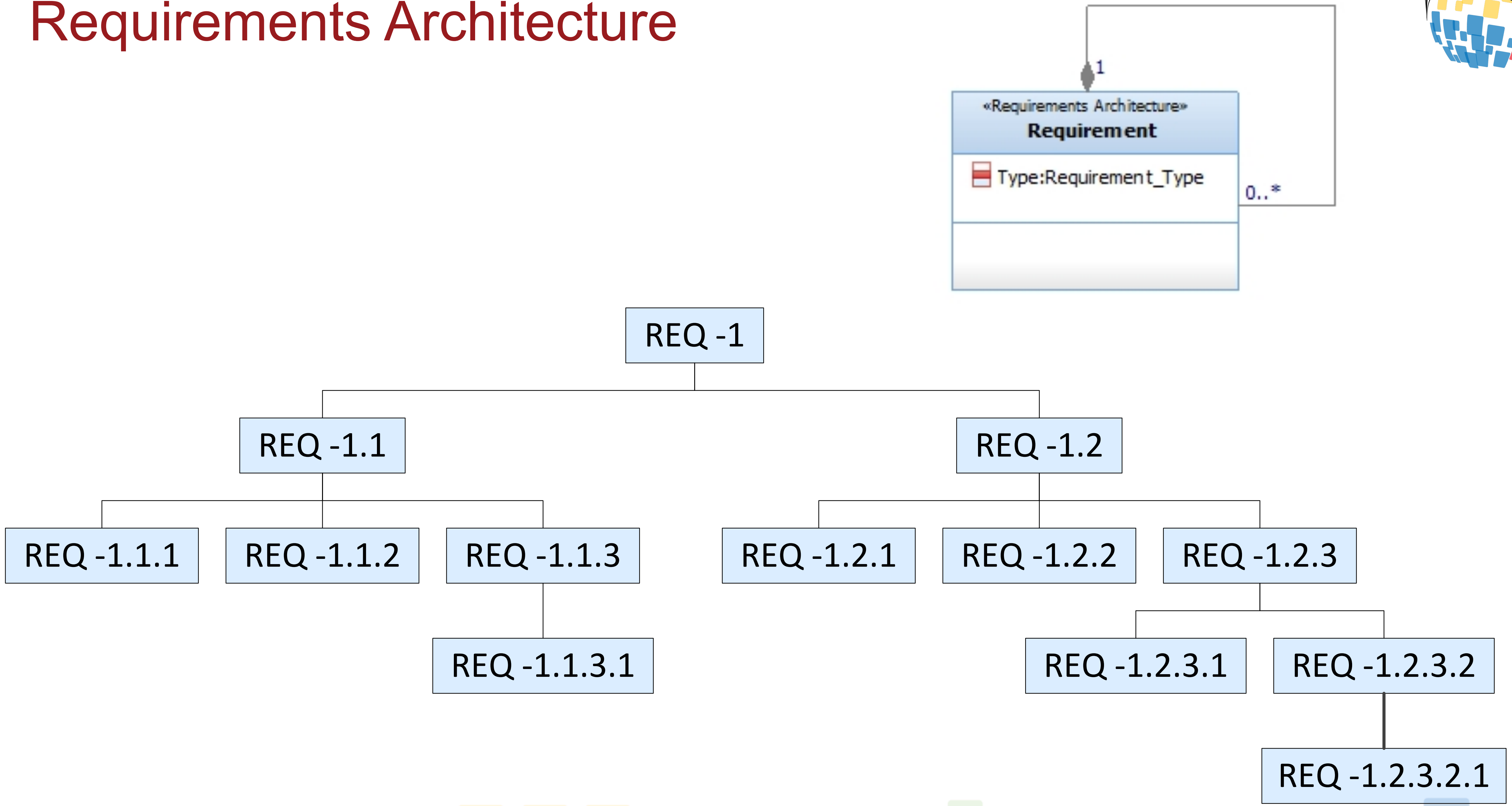
All attributes of the generalized object are inherited by the sub-typed objects

Aircraft is a subtype of Vehicle

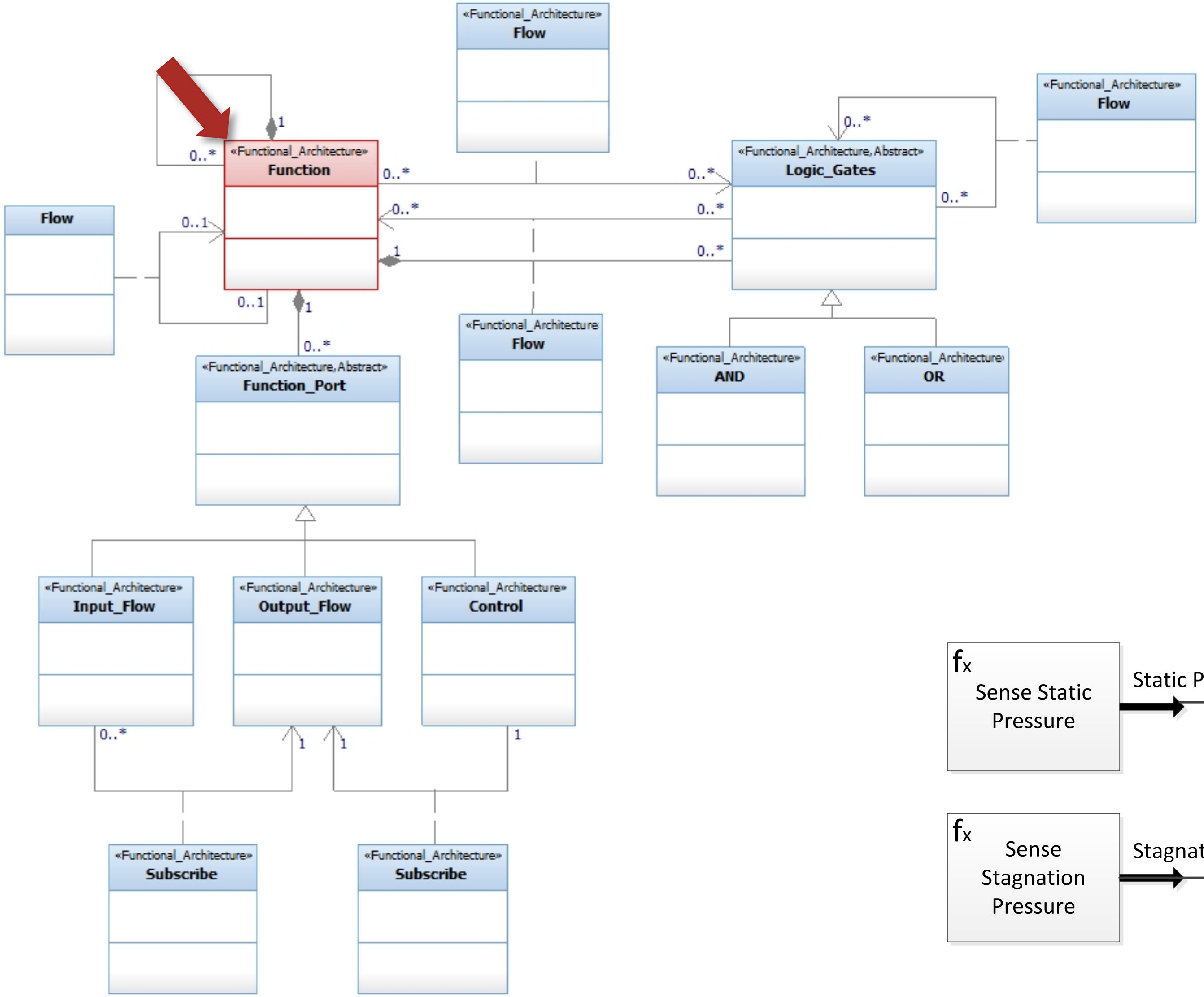
Helicopter is a subtype of Aircraft

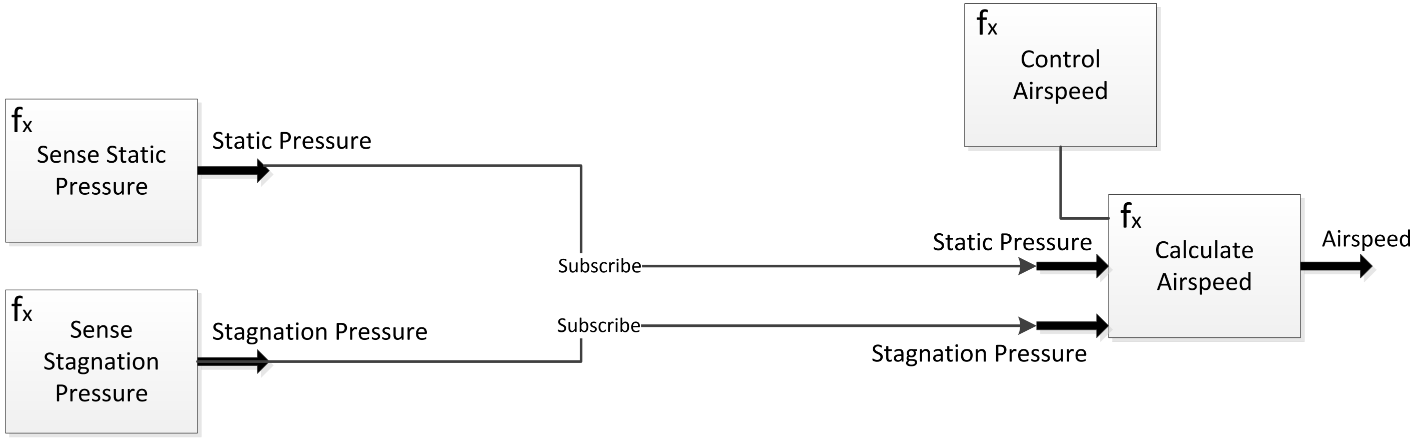


Requirements Architecture



Functional Architecture





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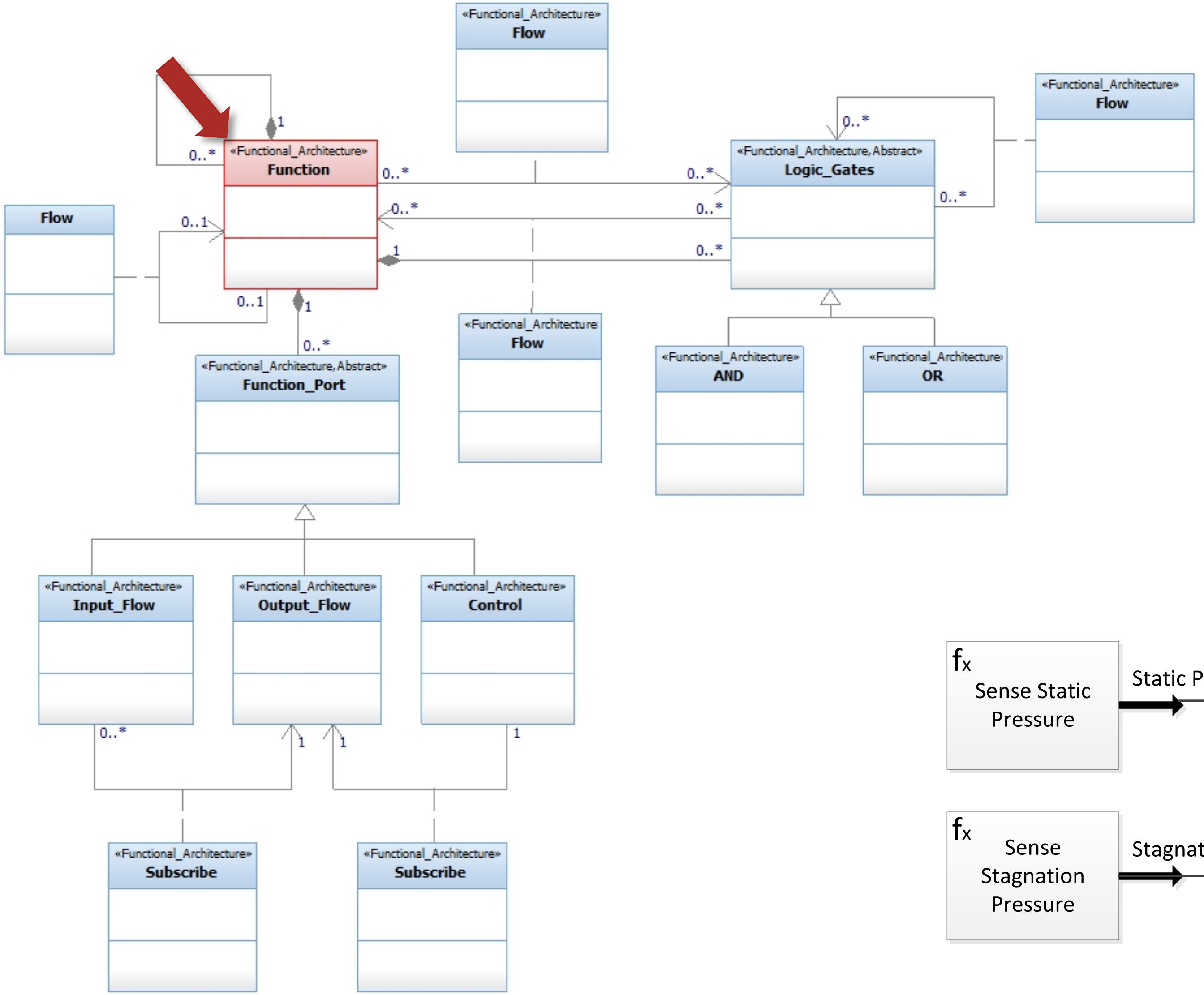

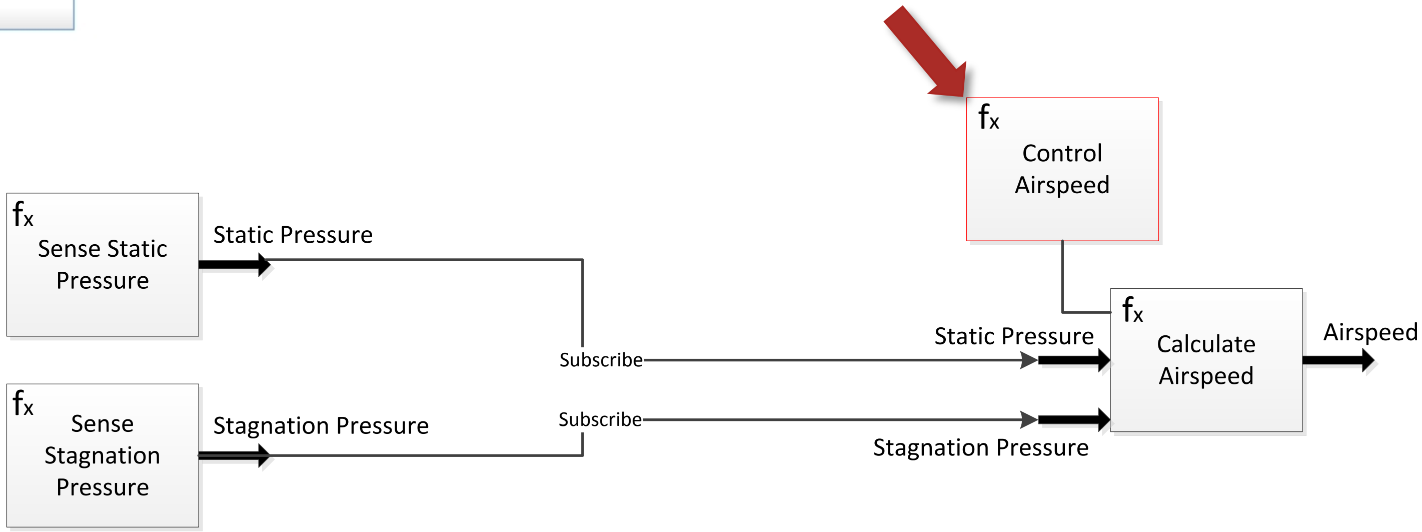

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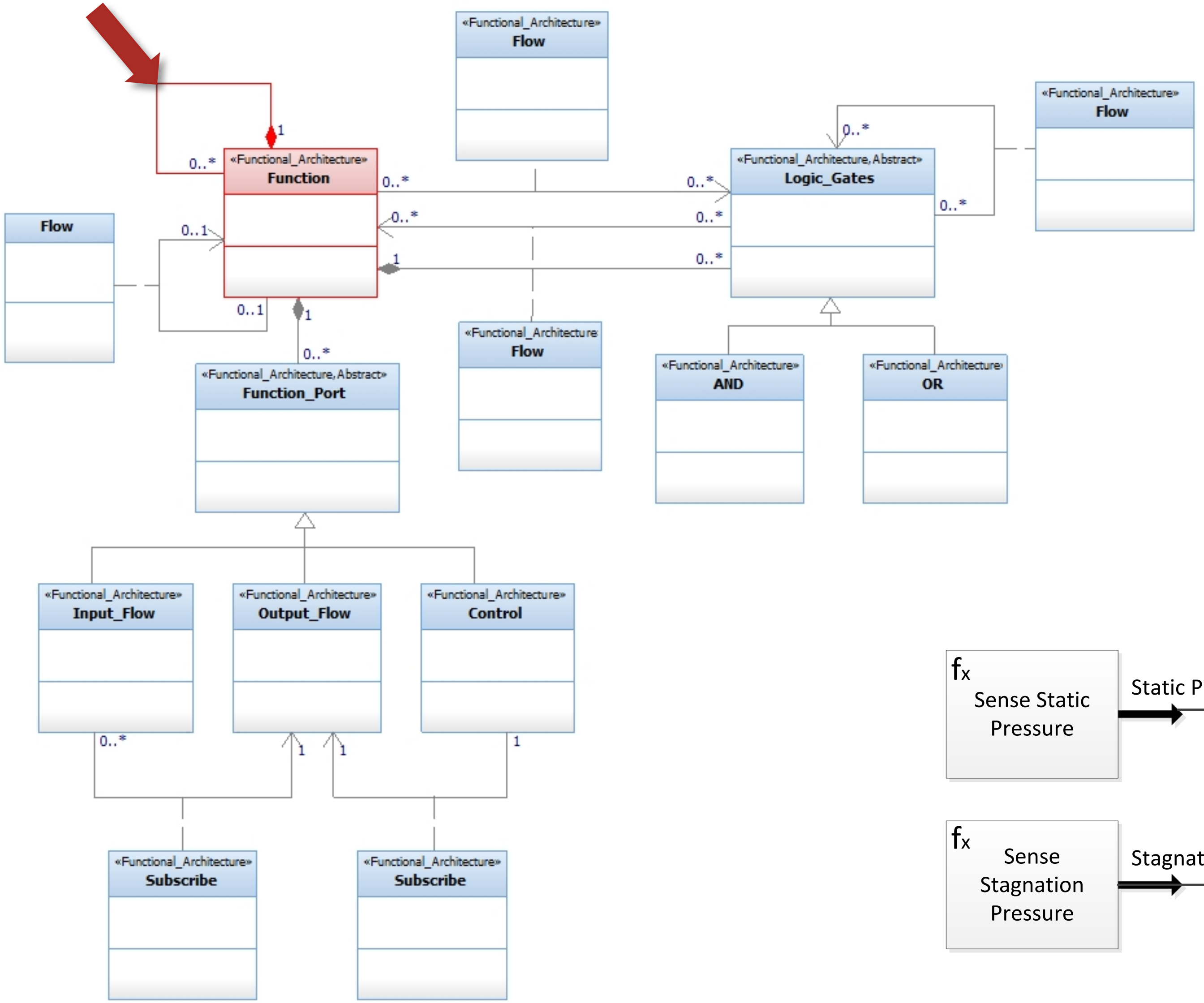

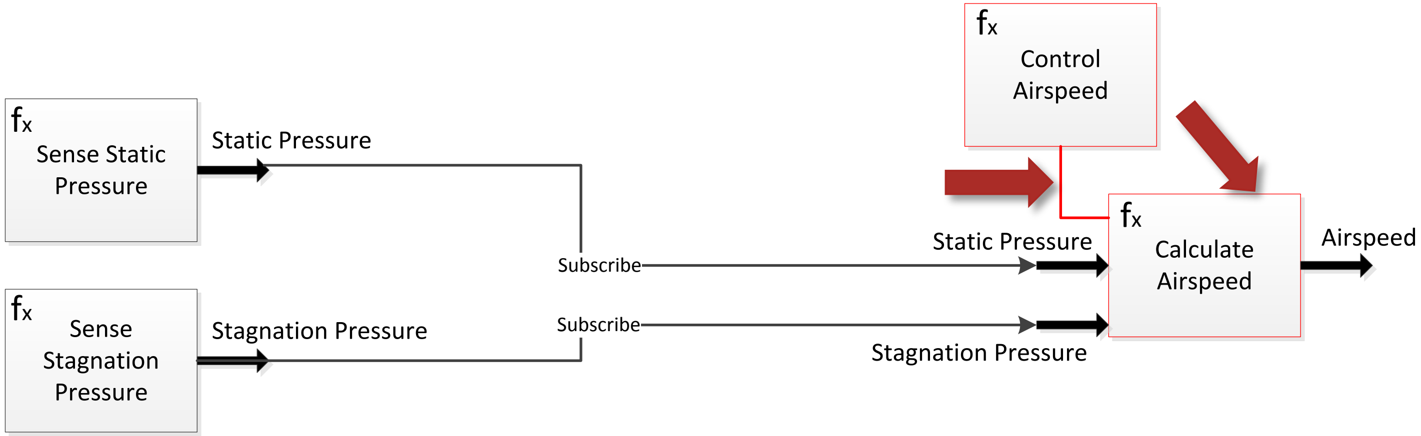

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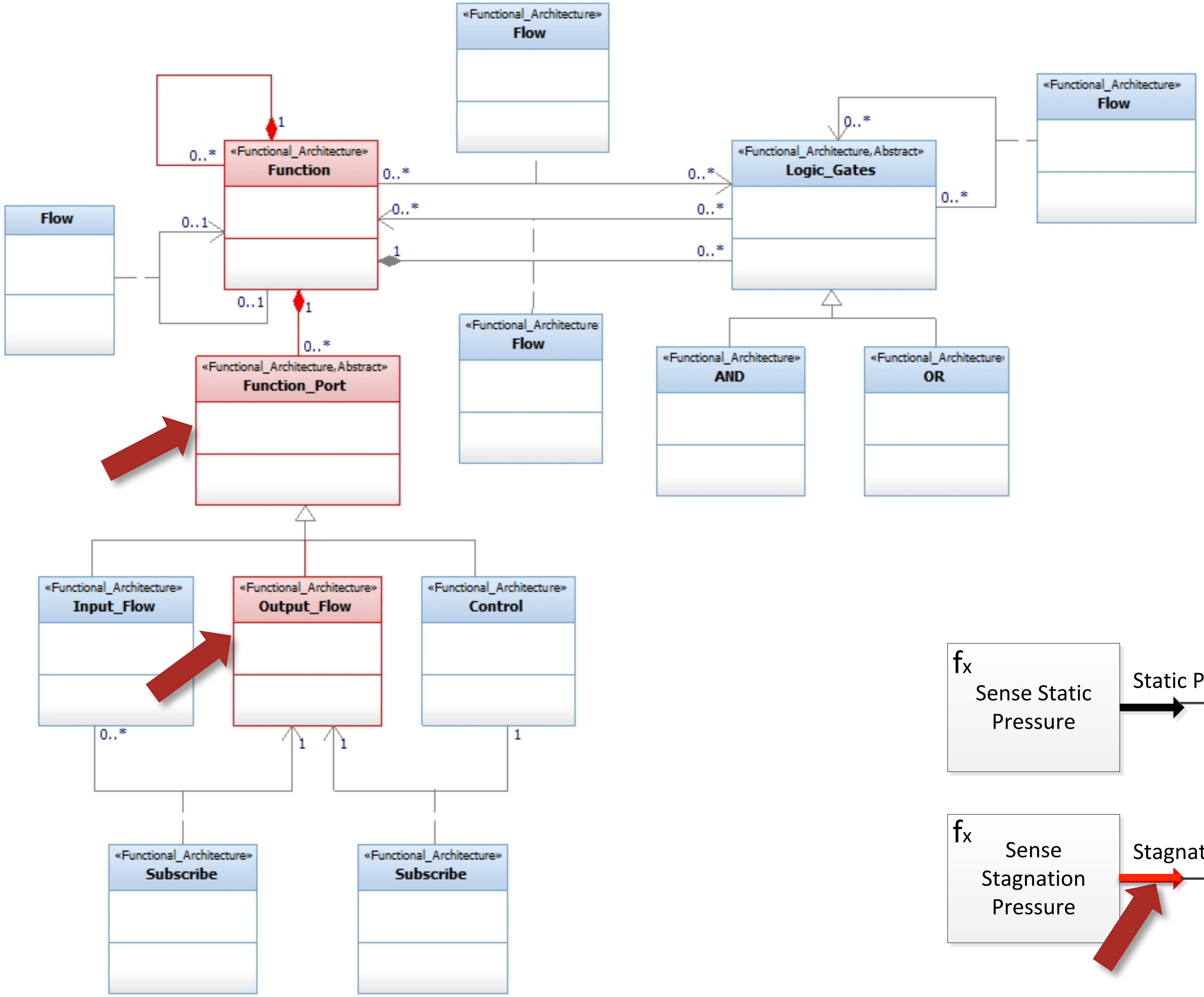

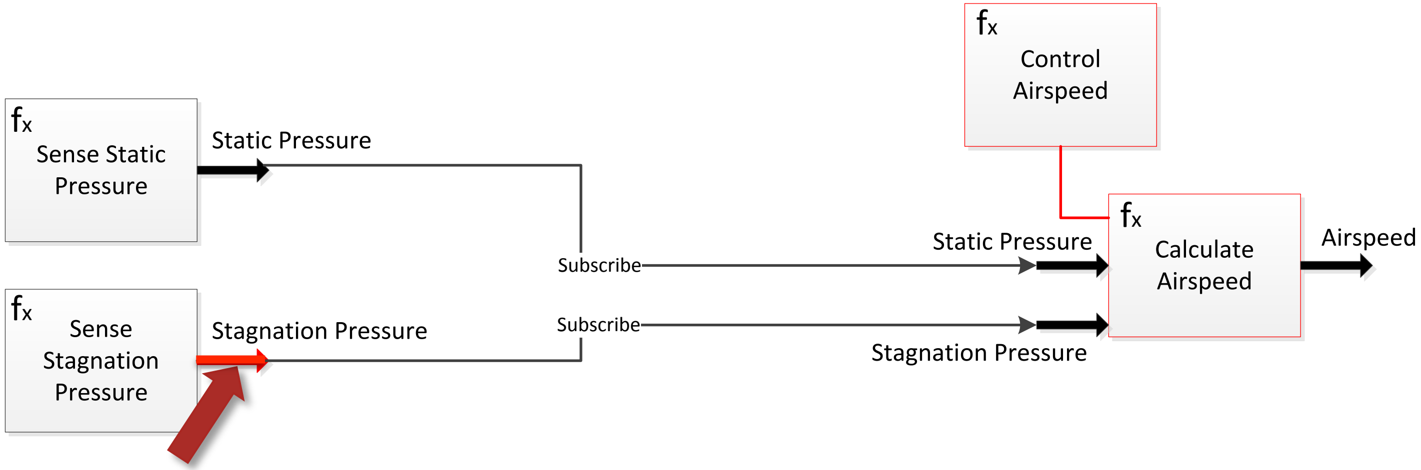

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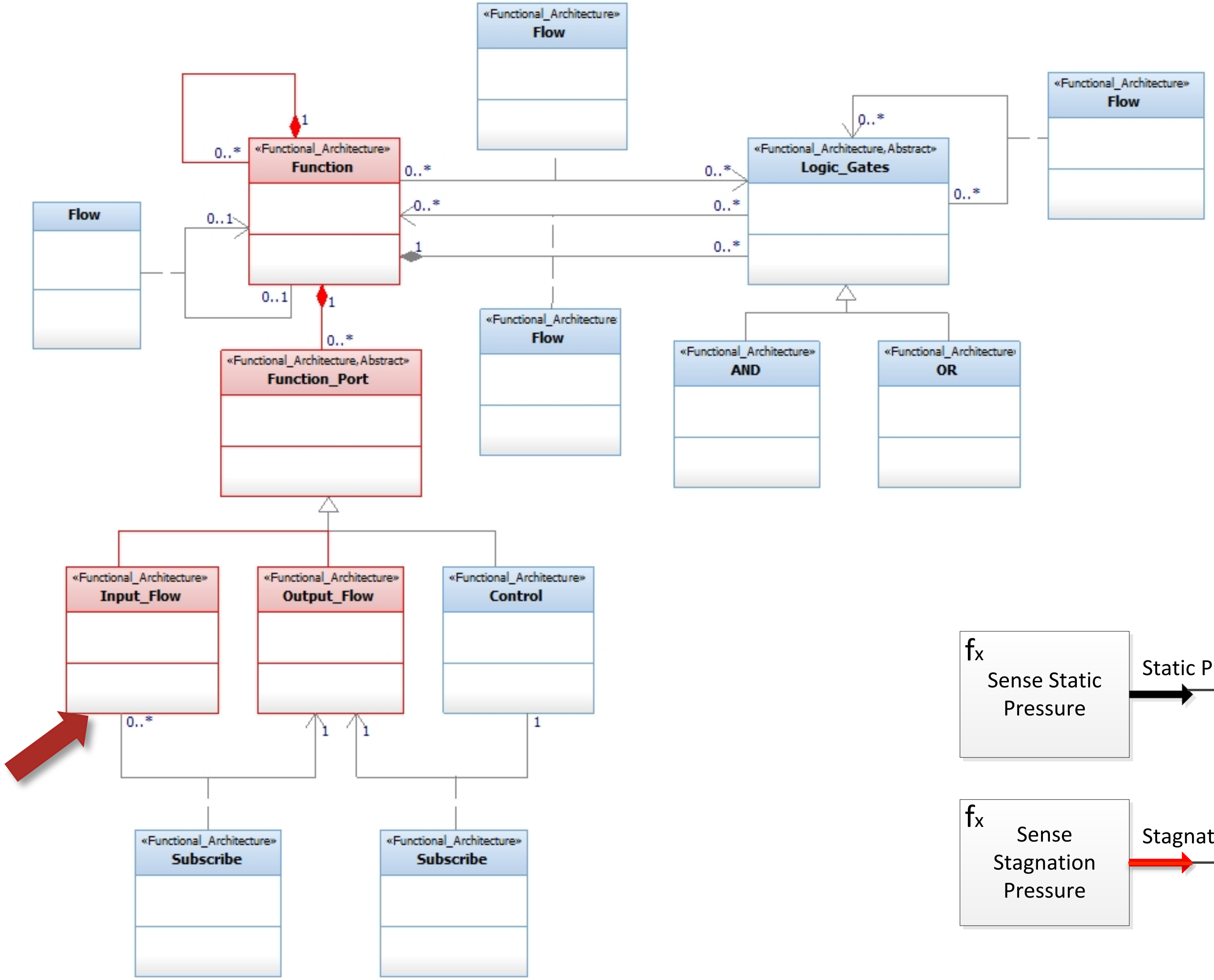

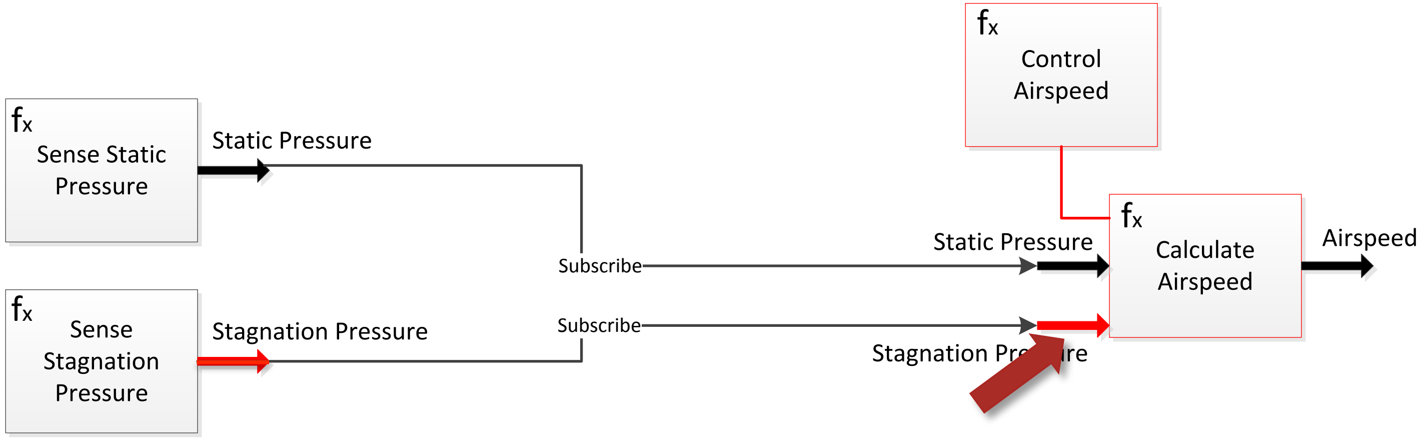

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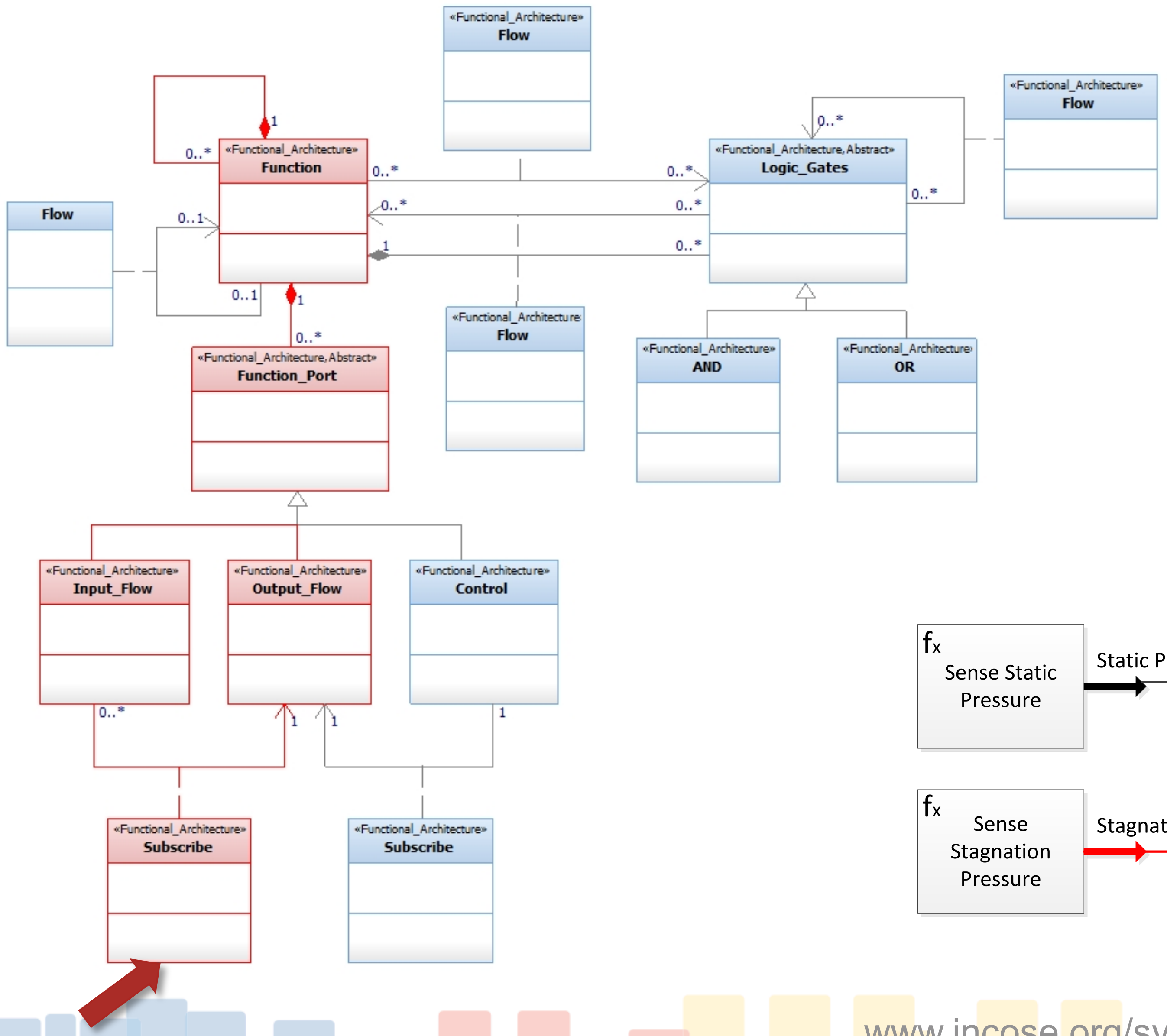

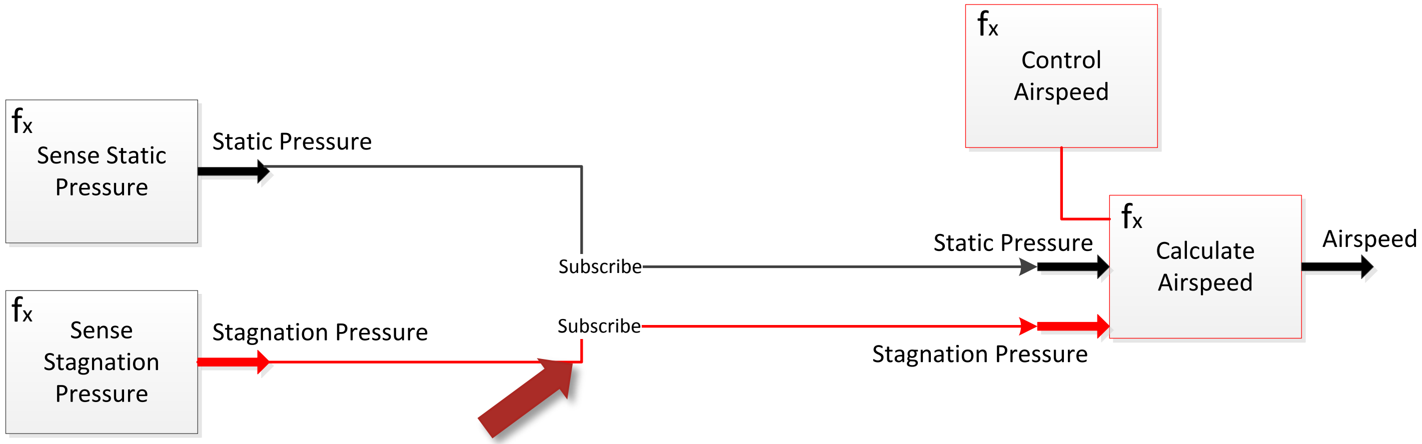

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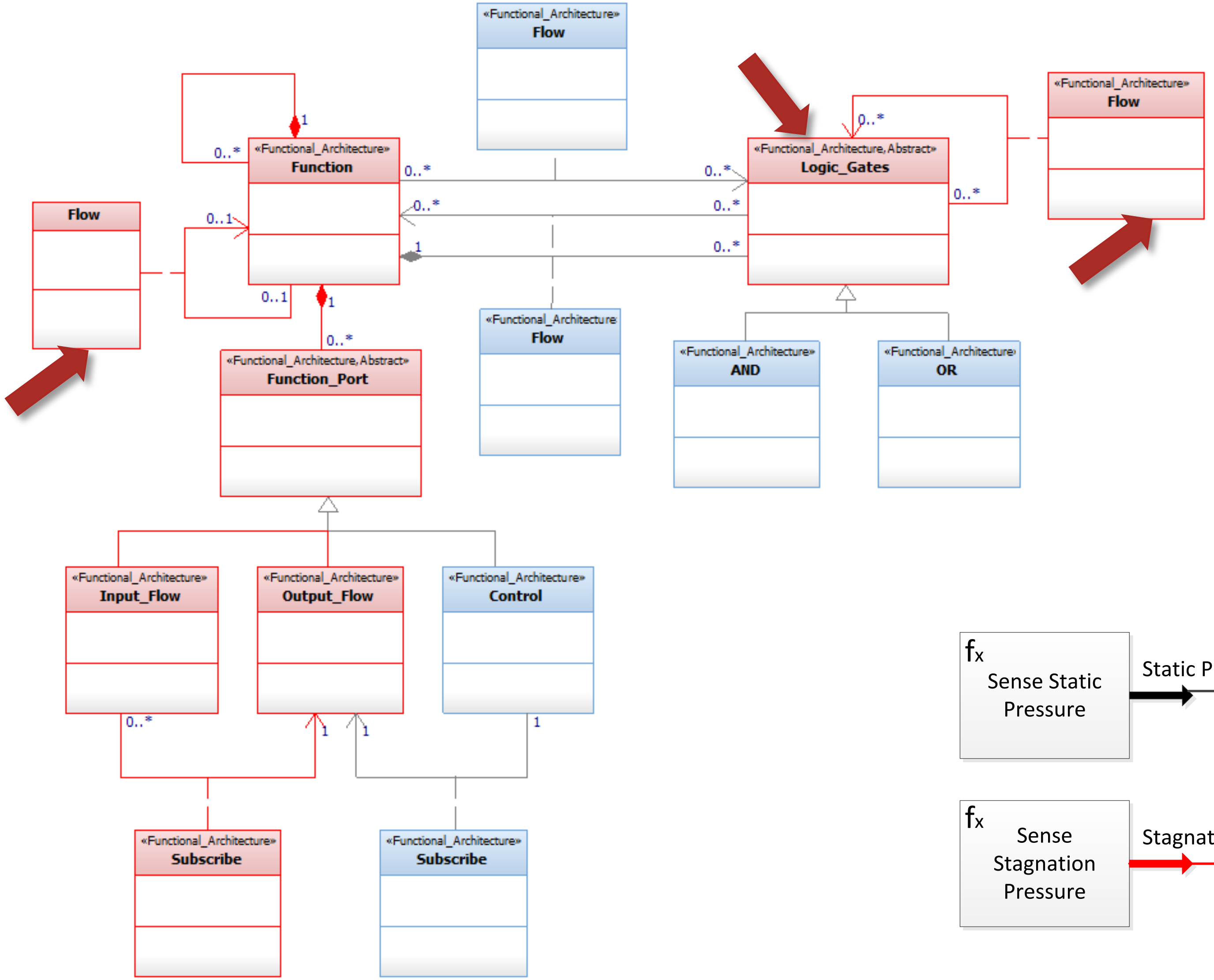
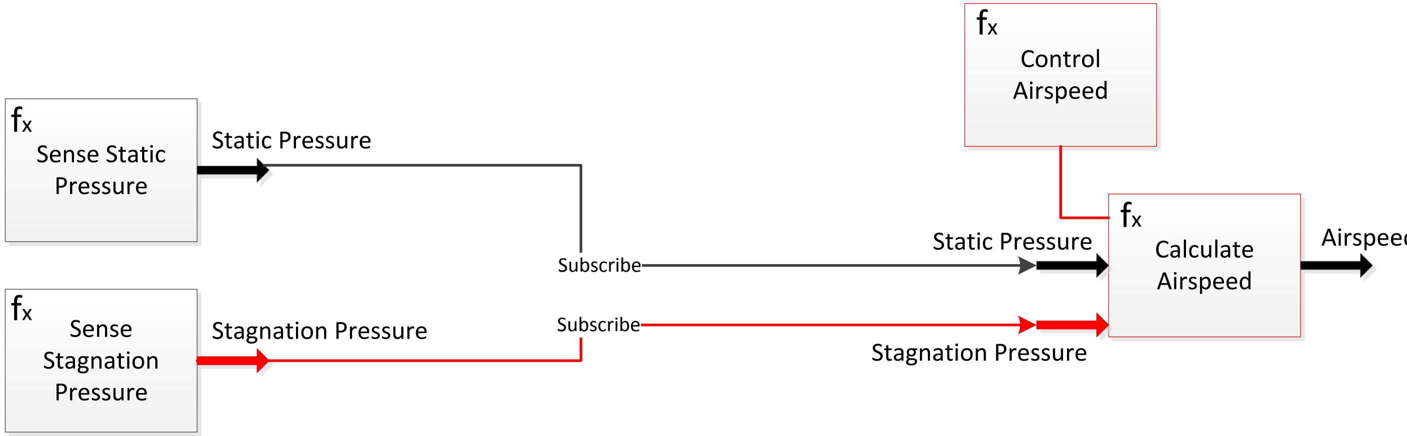
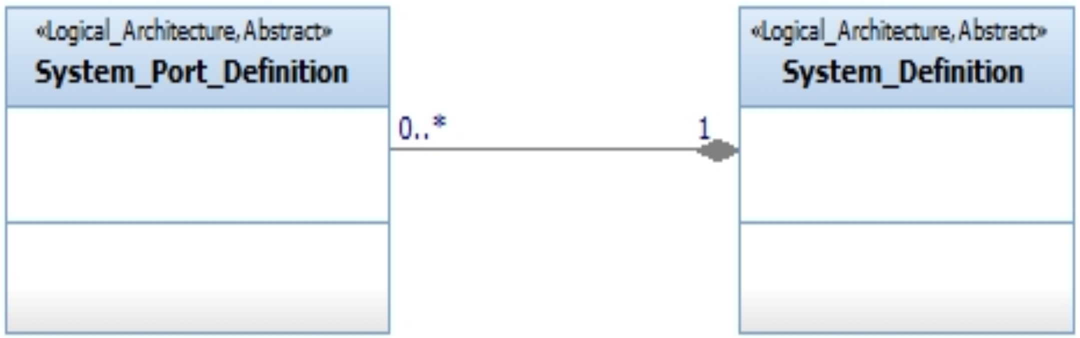
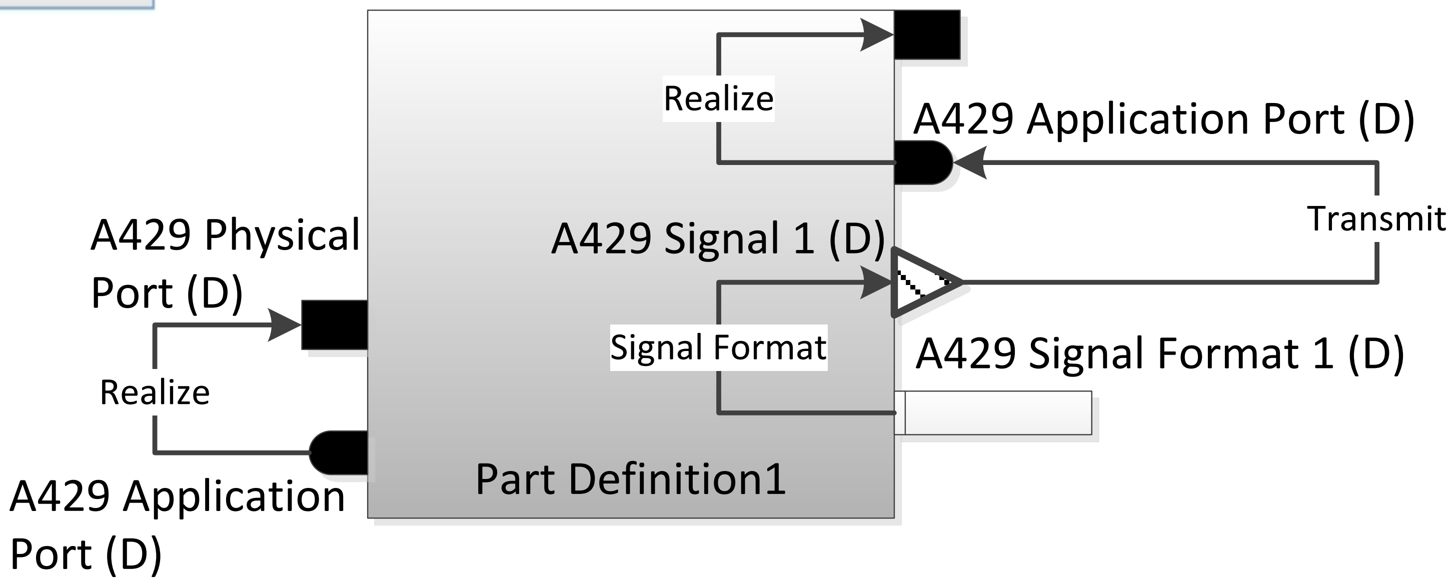




Logical Architecture
Systems and Ports





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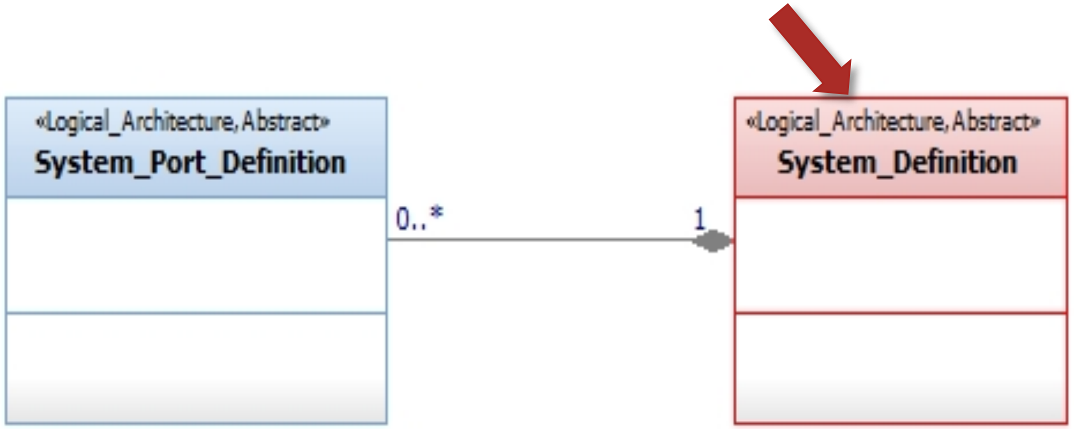
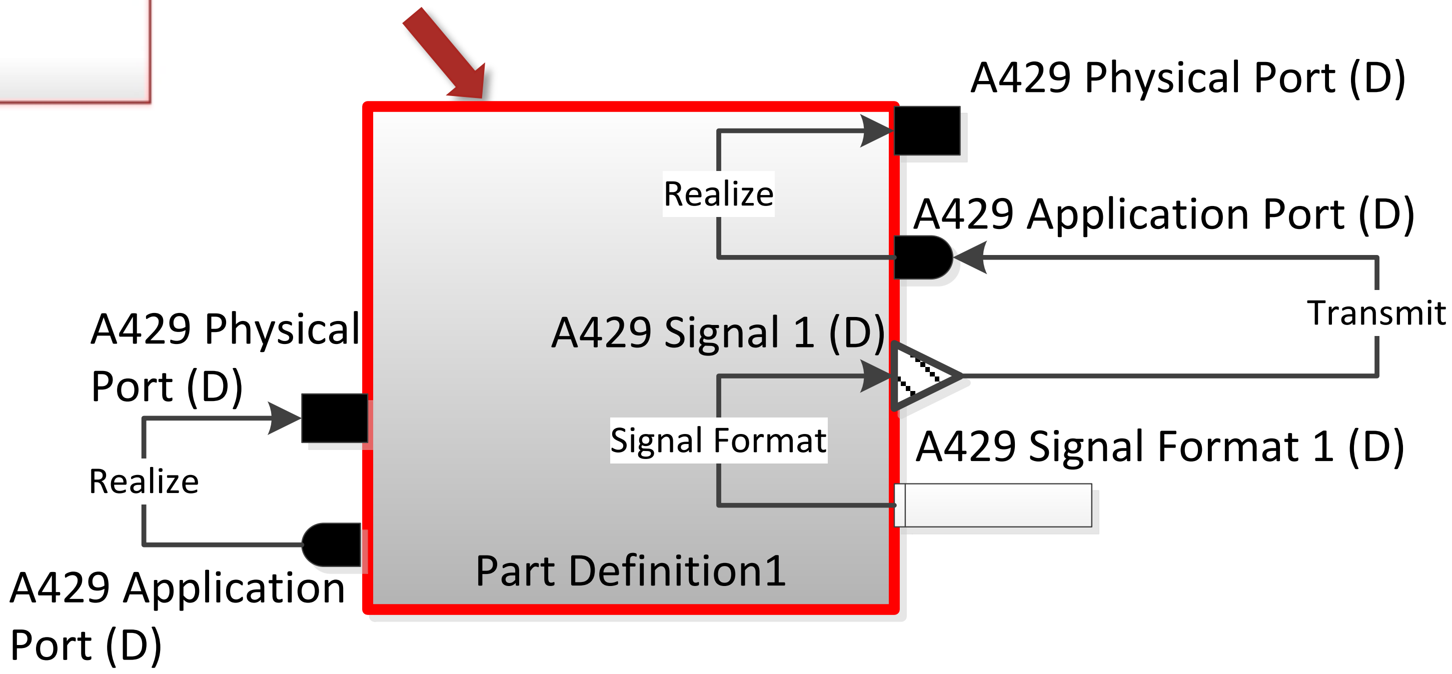
Systems and Ports





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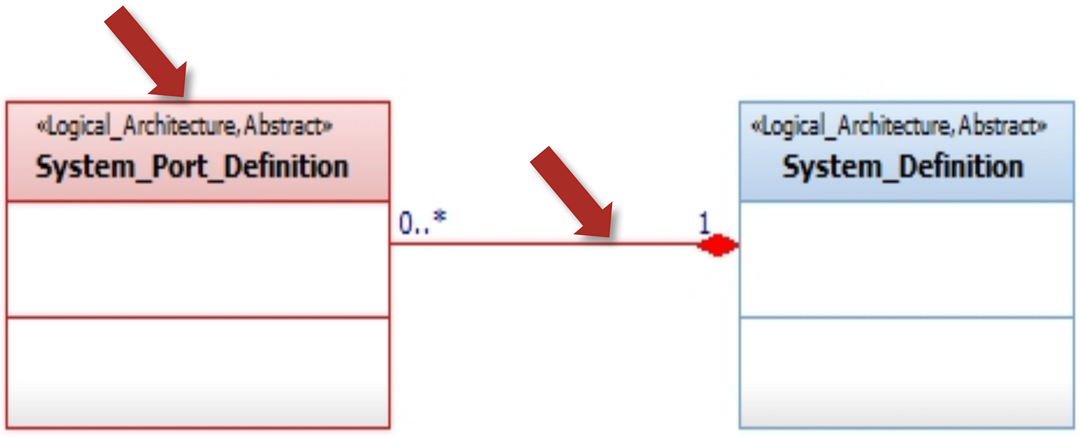
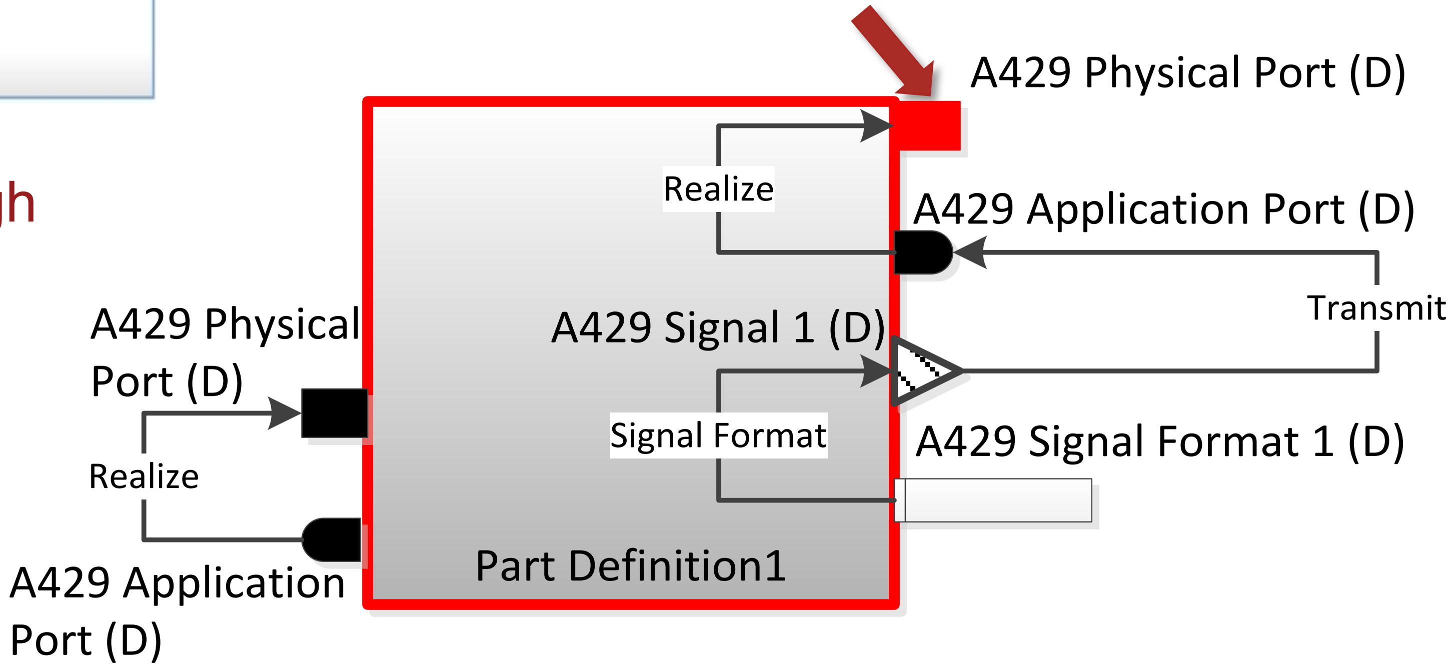
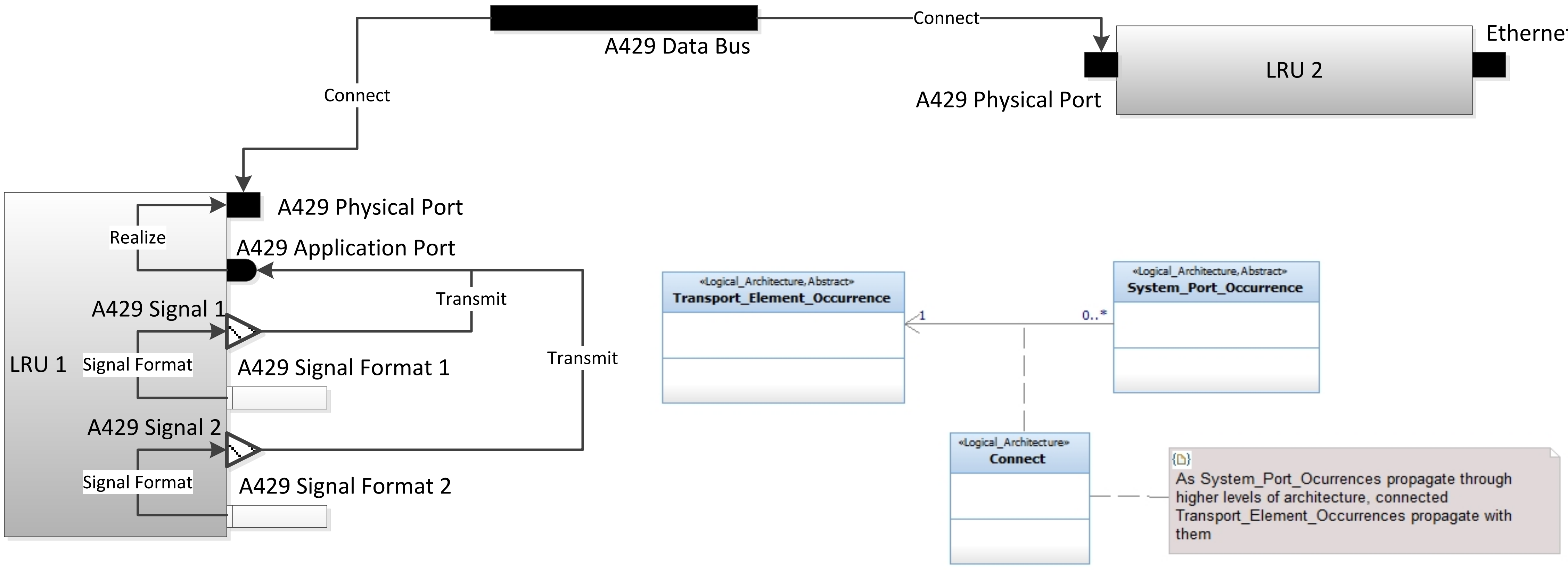


System objects communicate through System Ports



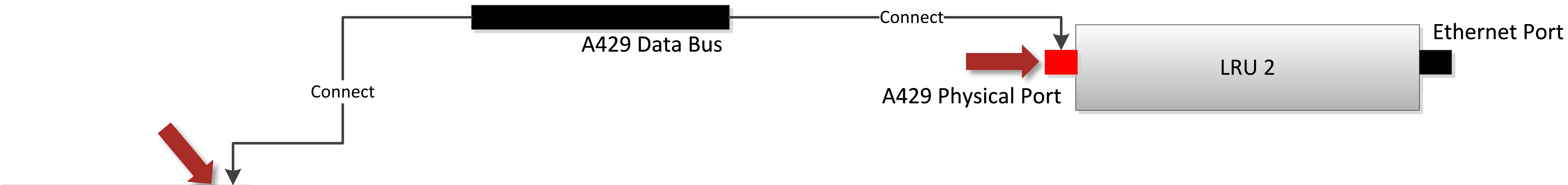
Logical Architecture

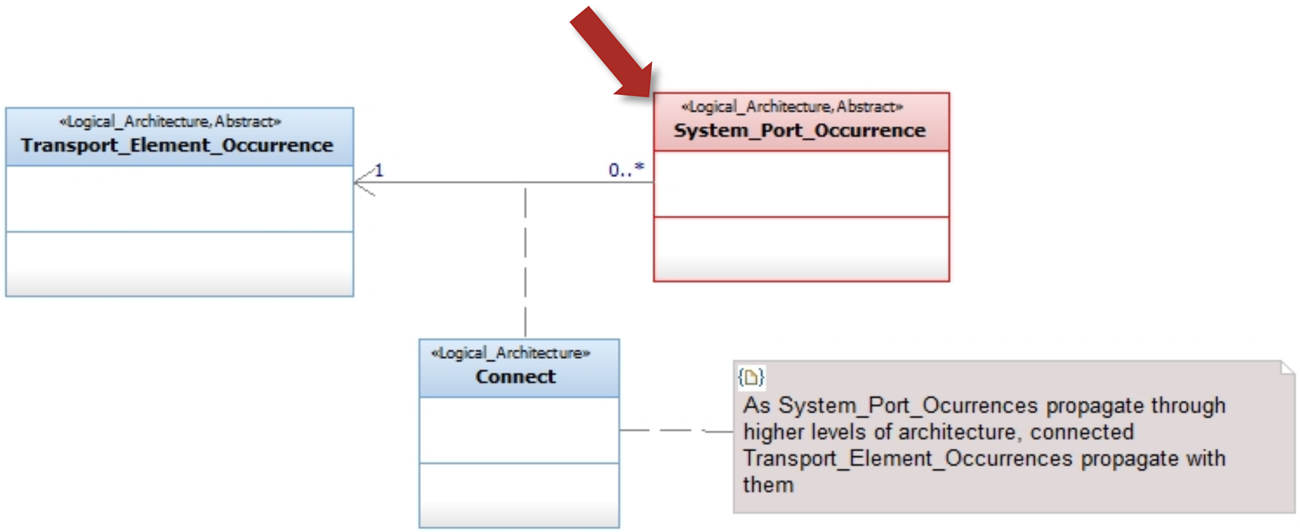
Systems Connectivity



Logical Architecture
Systems Connectivity

System objects interface physically through Physical Port objects

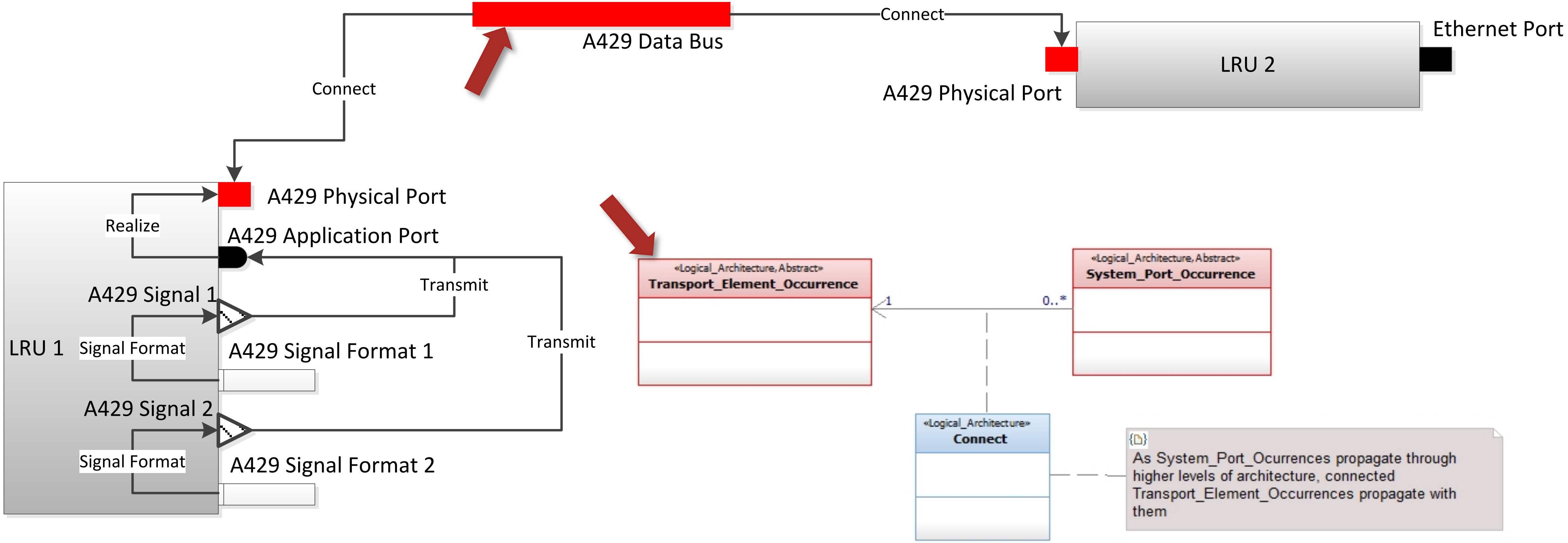




Occurrence Level View
No Definitions

Logical Architecture
Systems Connectivity

Physical Ports Connect to Transport Elements (Conduits)



Occurrence Level View
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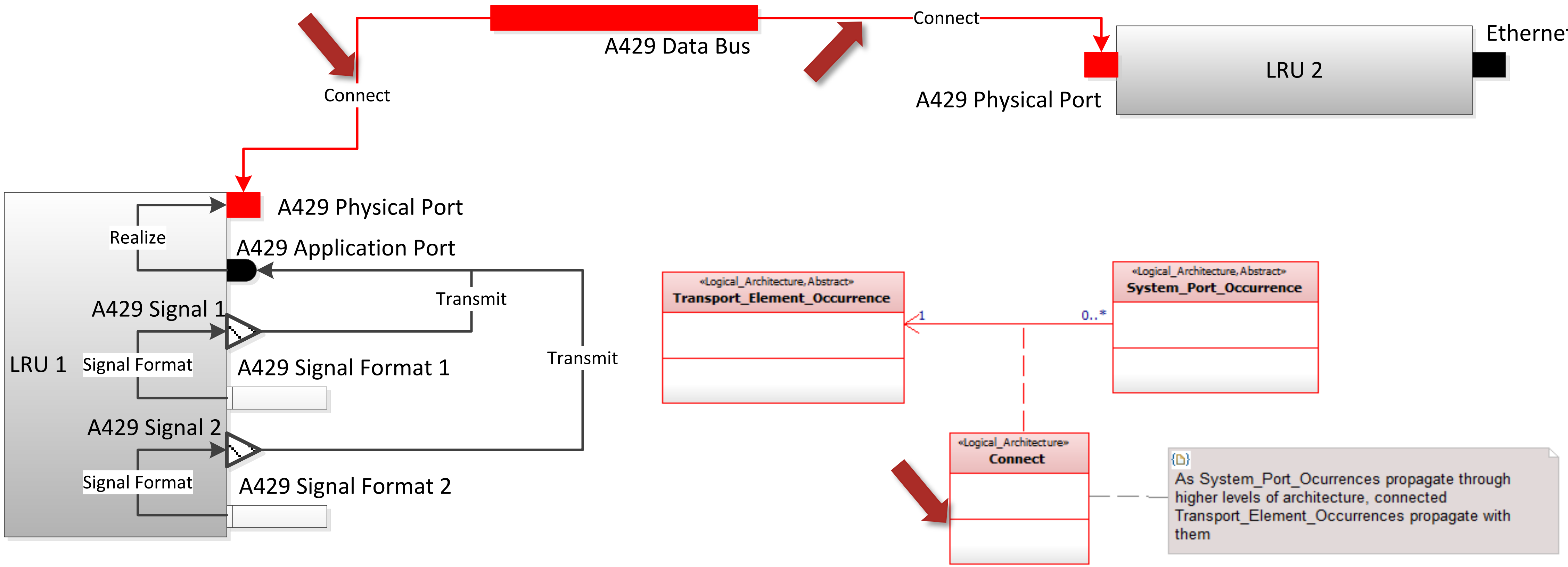
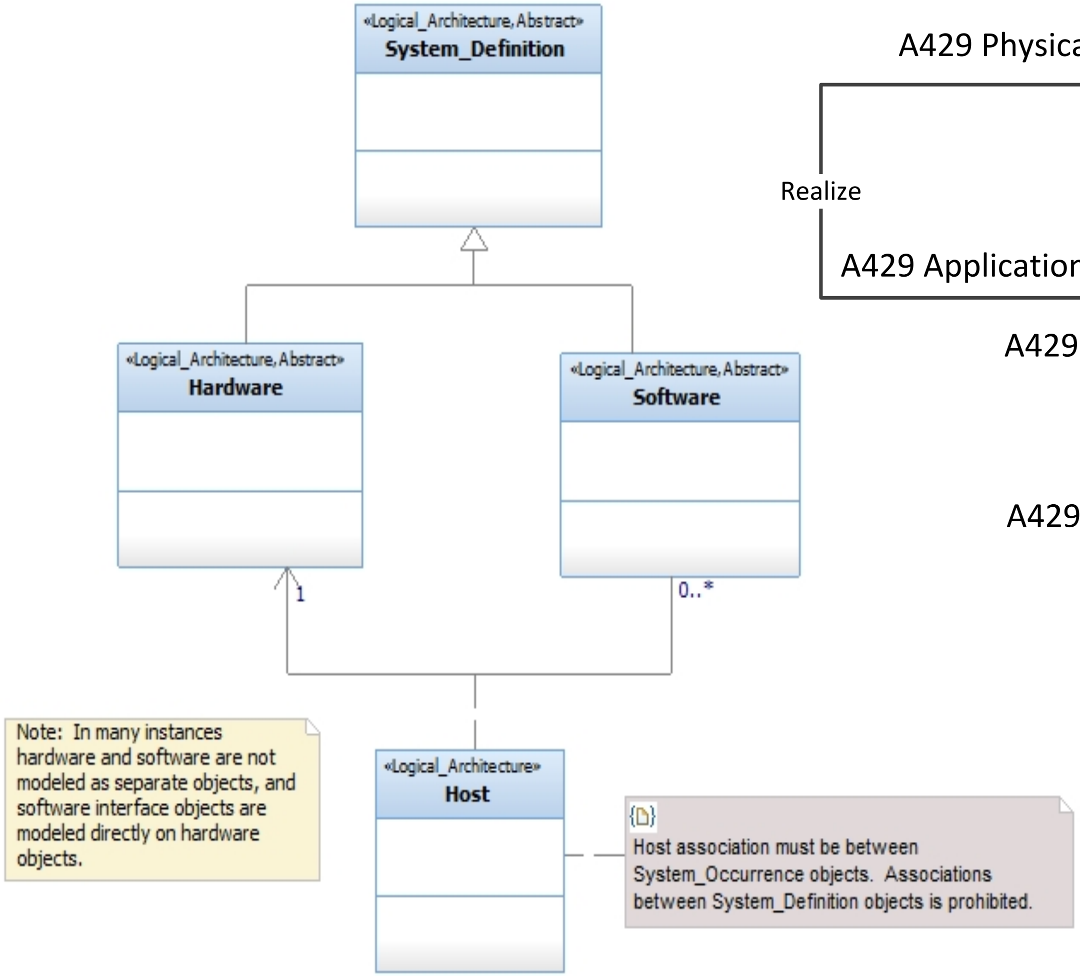
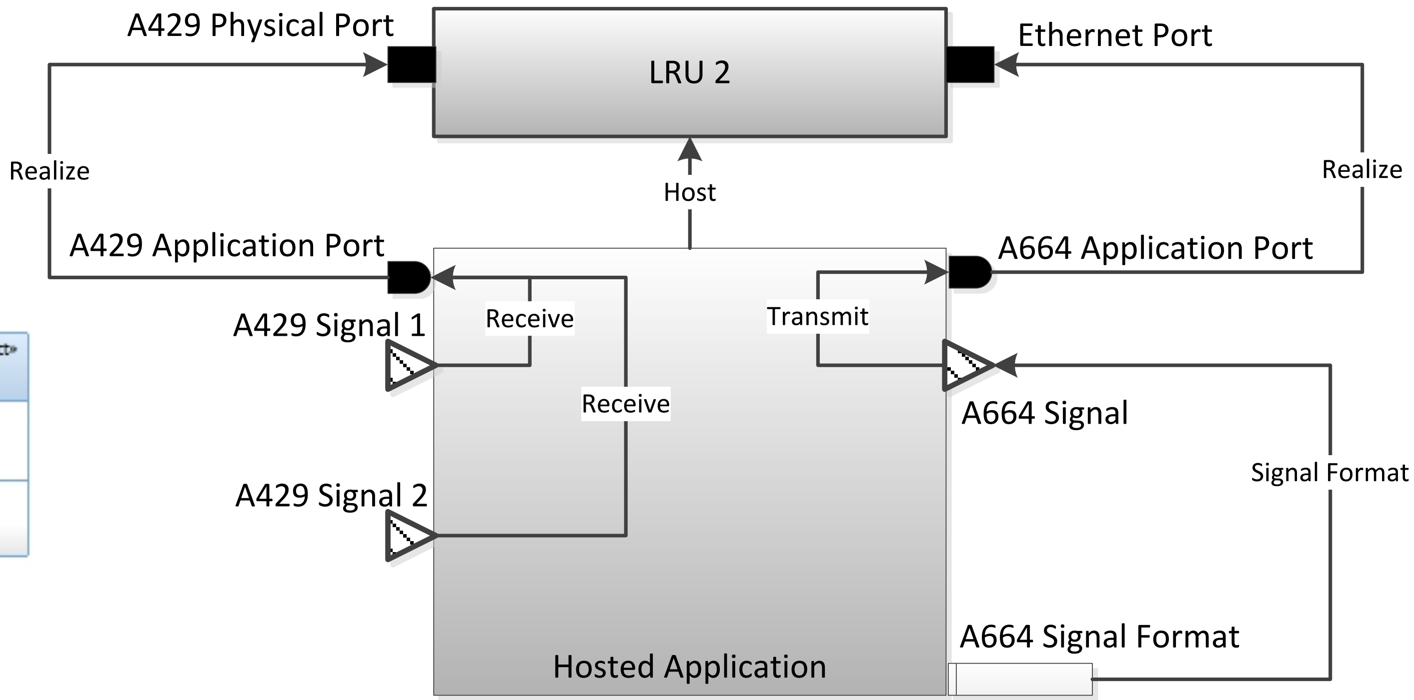


Logical Architecture
System Subtypes





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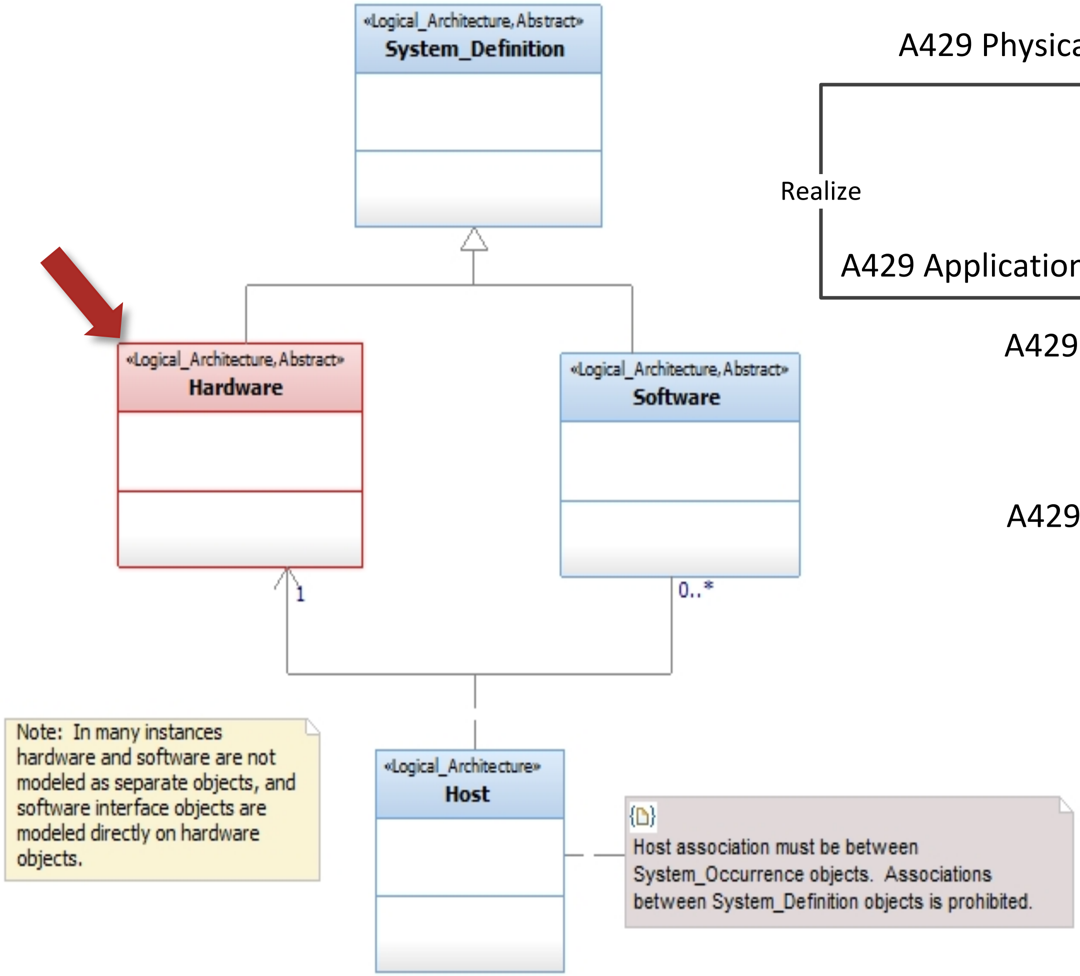

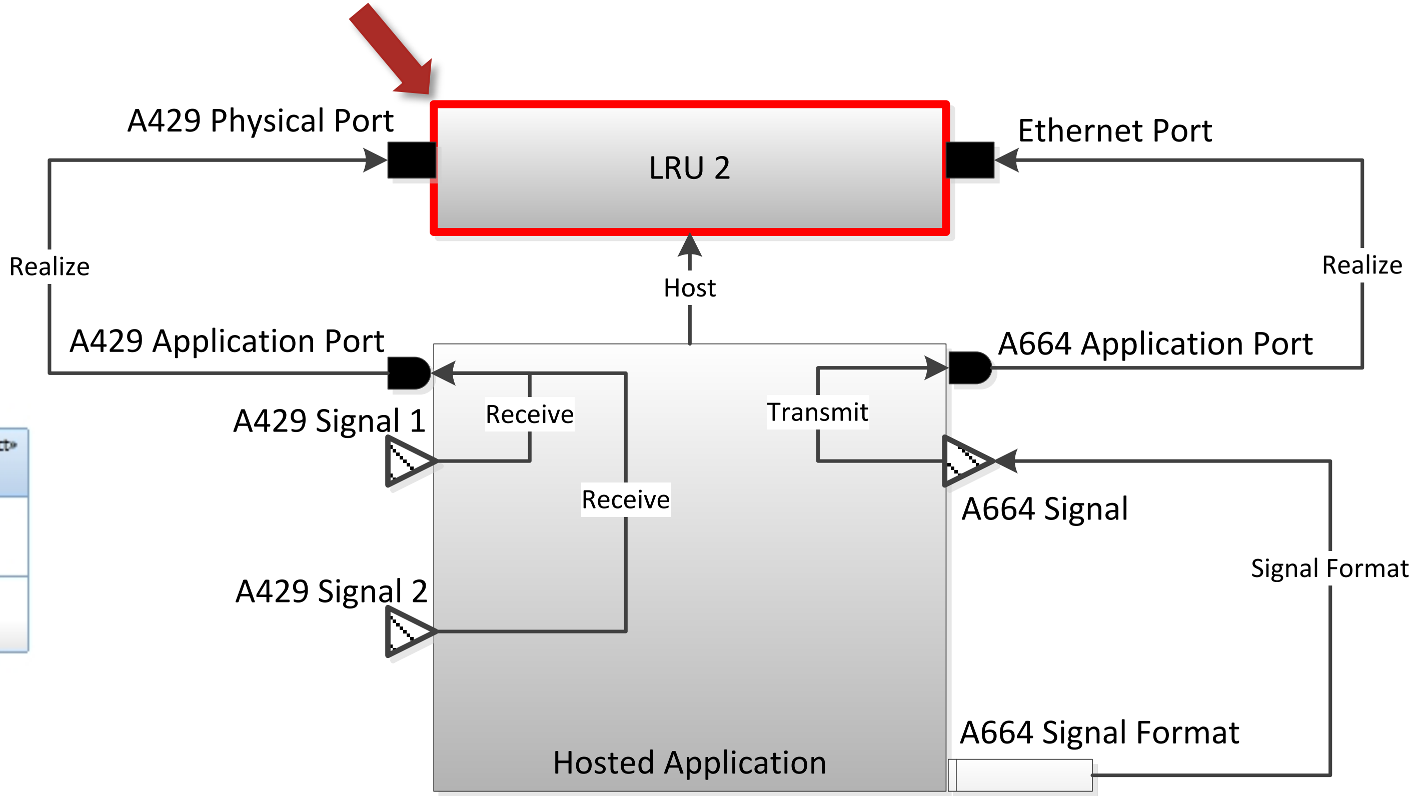

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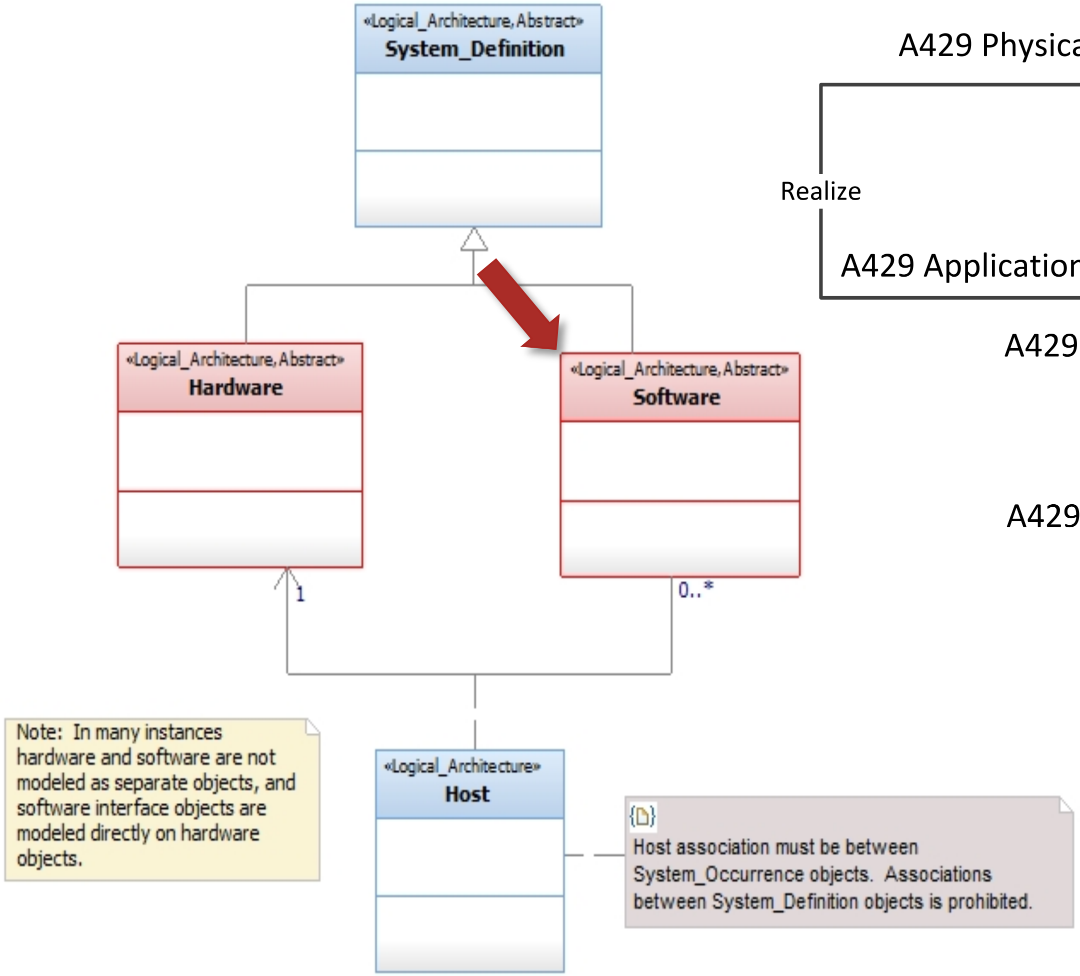

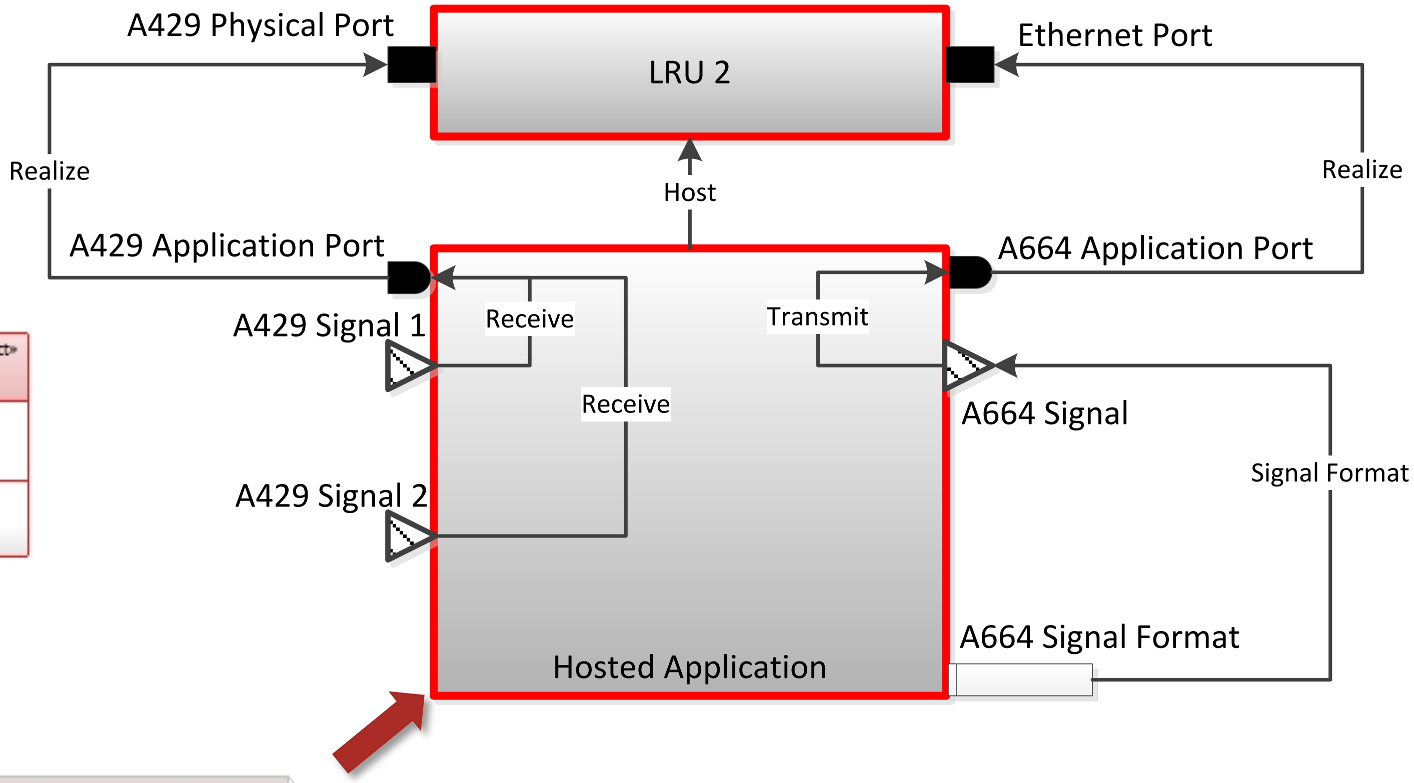

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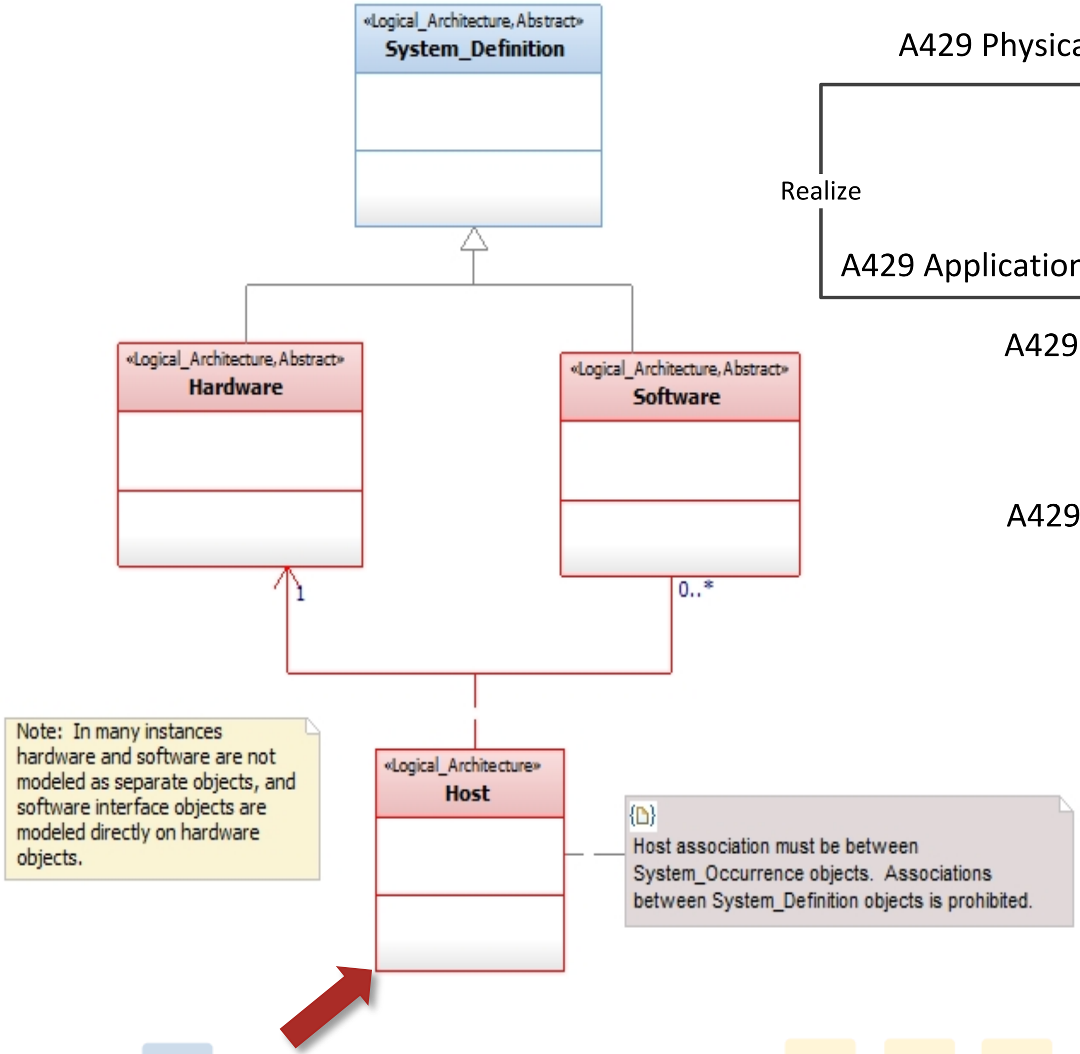
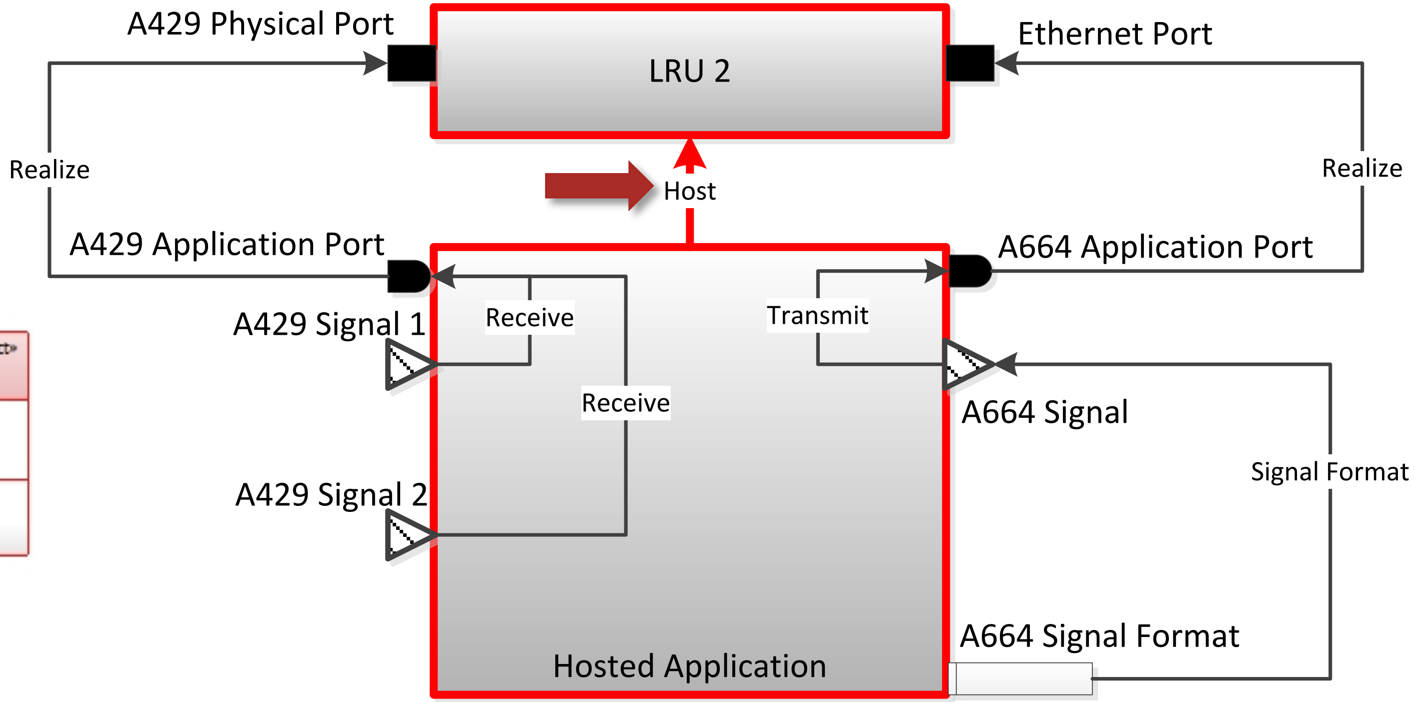
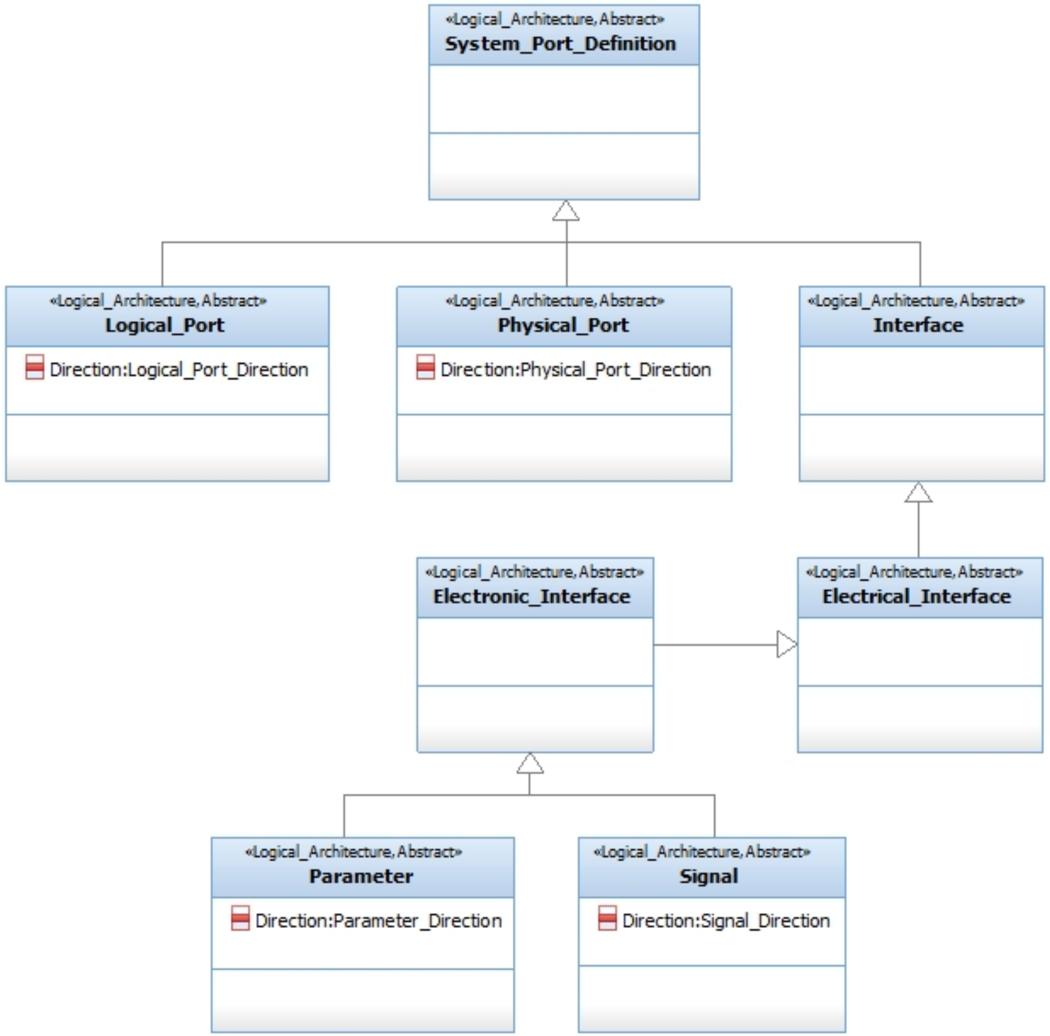
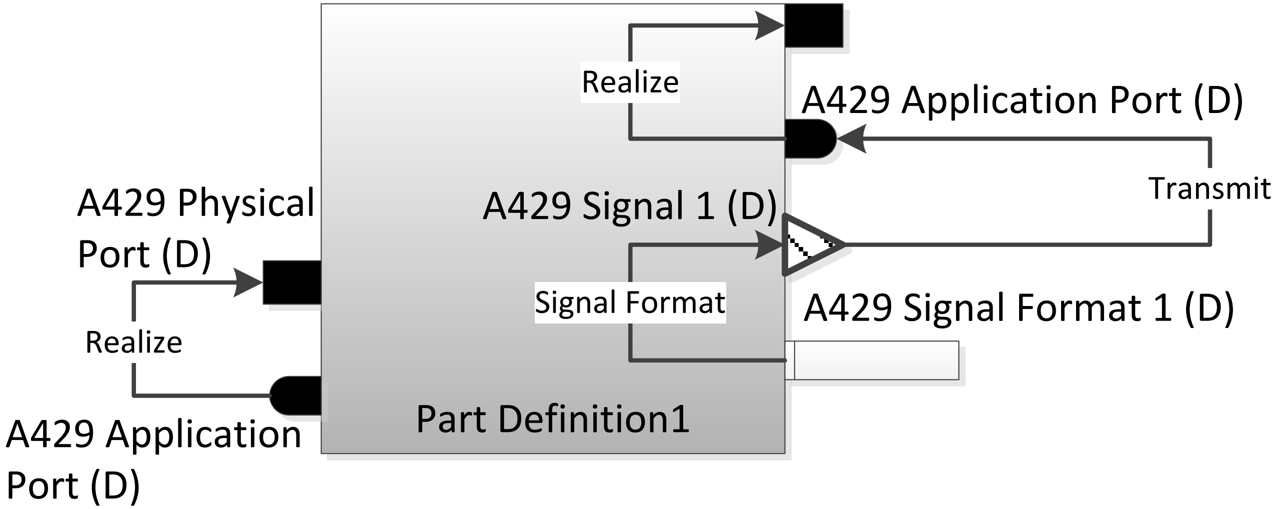




Logical Architecture
System Port Subtypes





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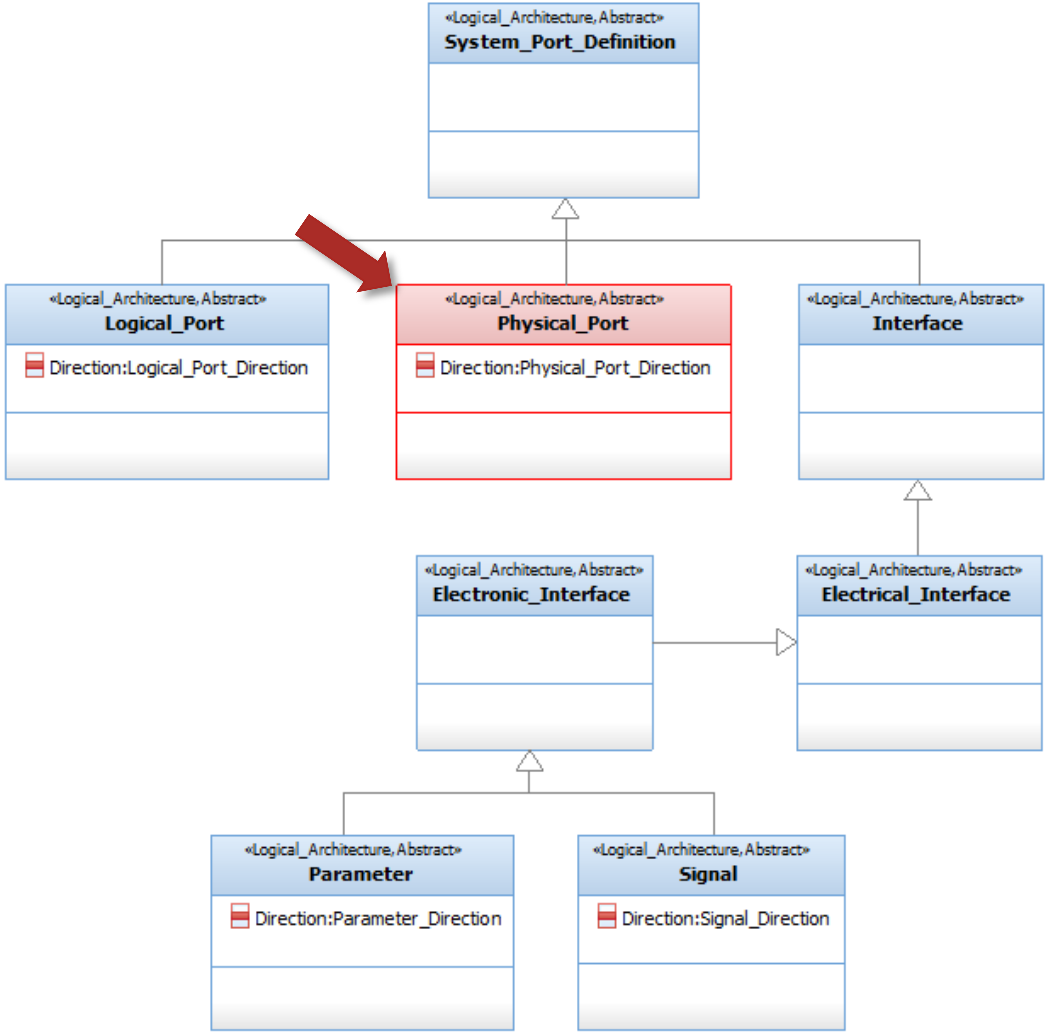

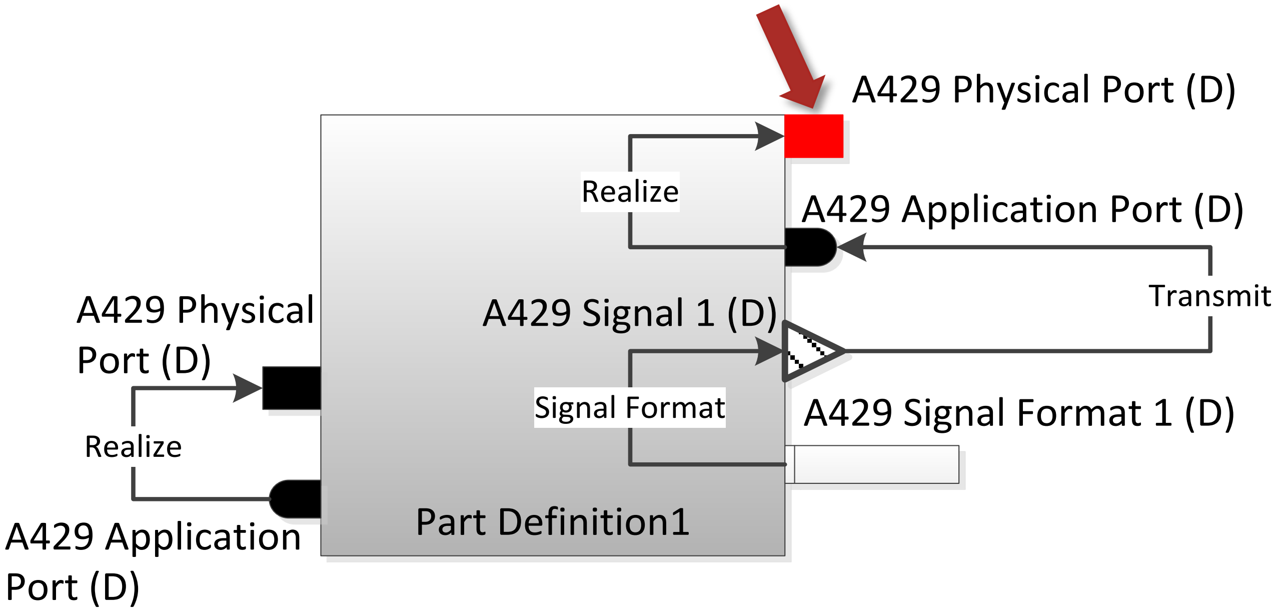

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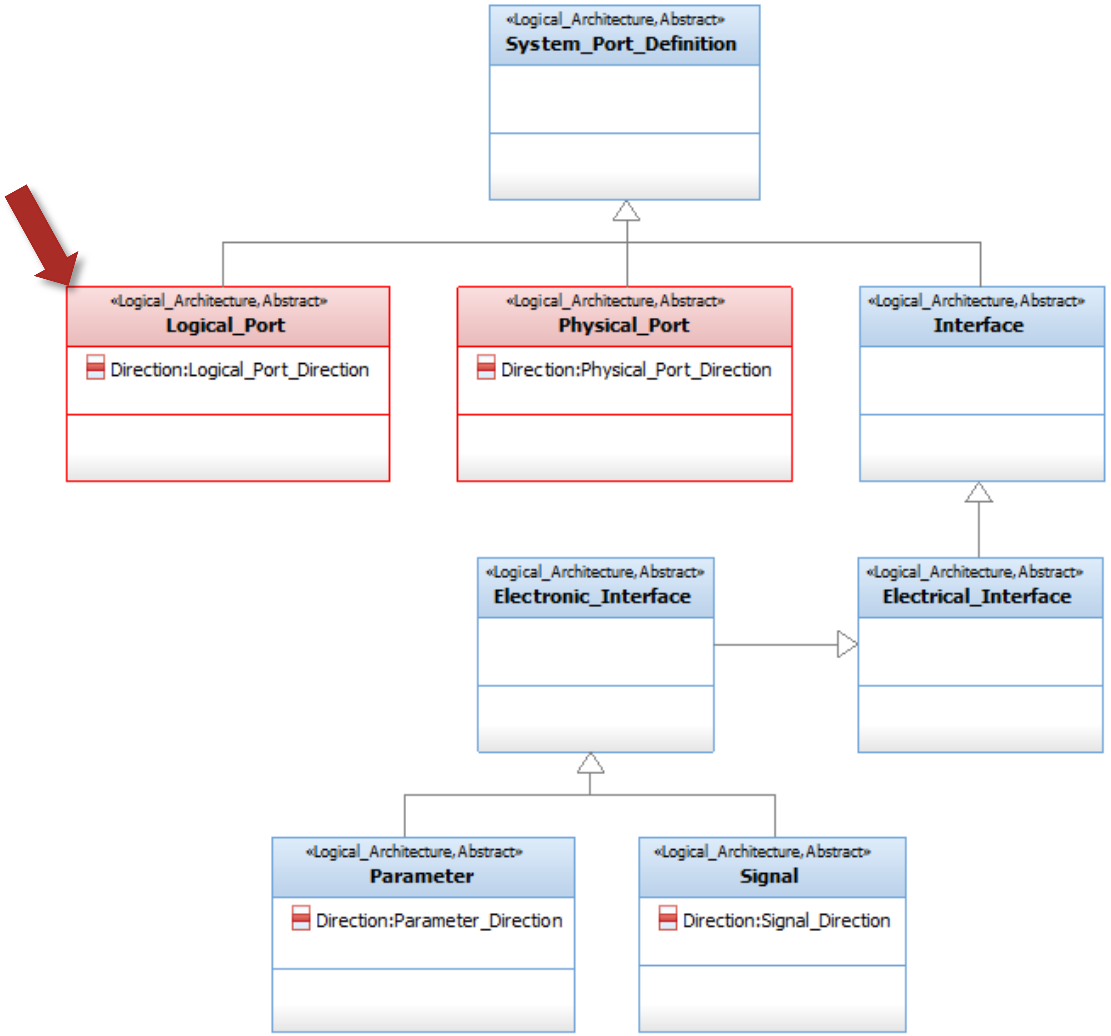

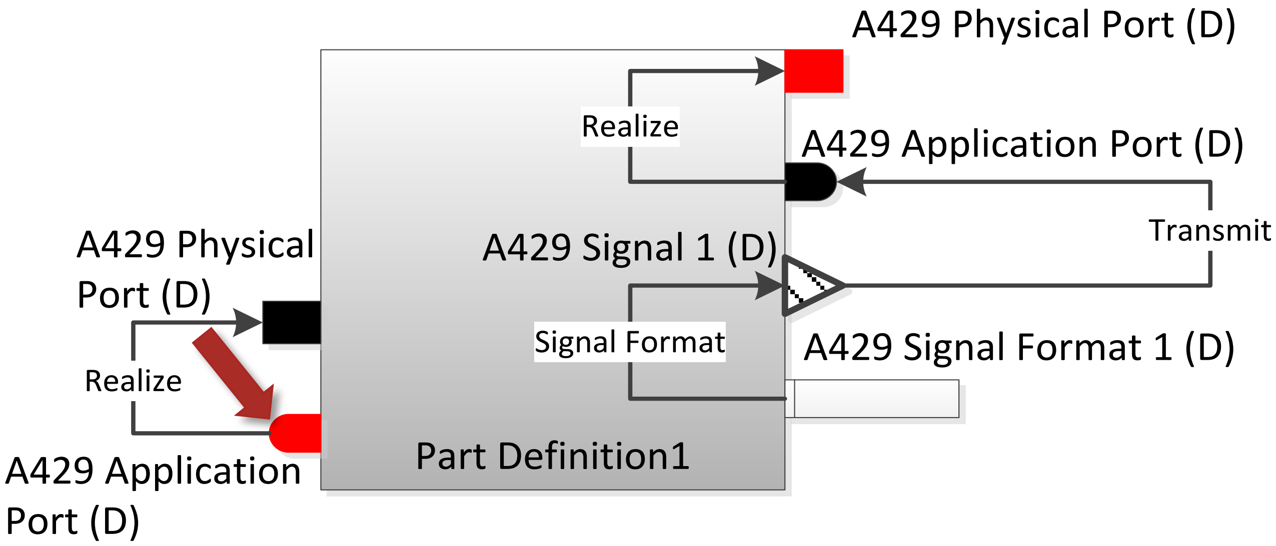

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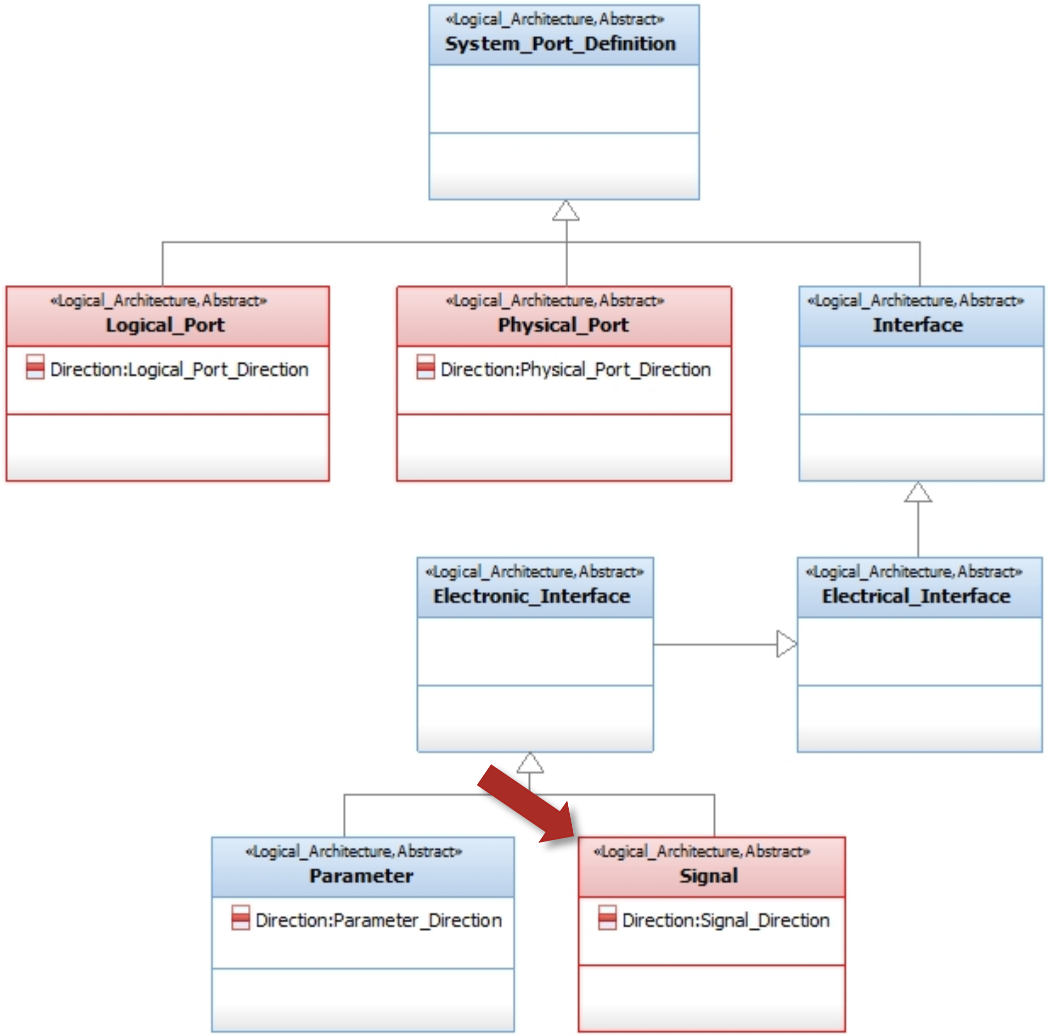
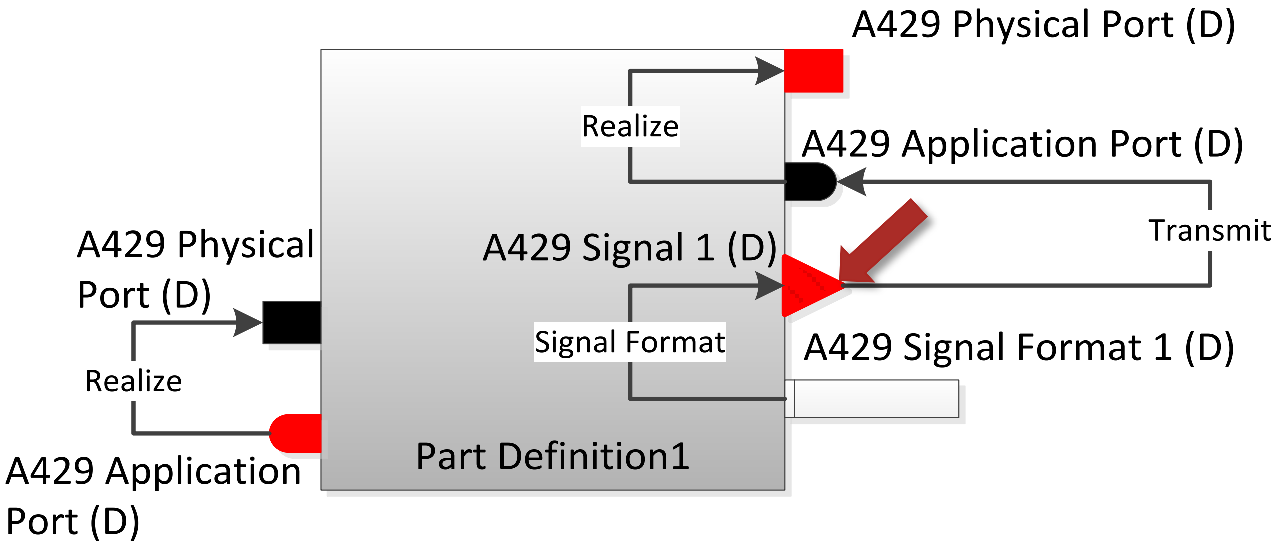
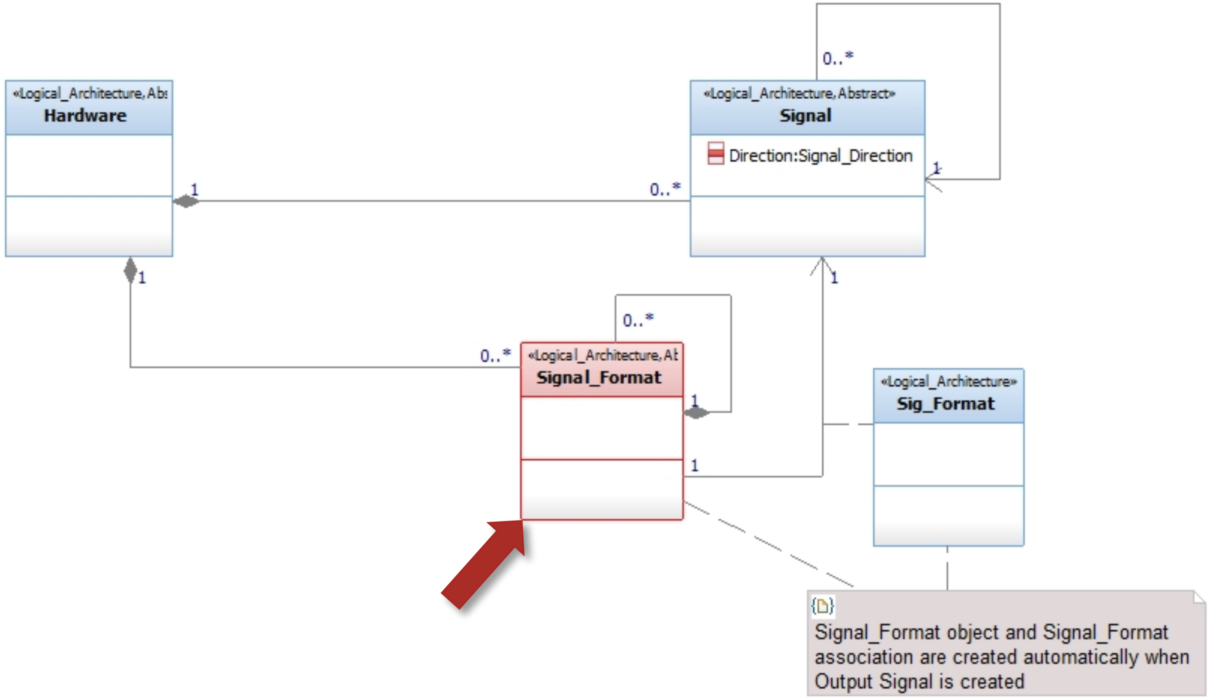
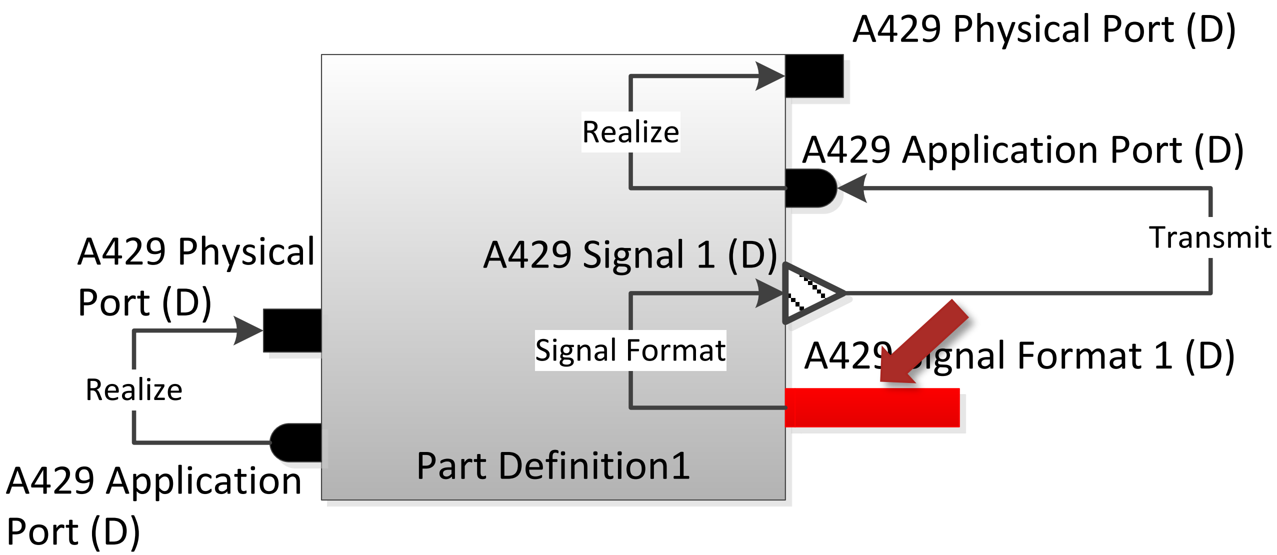




Logical Architecture

System Port Subtypes





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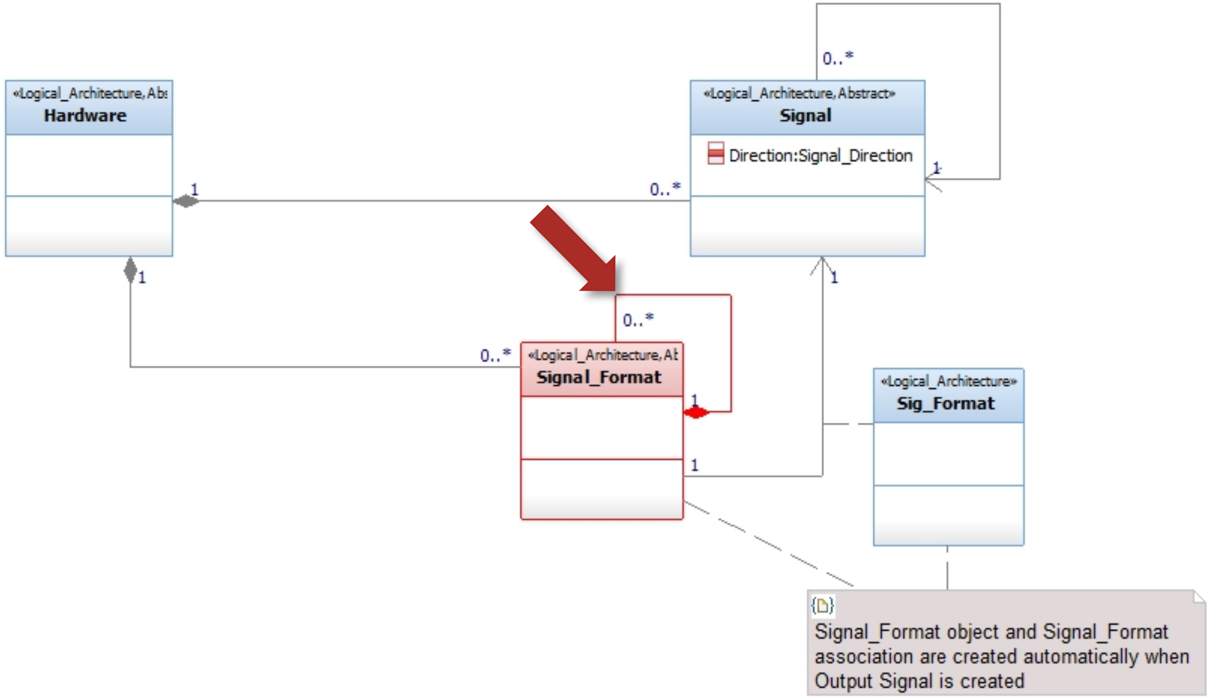
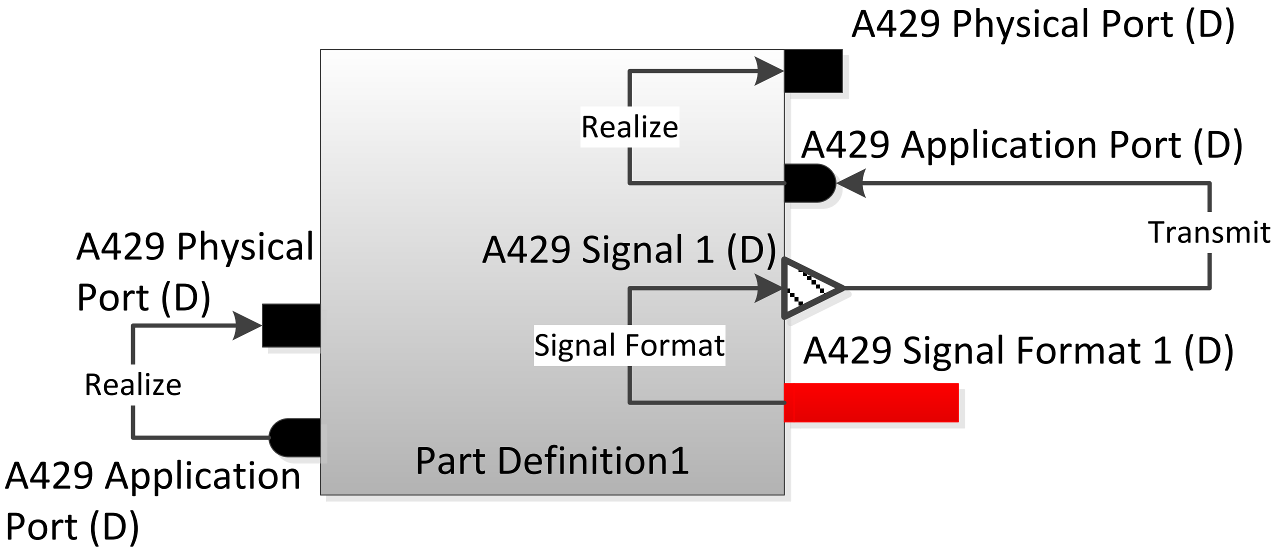
Logical Architecture
System Port Subtypes





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Logical Architecture
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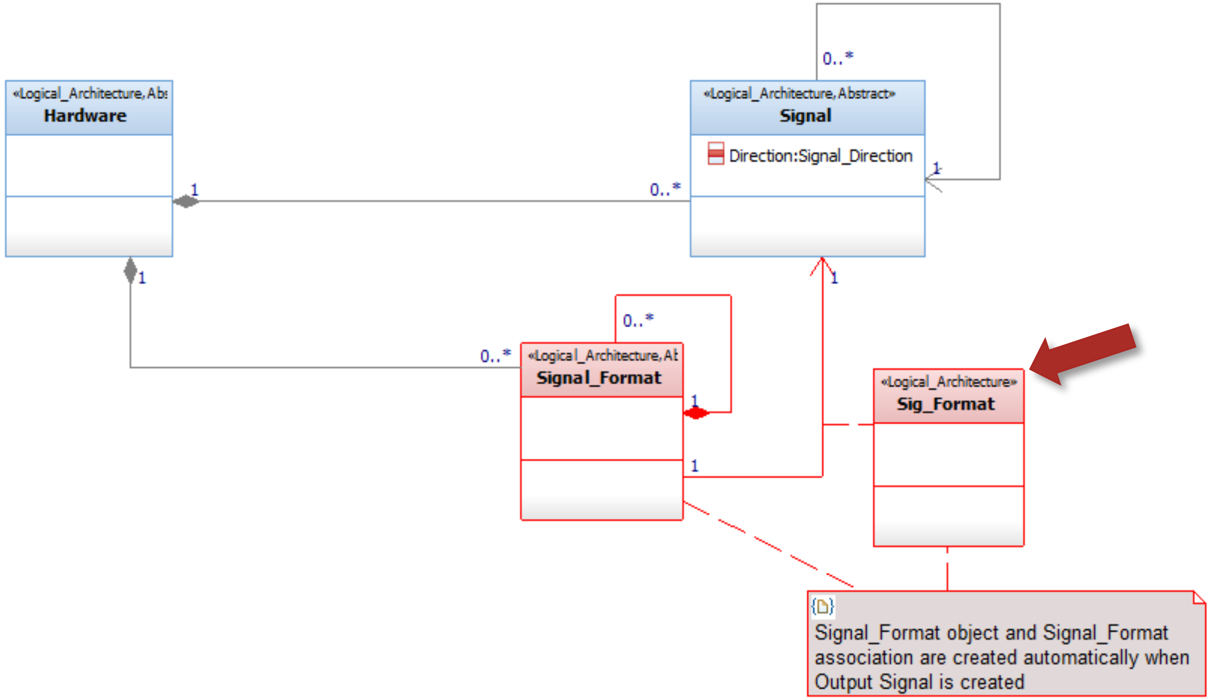

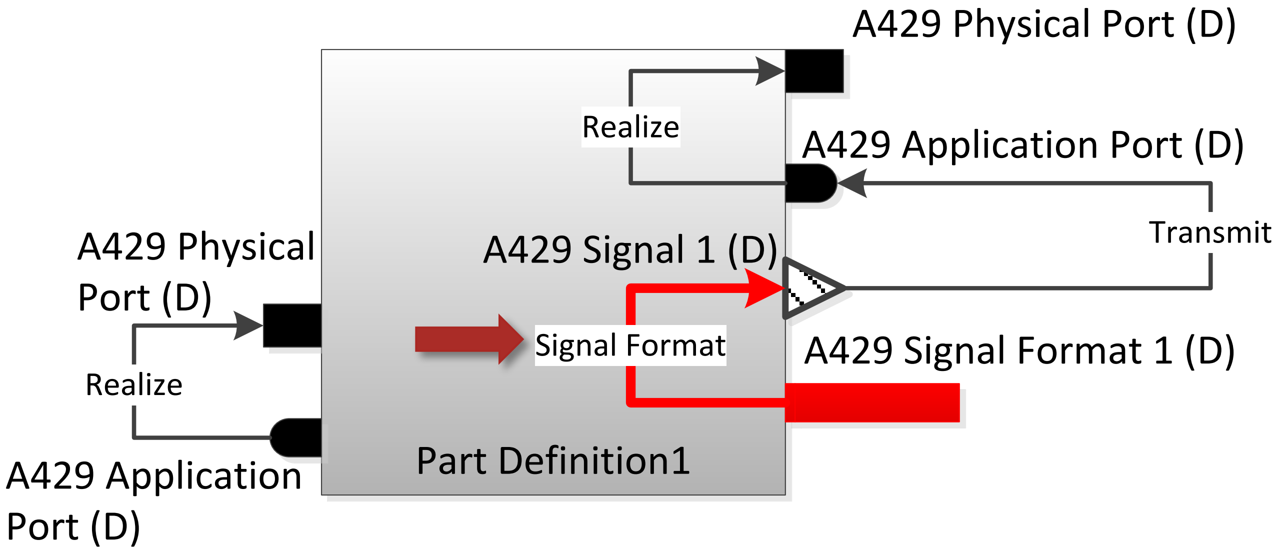

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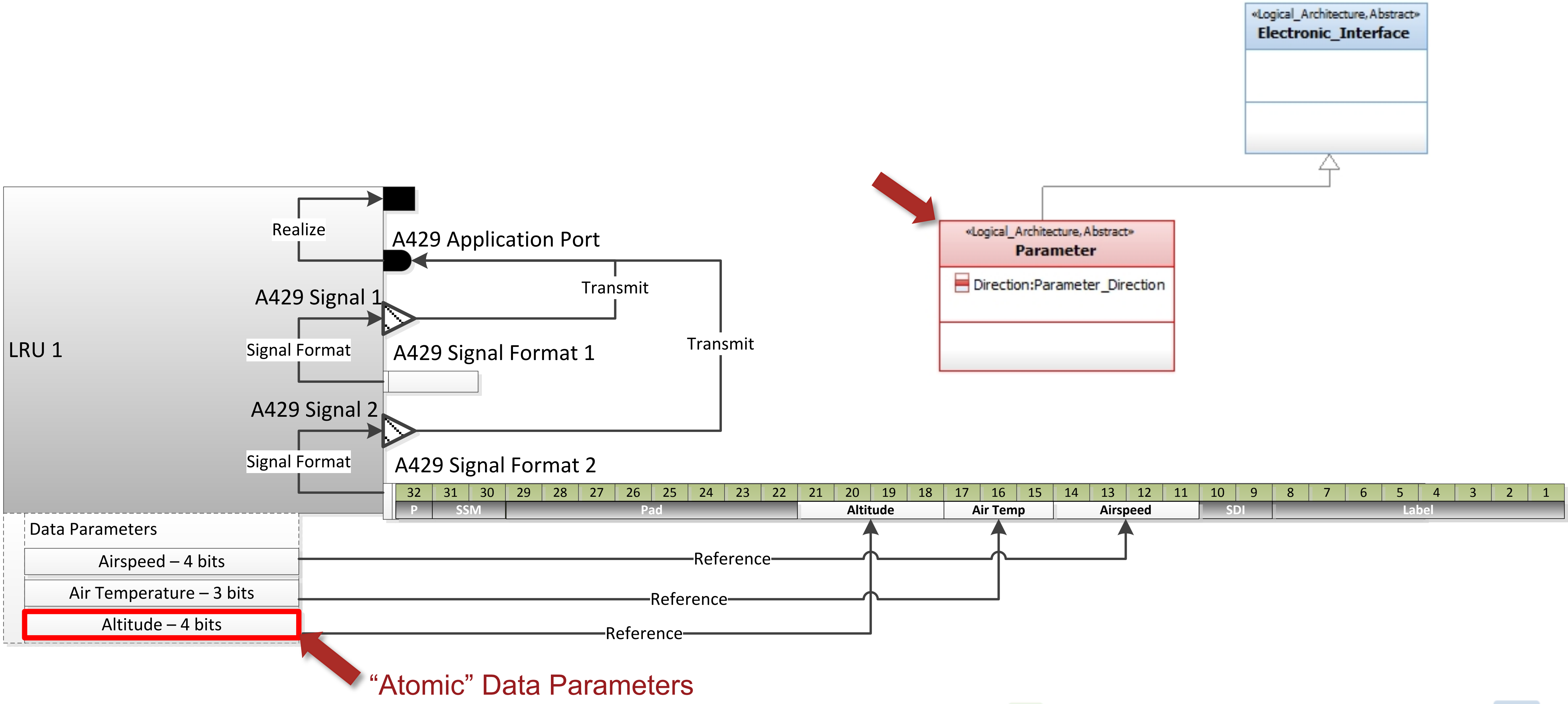
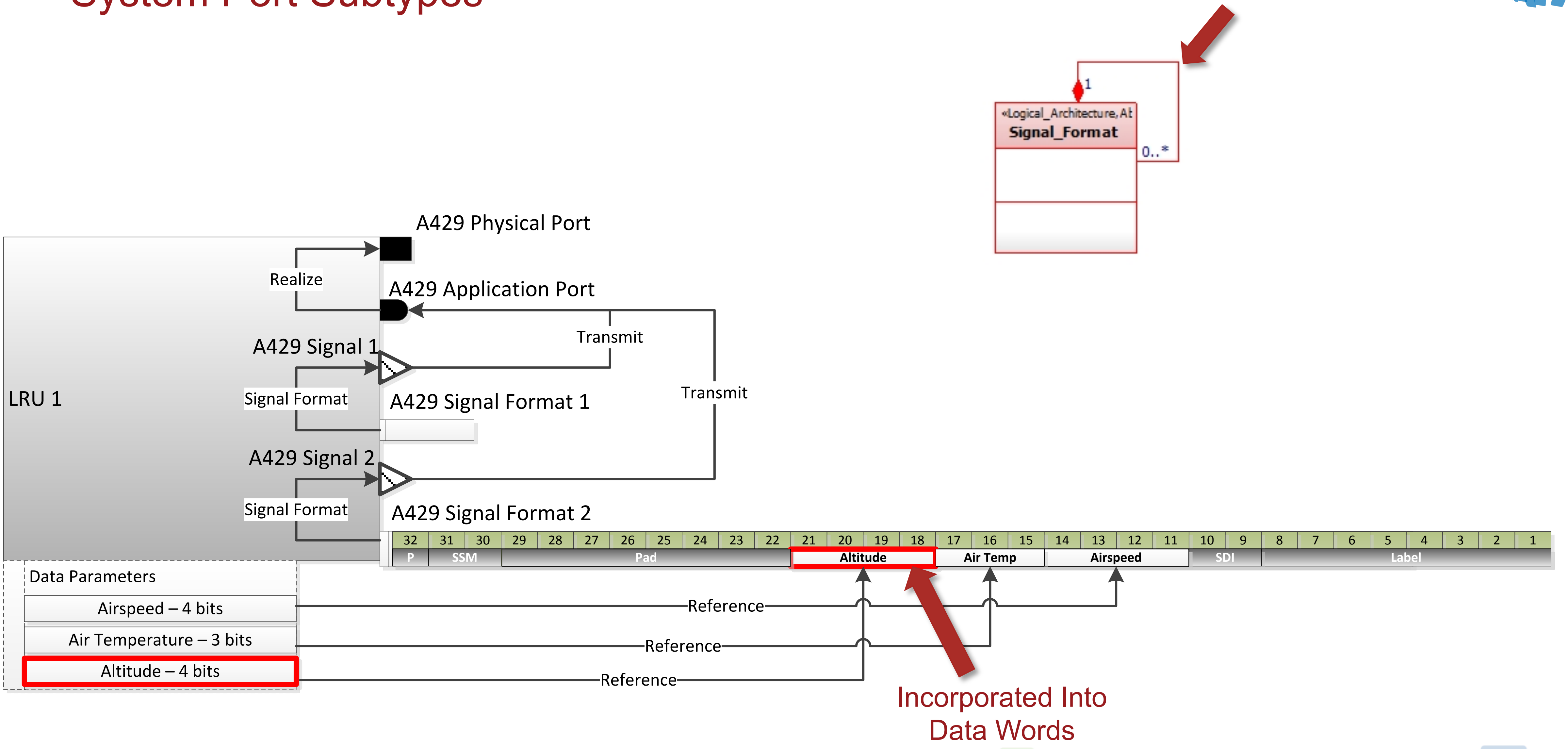
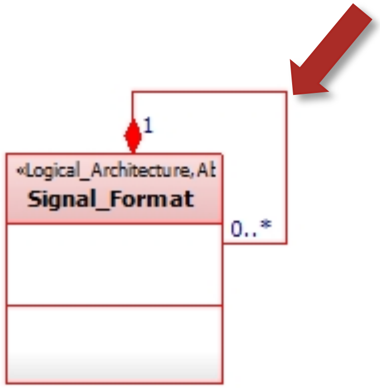
Logical Architecture
System Port Subtypes

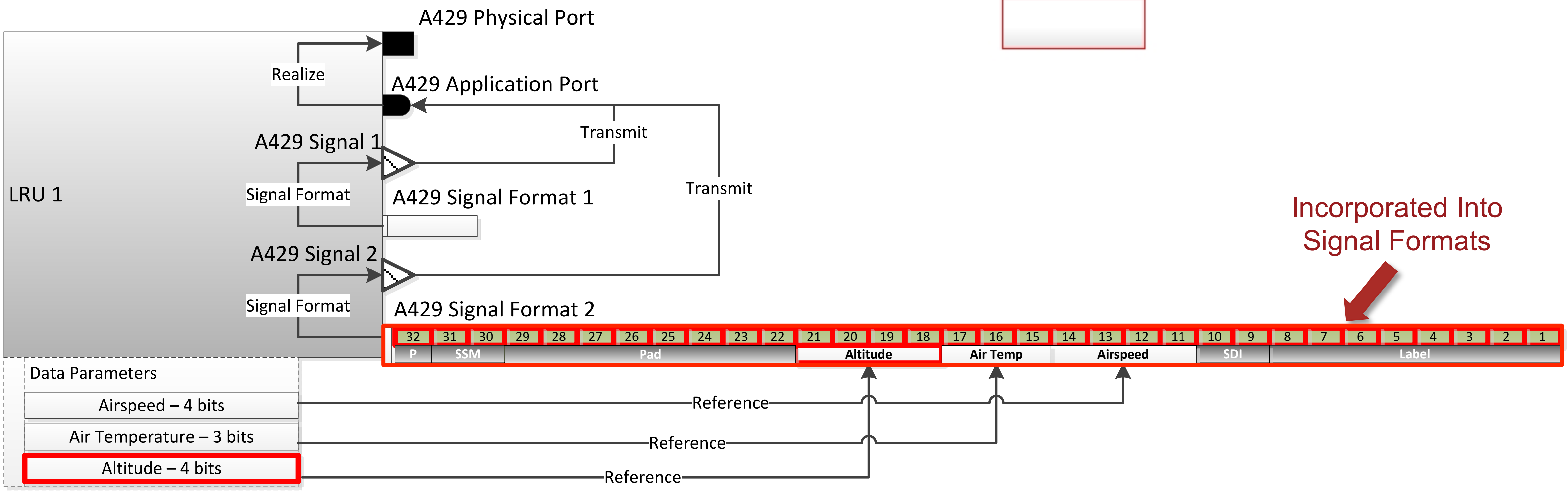


Logical Architecture
System Port Subtypes



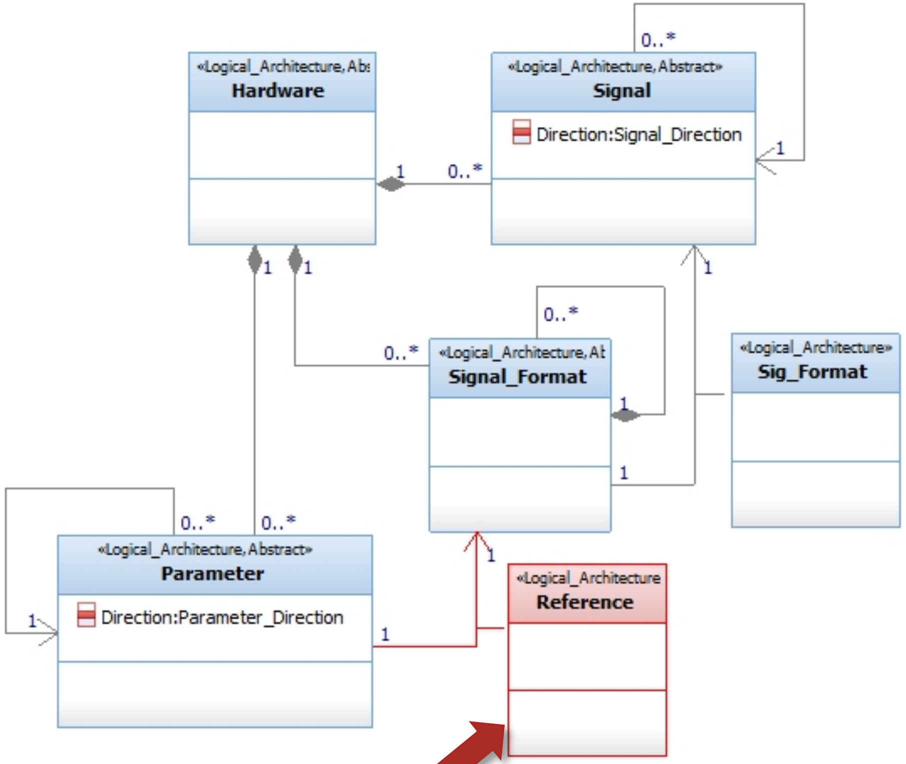
Logical Architecture
System Port Subtypes

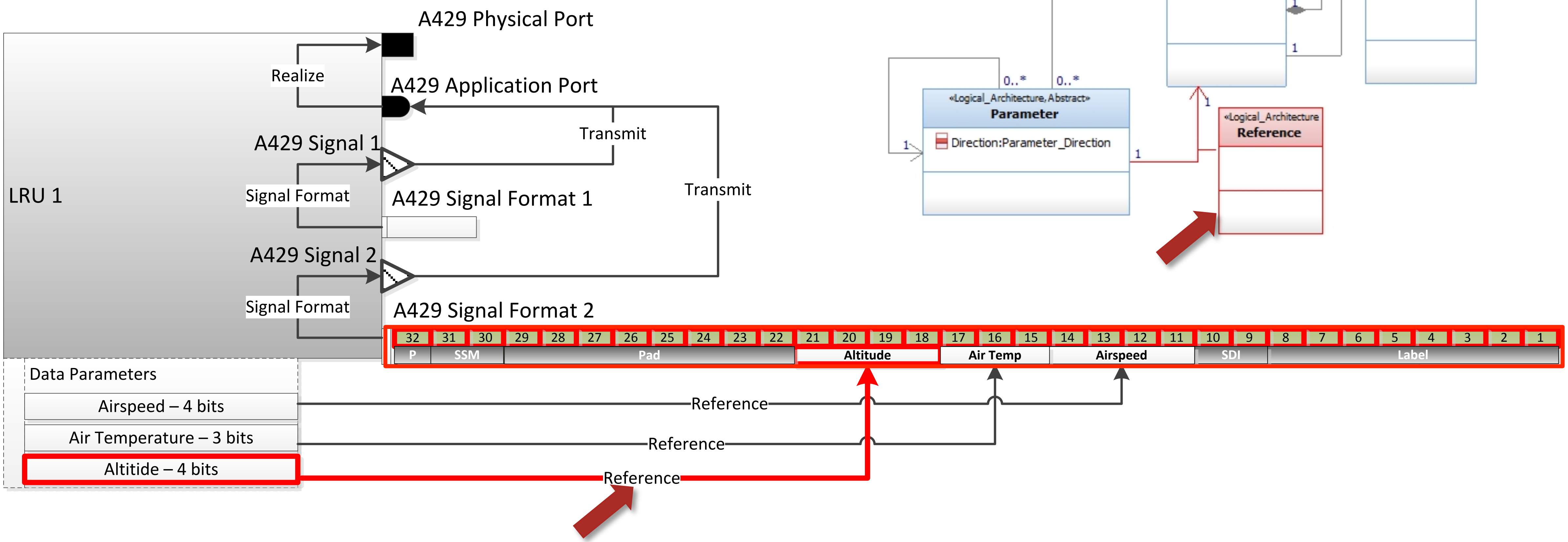




Logical Architecture

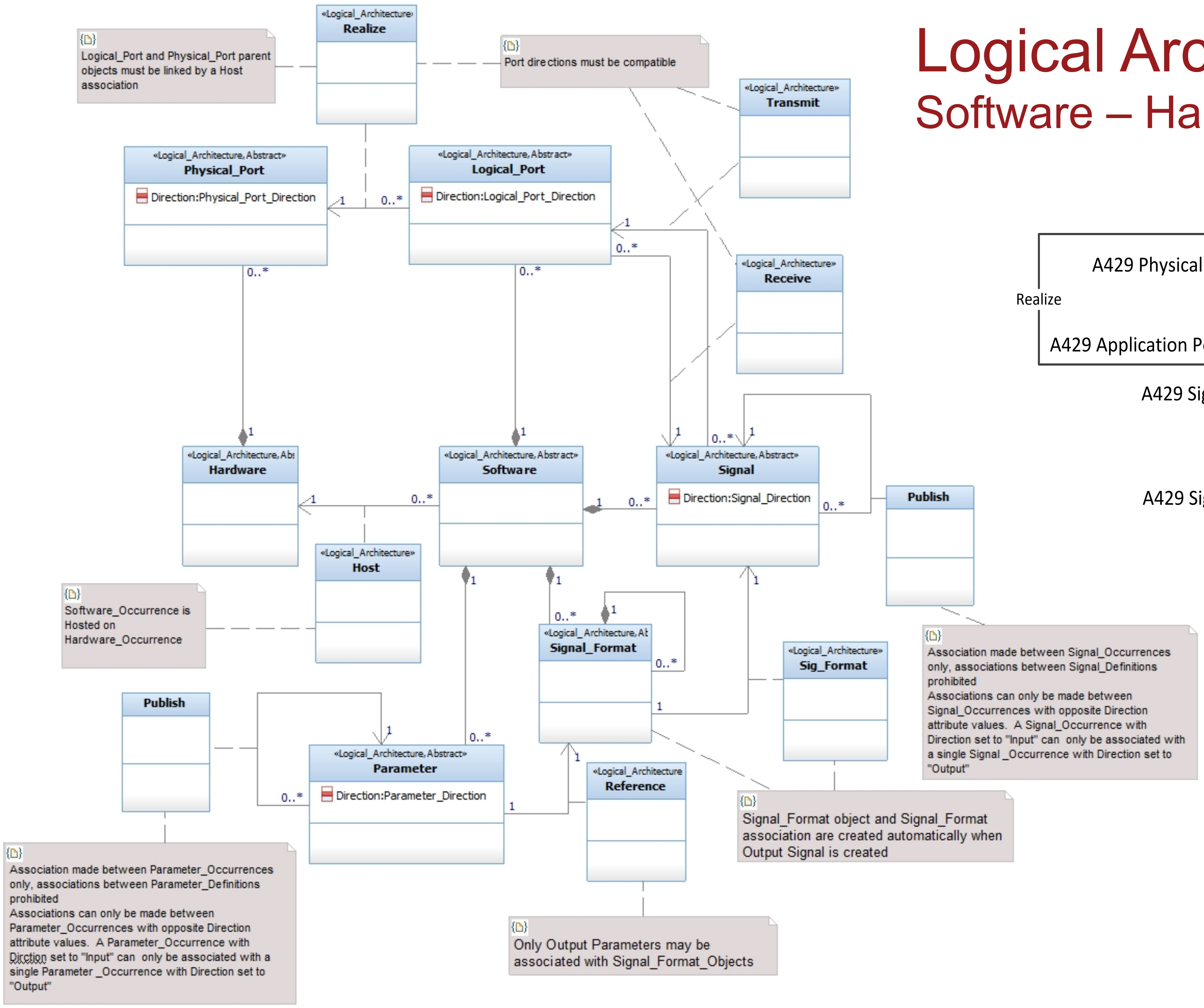
System Port Subtypes

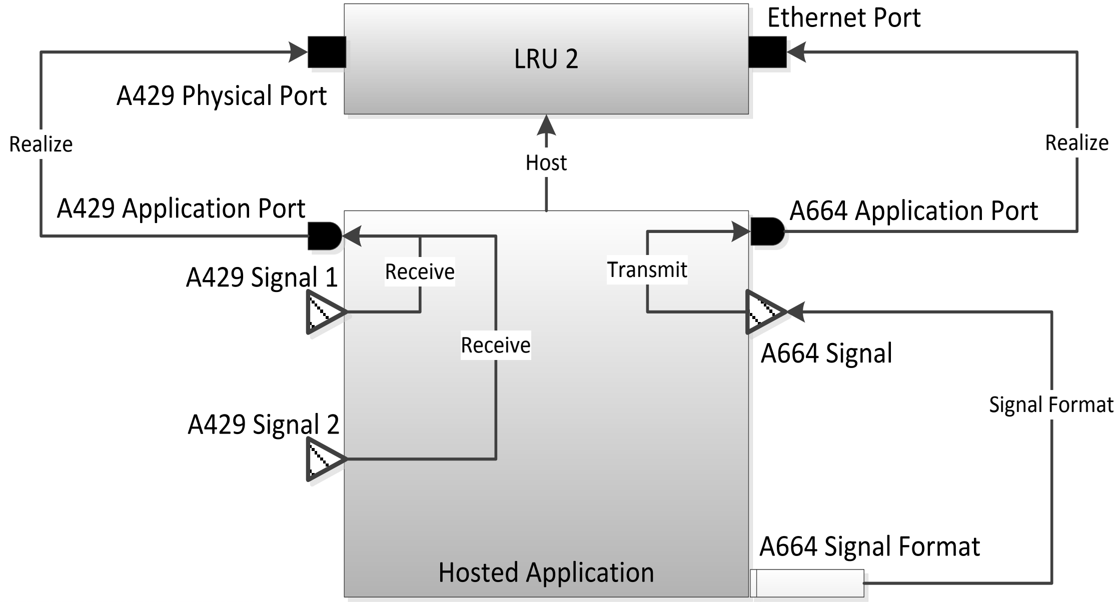




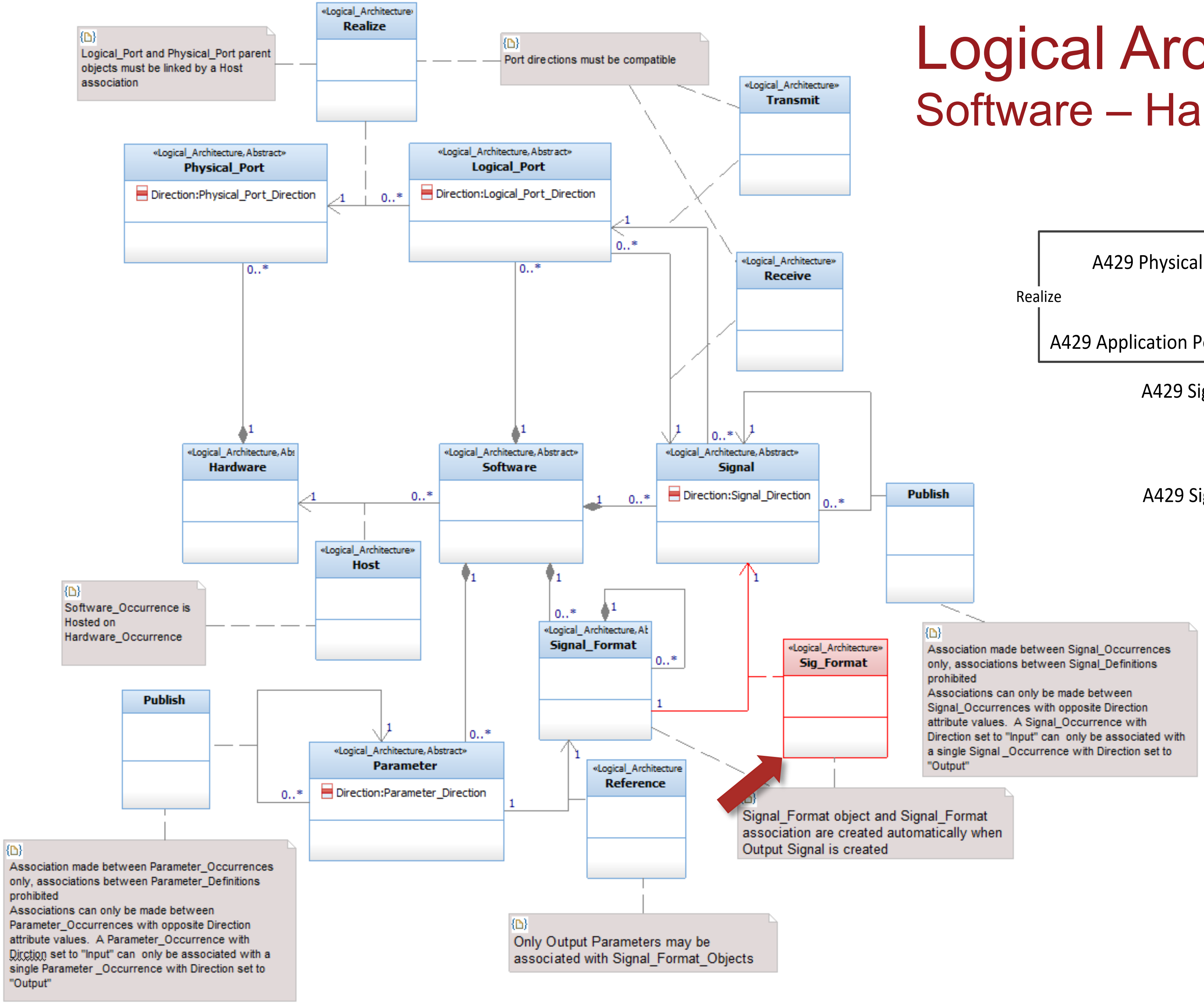
Logical Architecture

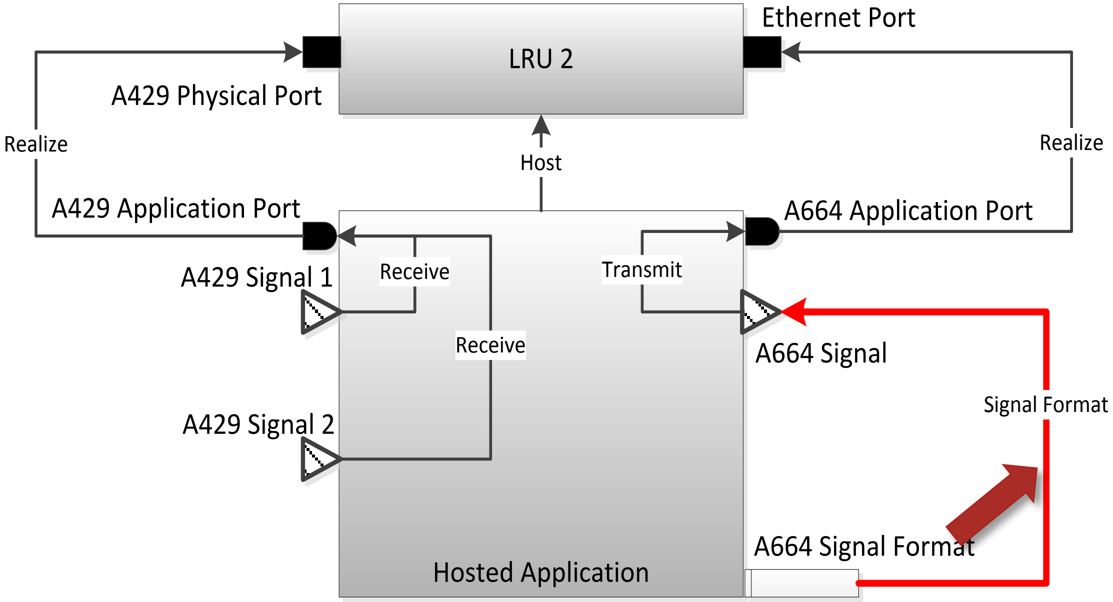
Software – Hardware Integration



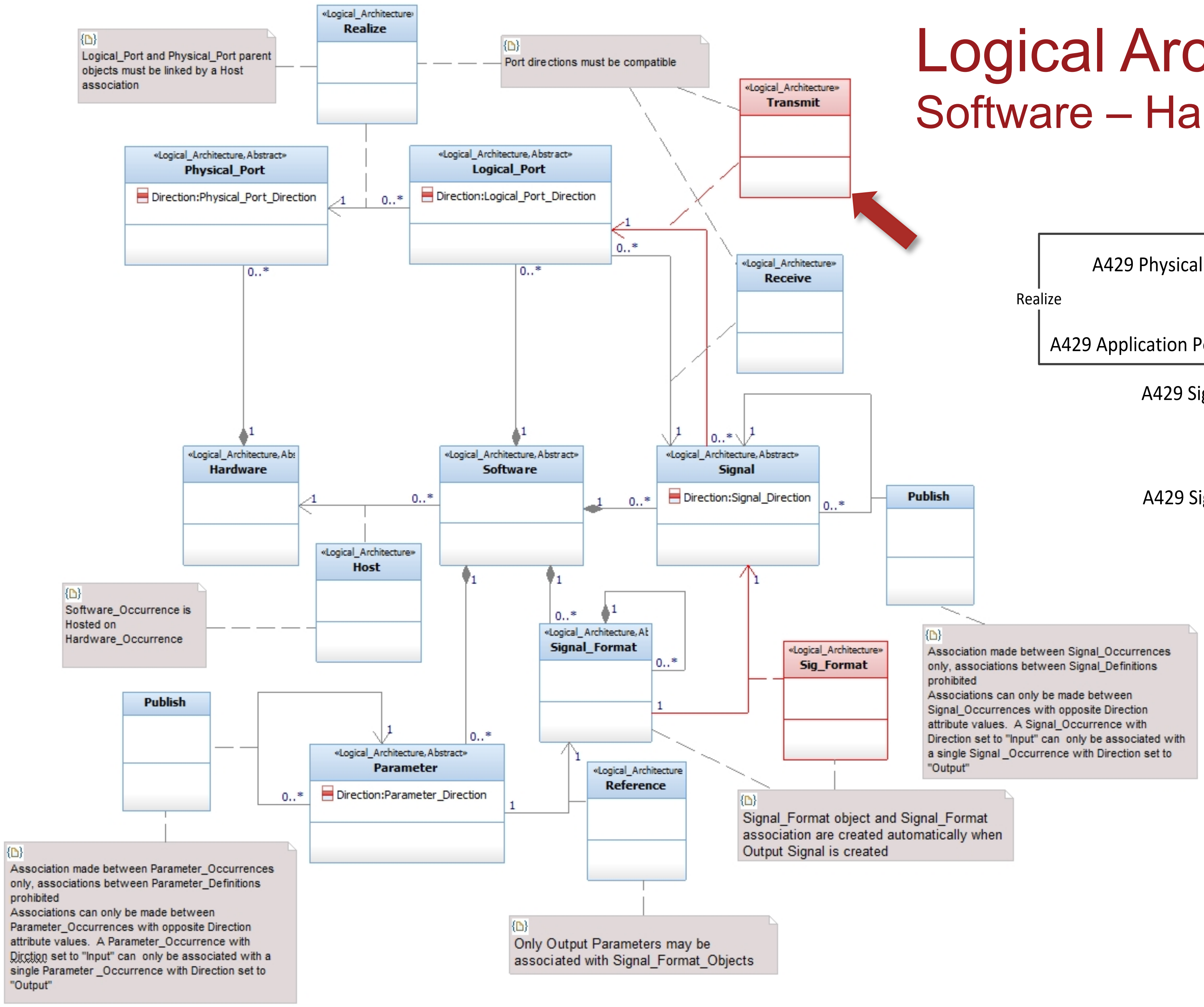


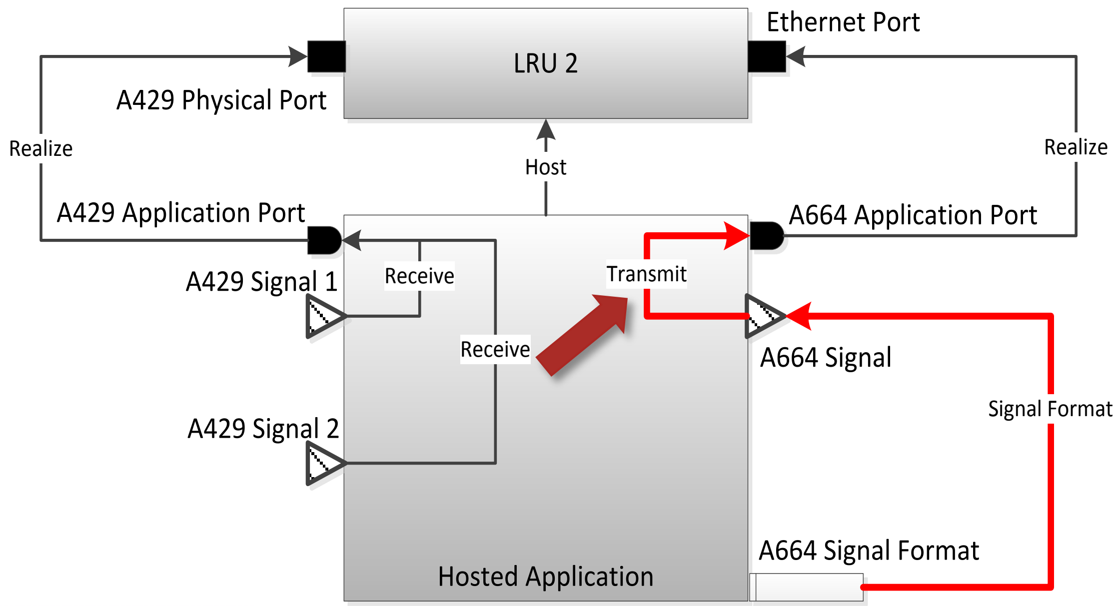
Logical Architecture
Software – Hardware Integration



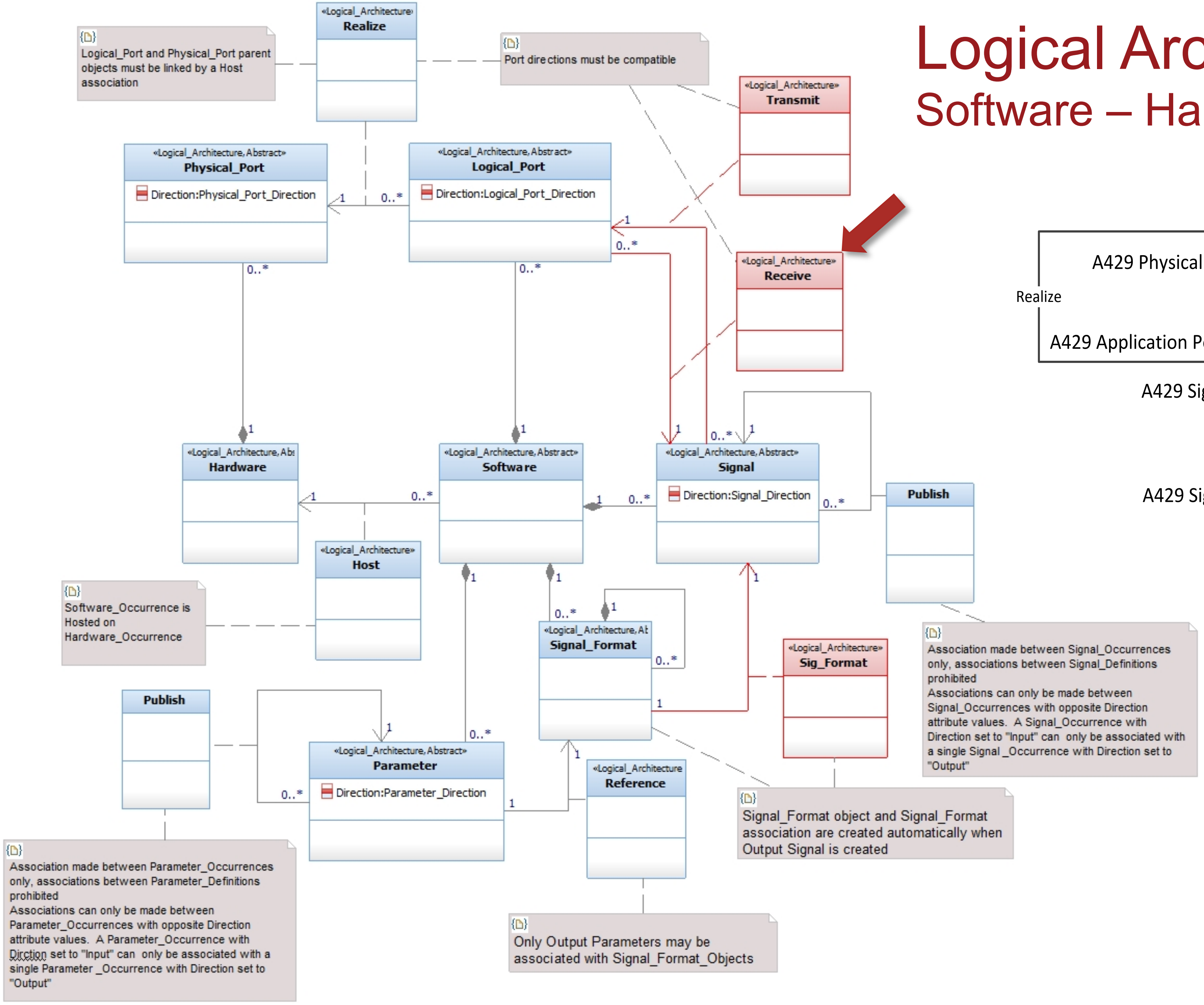


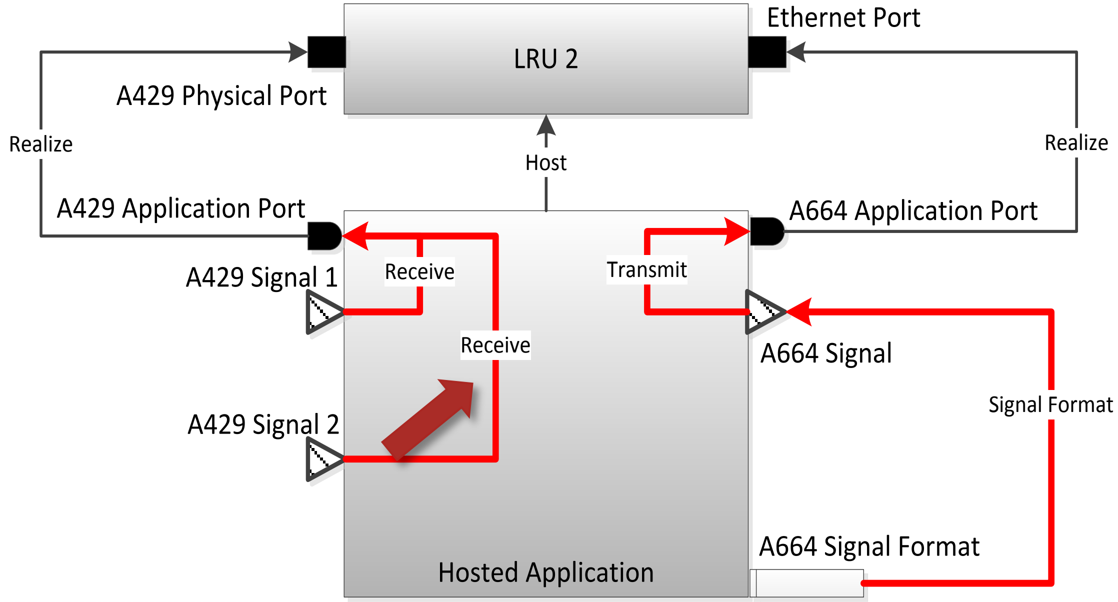
Logical Architecture
Software – Hardware Integration





Logical Architecture
Software – Hardware Integration





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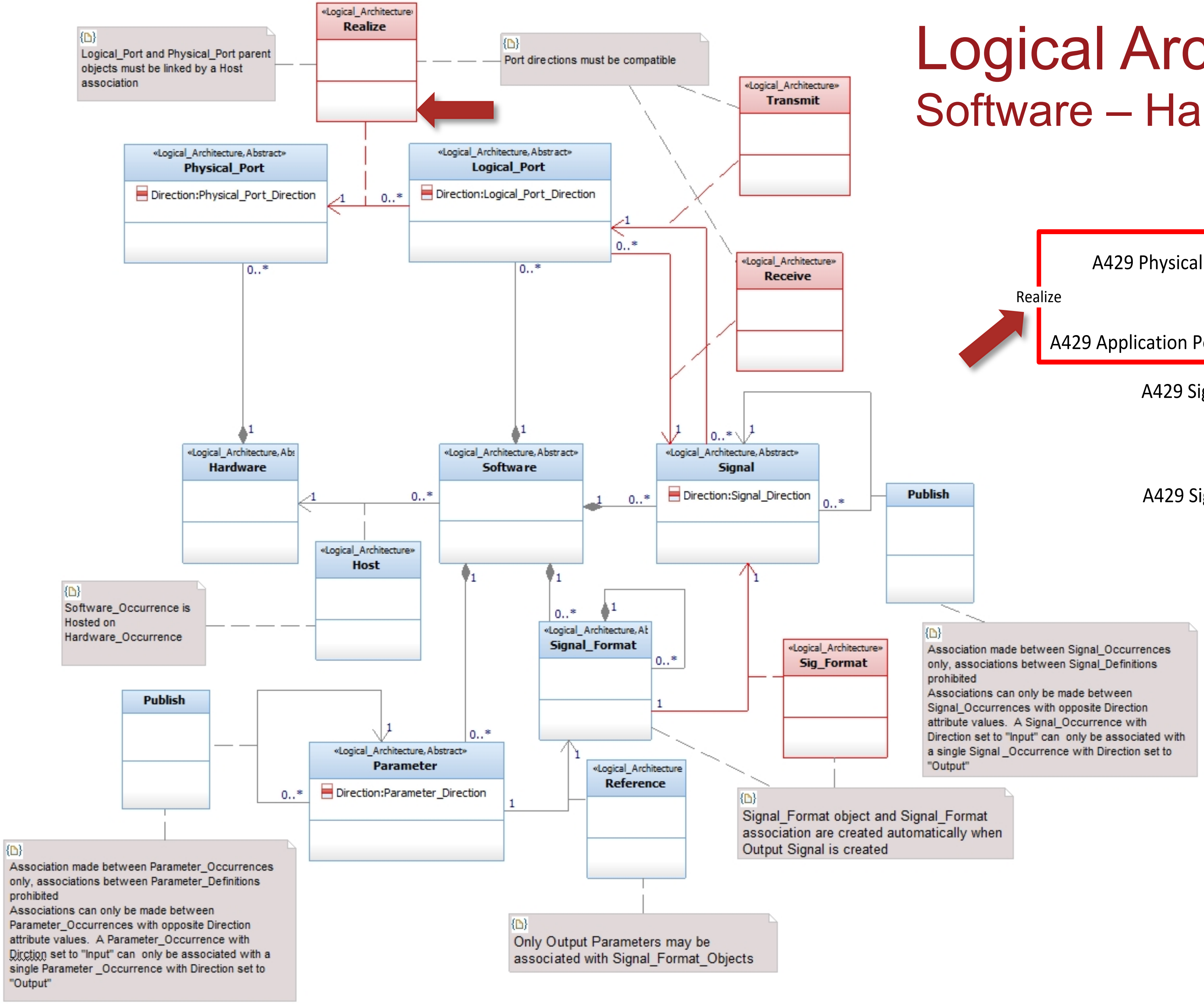
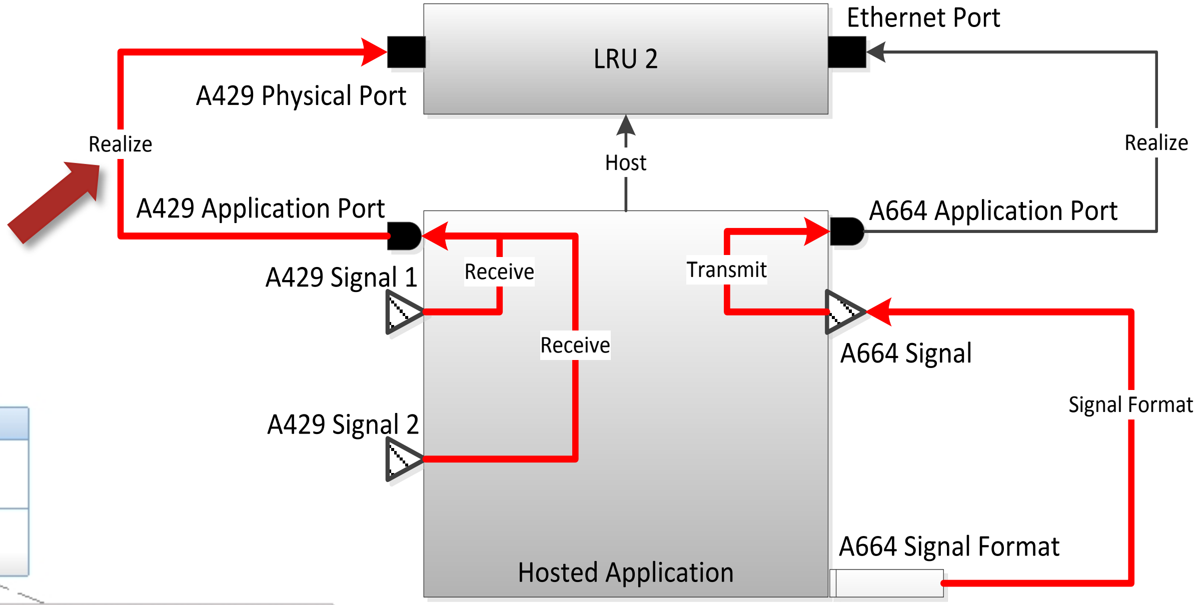
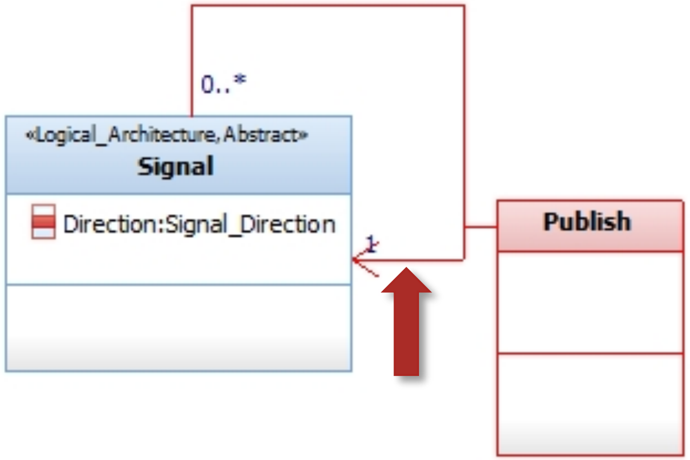
Logical Architecture

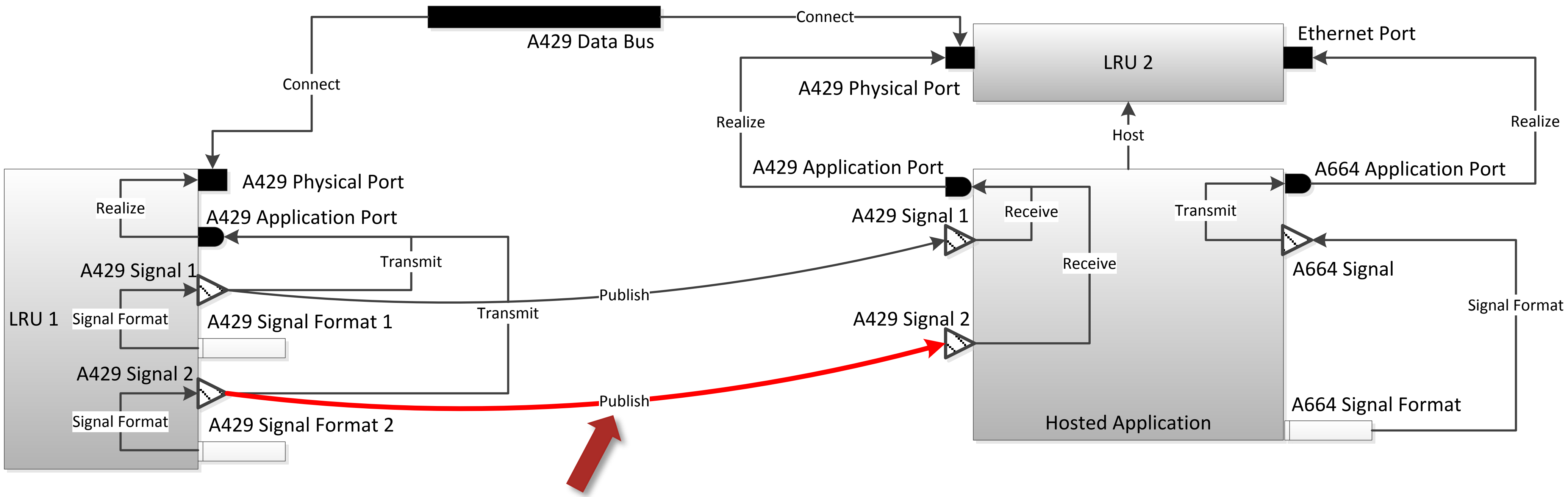
Software – Hardware Integration





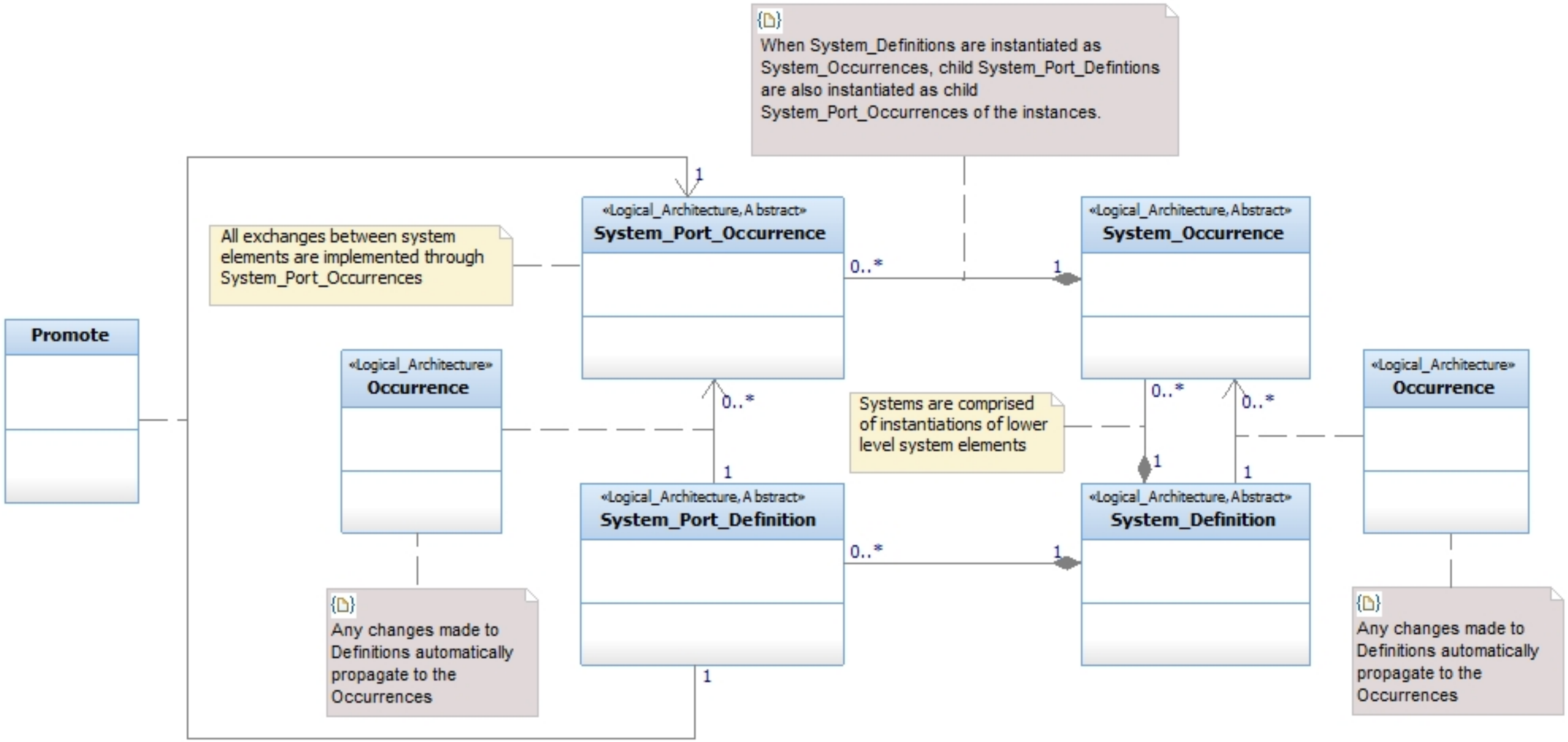
Logical Architecture
Interface Reconciliation





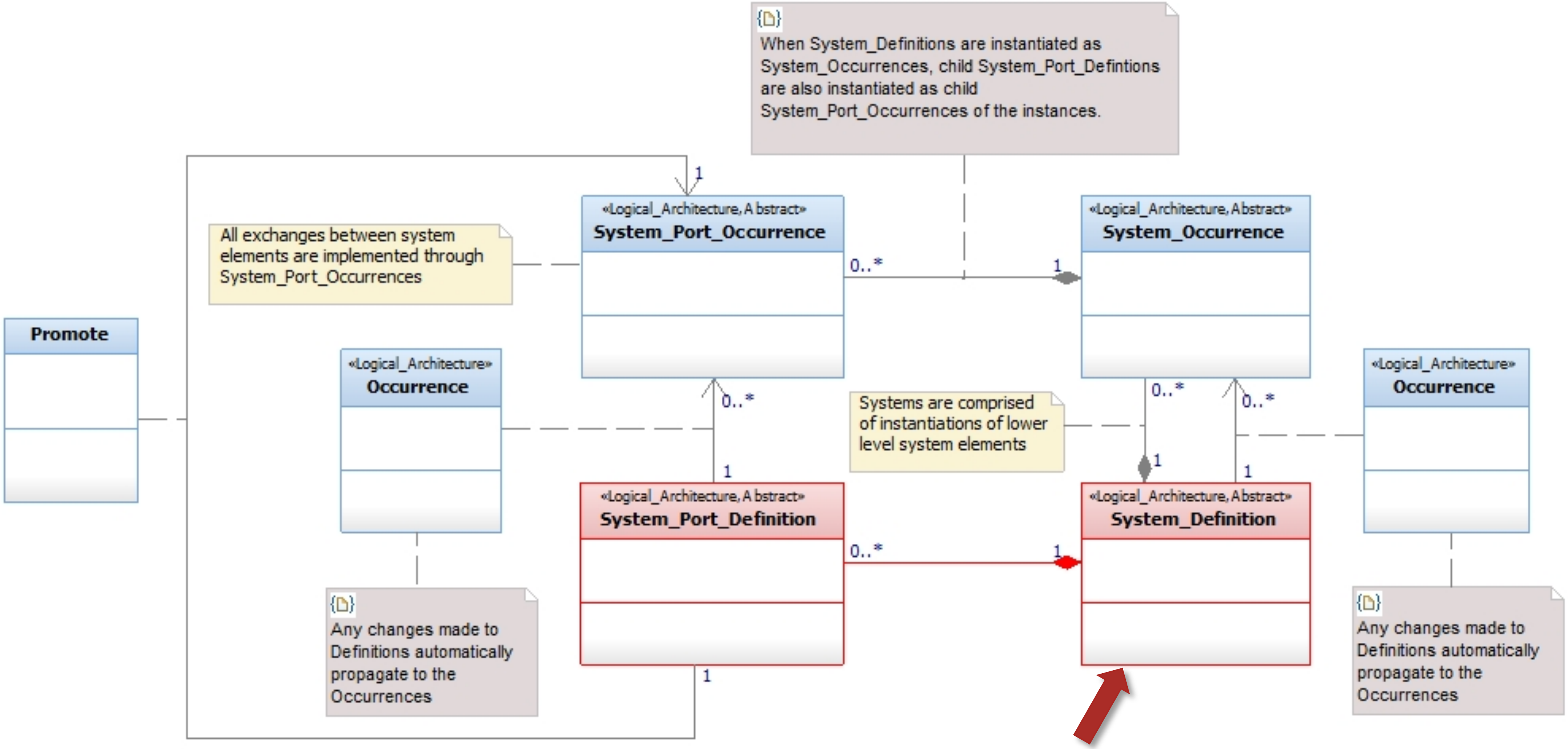
Occurrence Level View
No Definitions

Logical Architecture
Occurrence Model

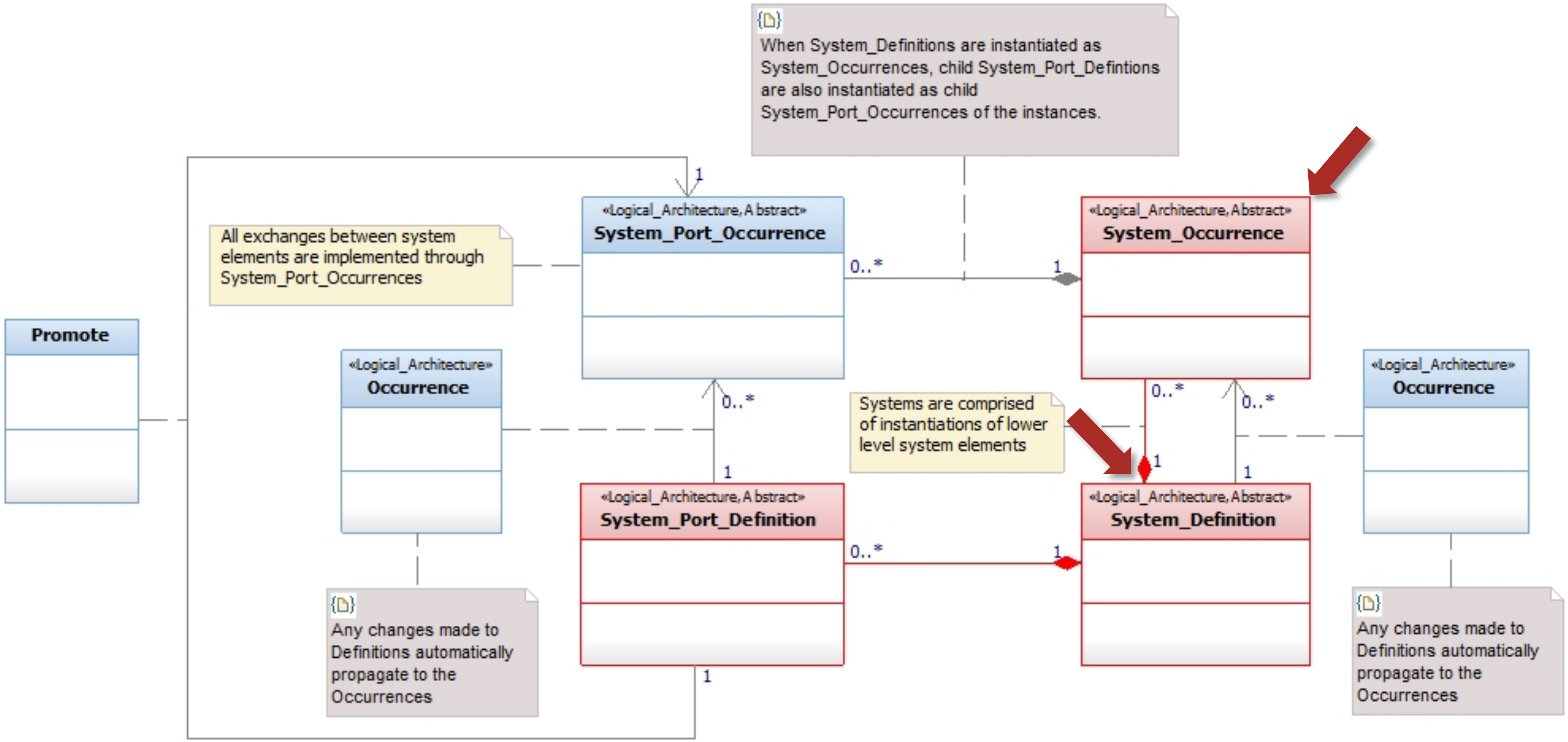


Logical Architecture

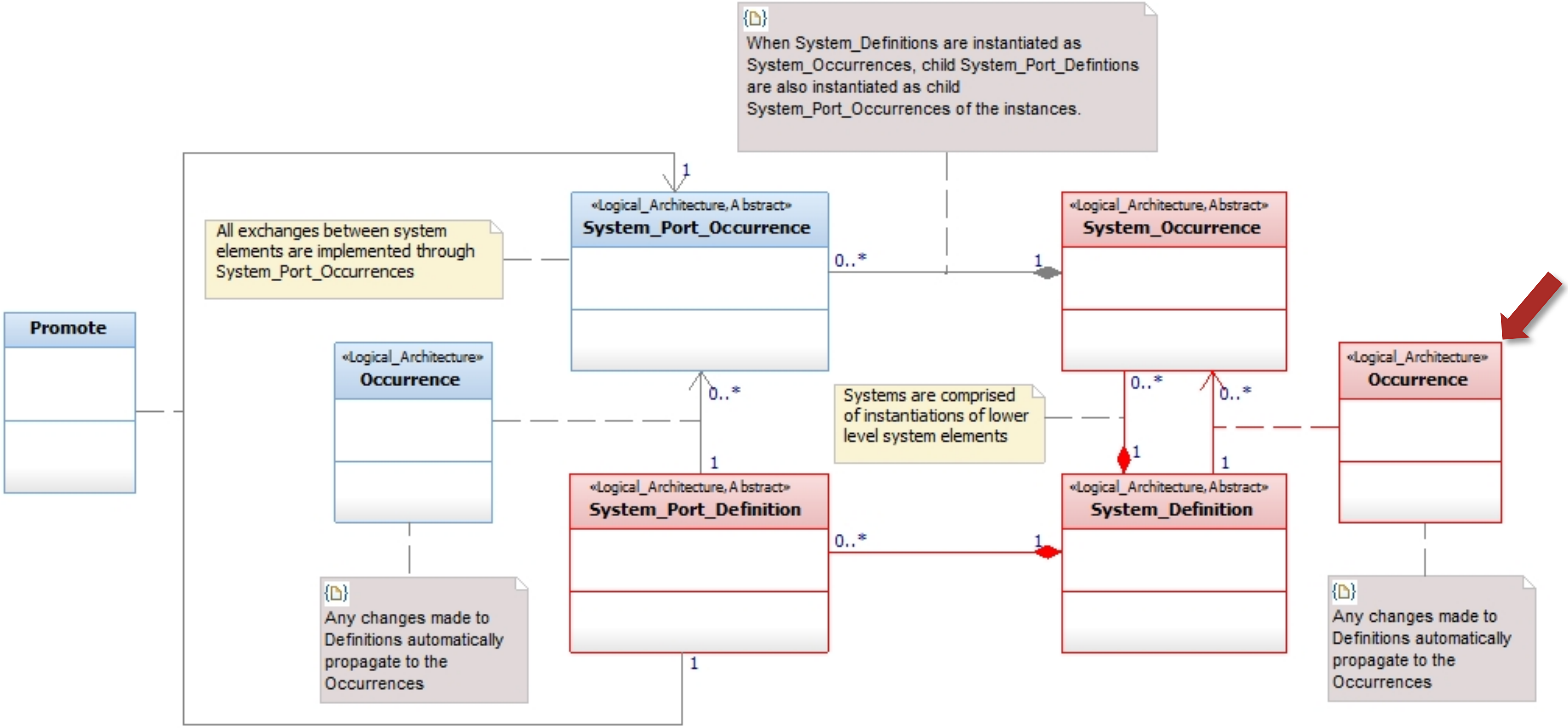
Occurrence Model



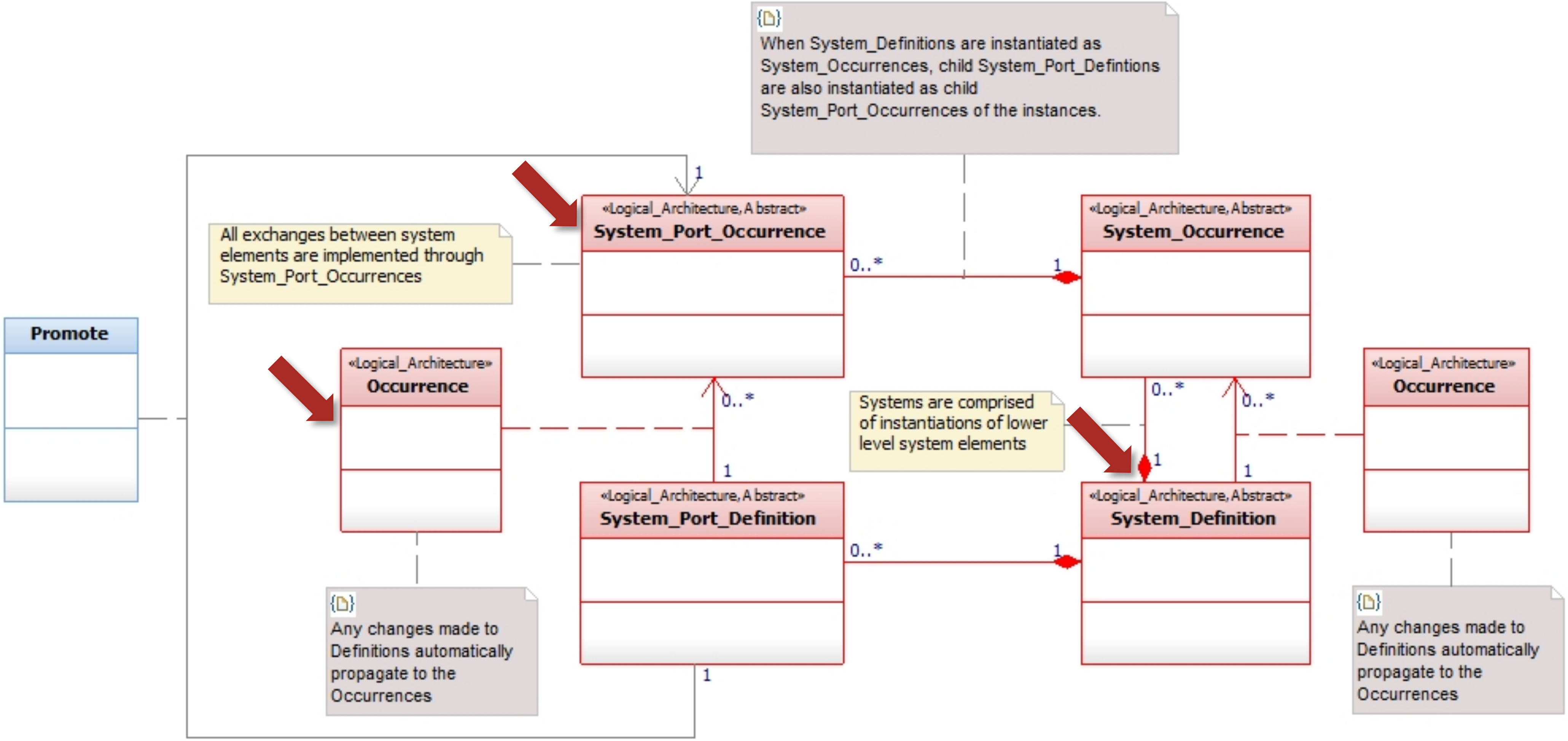
Logical Architecture
Occurrence Model



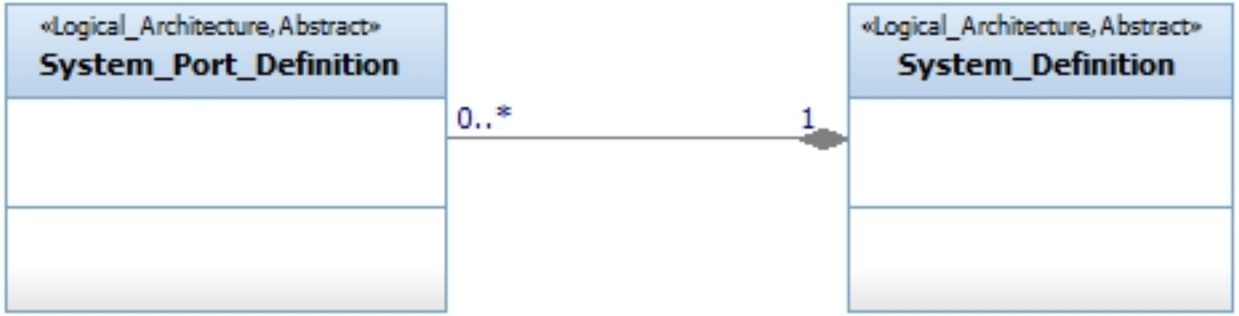
Logical Architecture
Occurrence Model



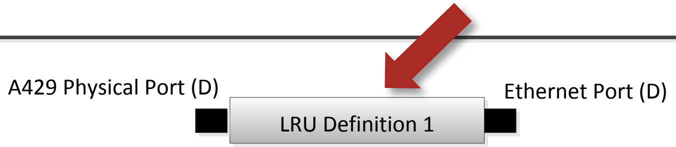
Logical Architecture
Occurrence Model



Product



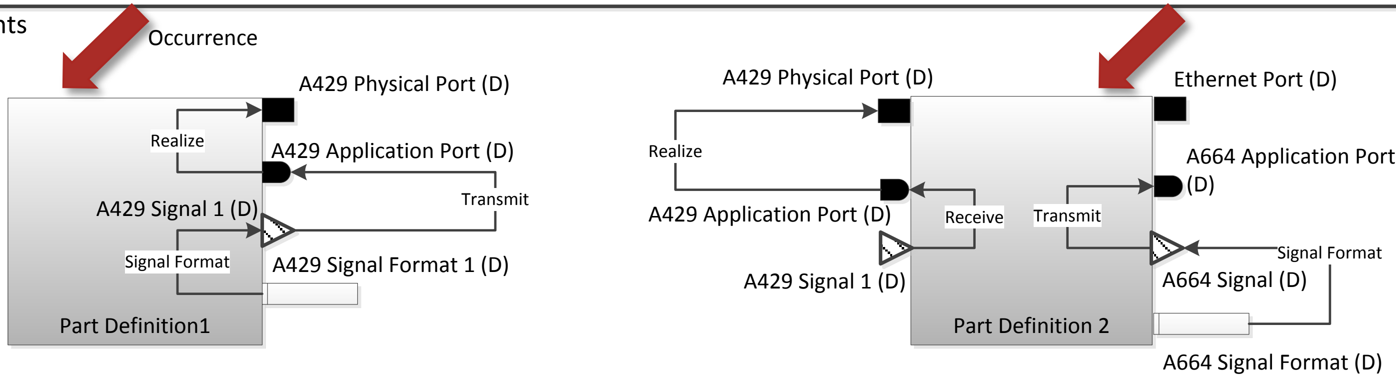
Assemblies
(Occurrences)



… on this system object …

Logical Architecture
Occurrence Model

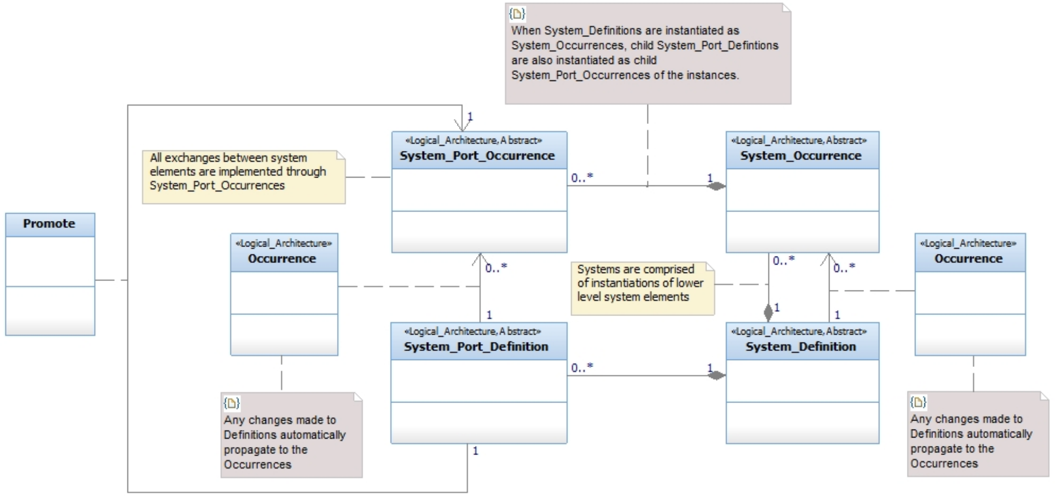
Parts/Components
(Definitions)



User installs these system objects …

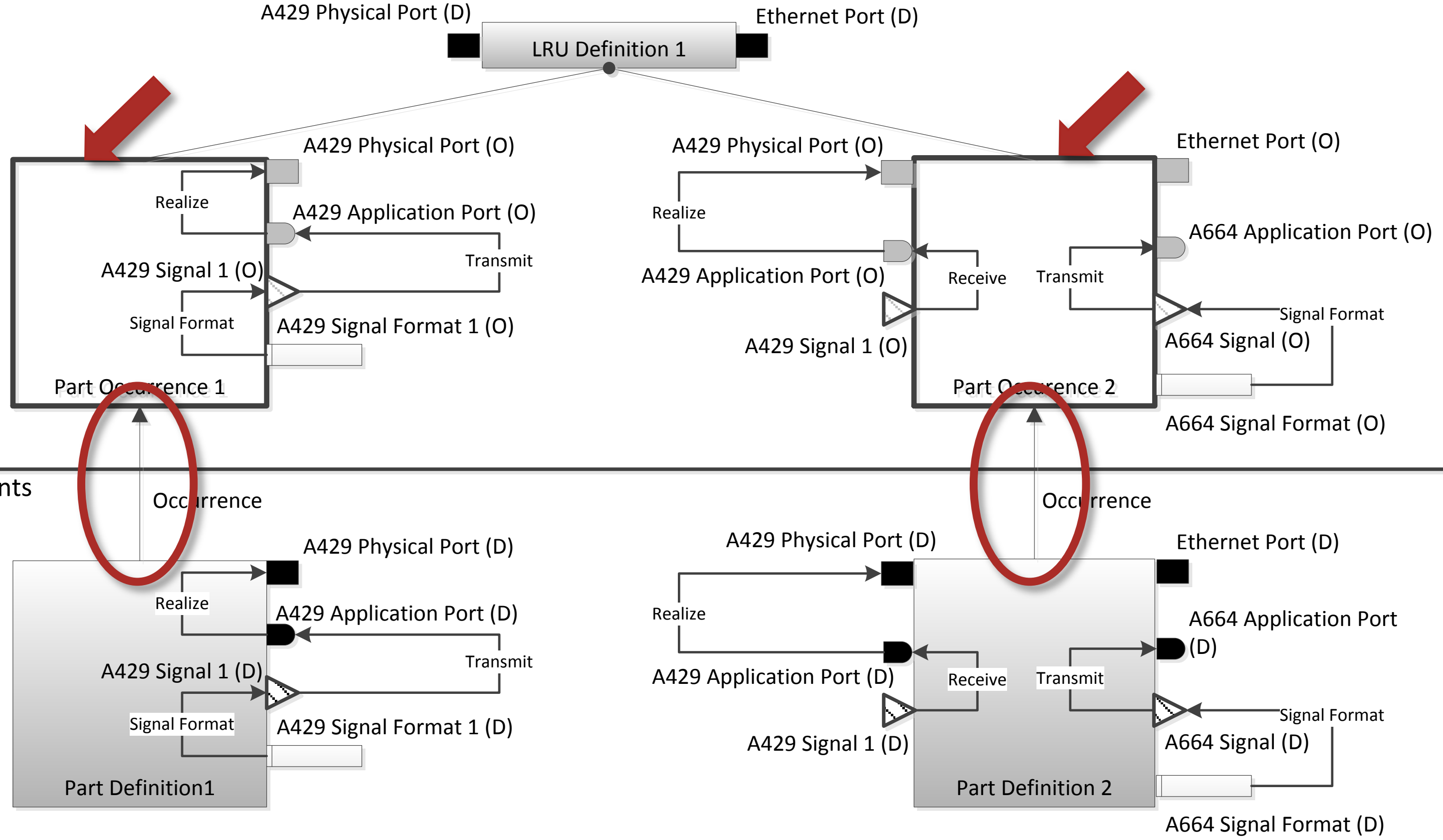
Product

Logical Architecture
Occurrence Model

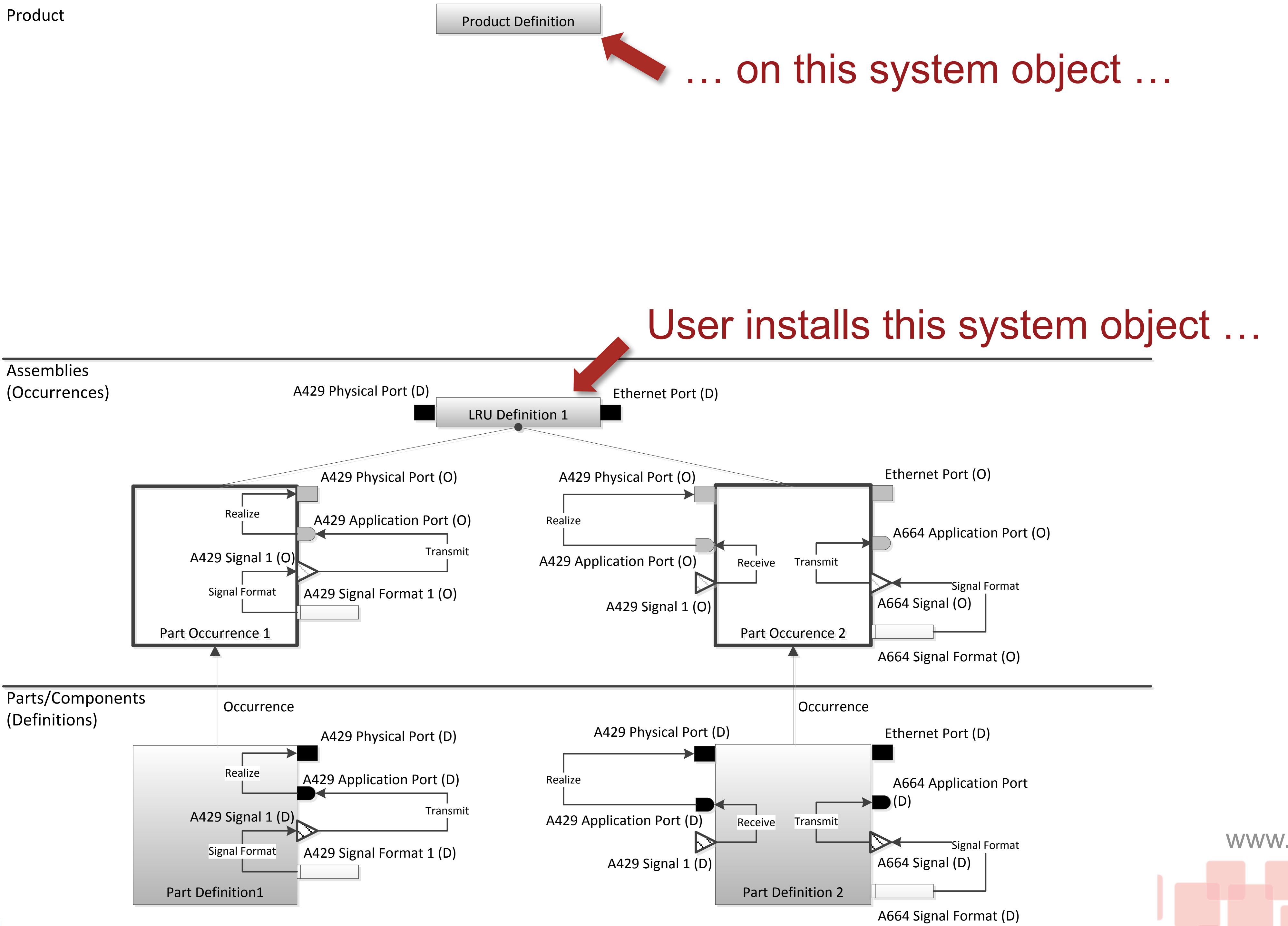


Assemblies
(Occurrences)

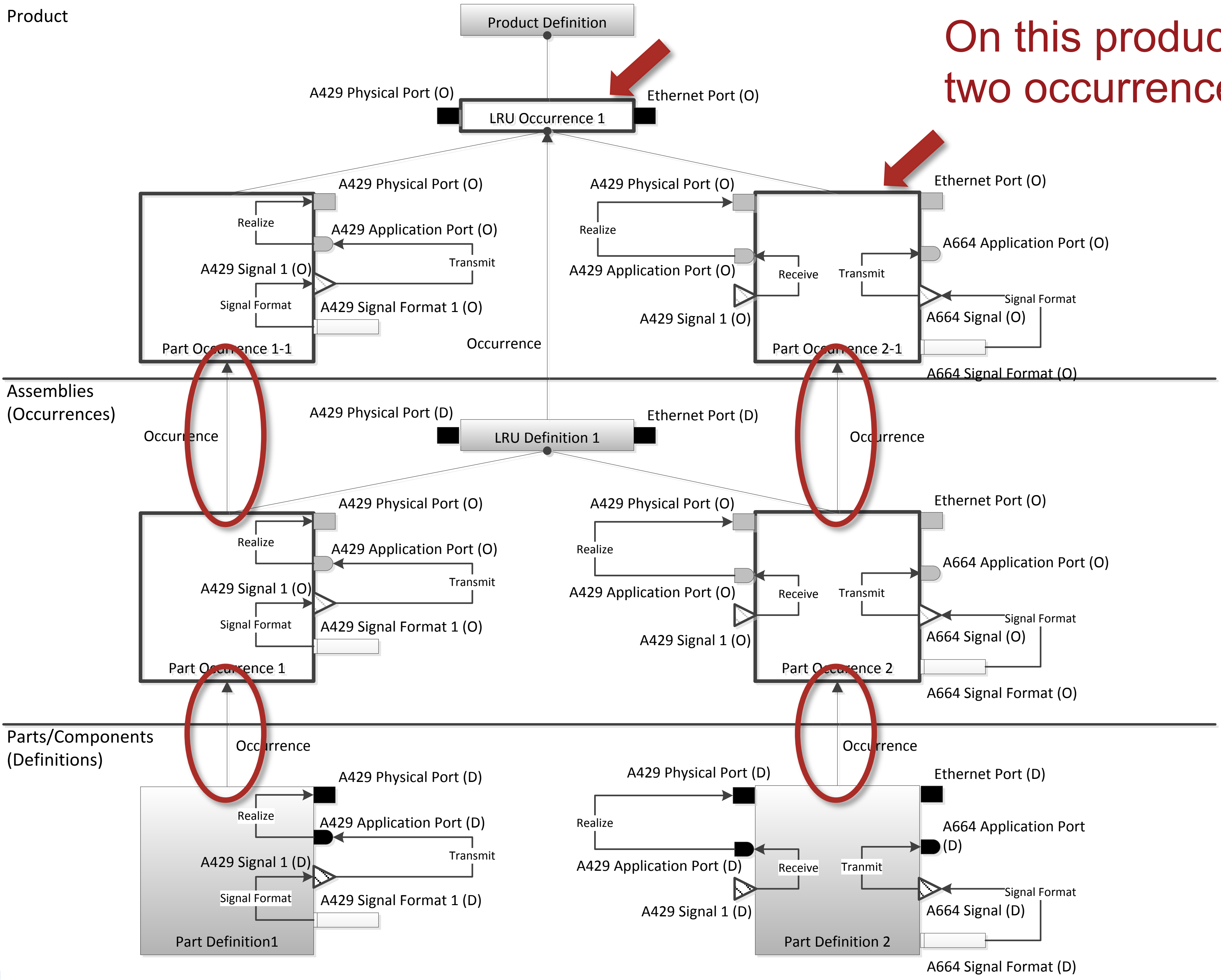
Parts/Components
(Definitions)



… and all these occurrence objects and relationships propagate

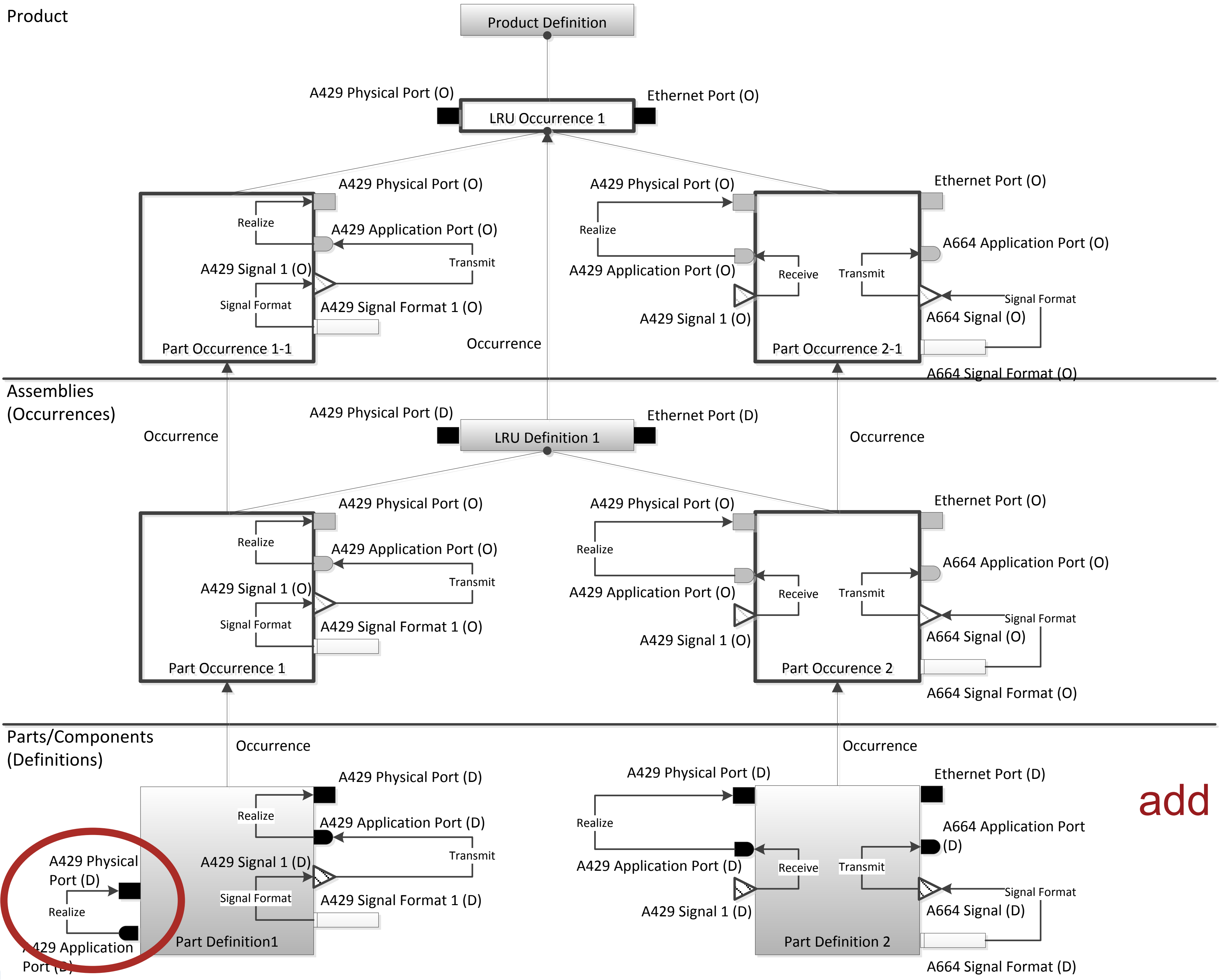


Logical Architecture
Occurrence Model



On this product there are two occurrence levels

Logical Architecture
Occurrence Model

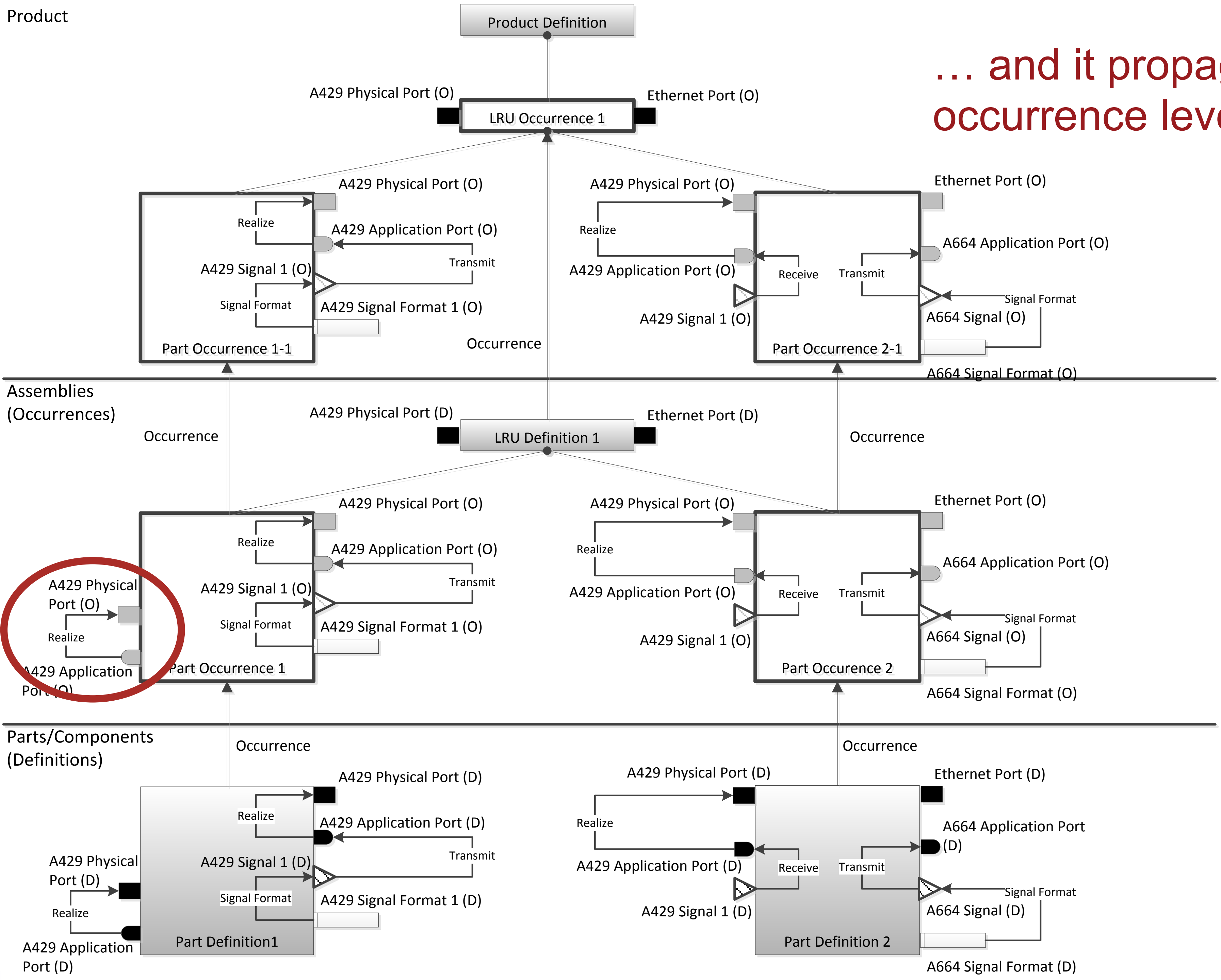


Logical Architecture

Occurrence Model

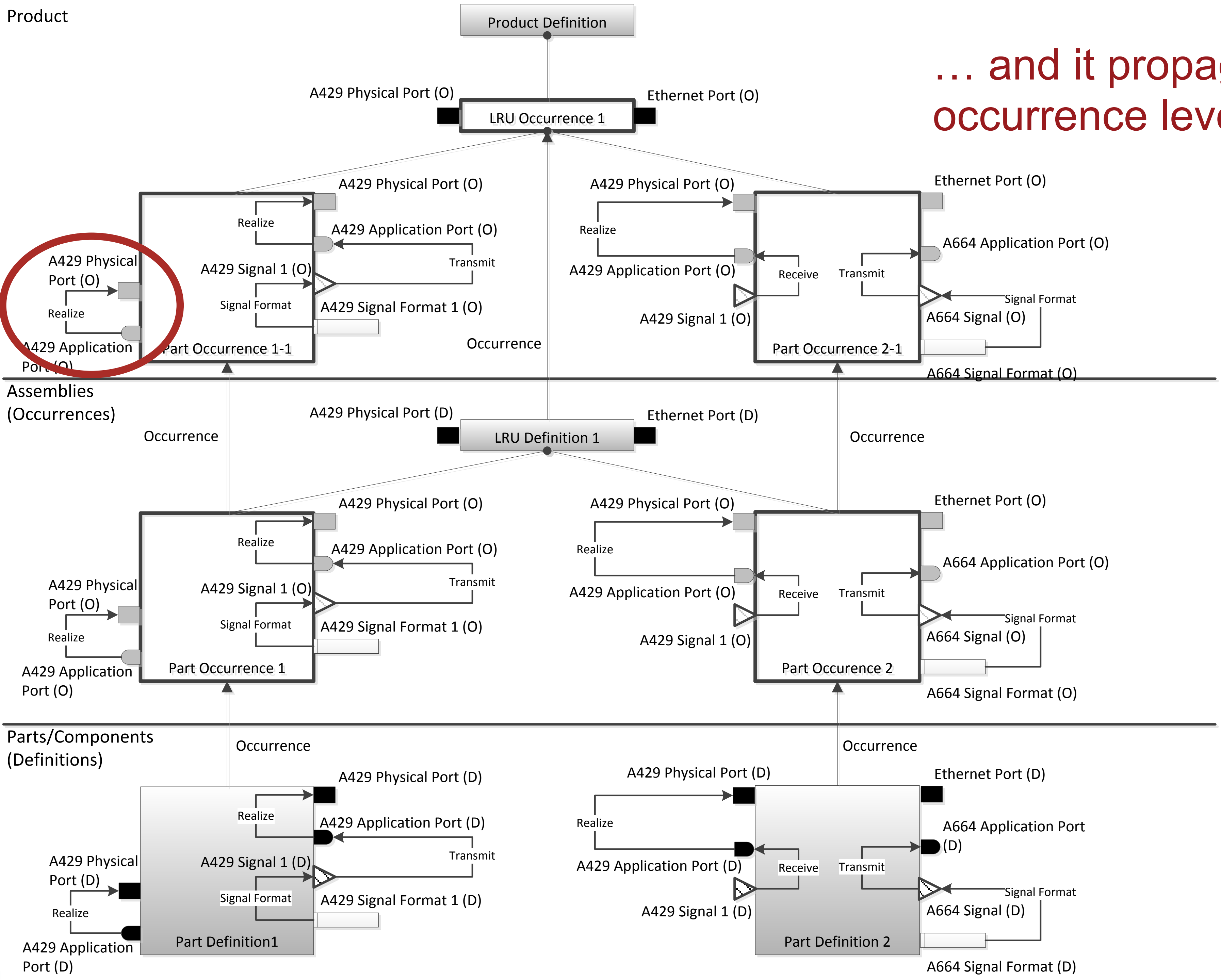
add more system definition …

… and it propagates to all occurrence levels



Logical Architecture
Occurrence Model

… and it propagates to all occurrence levels



Logical Architecture Occurrence Model

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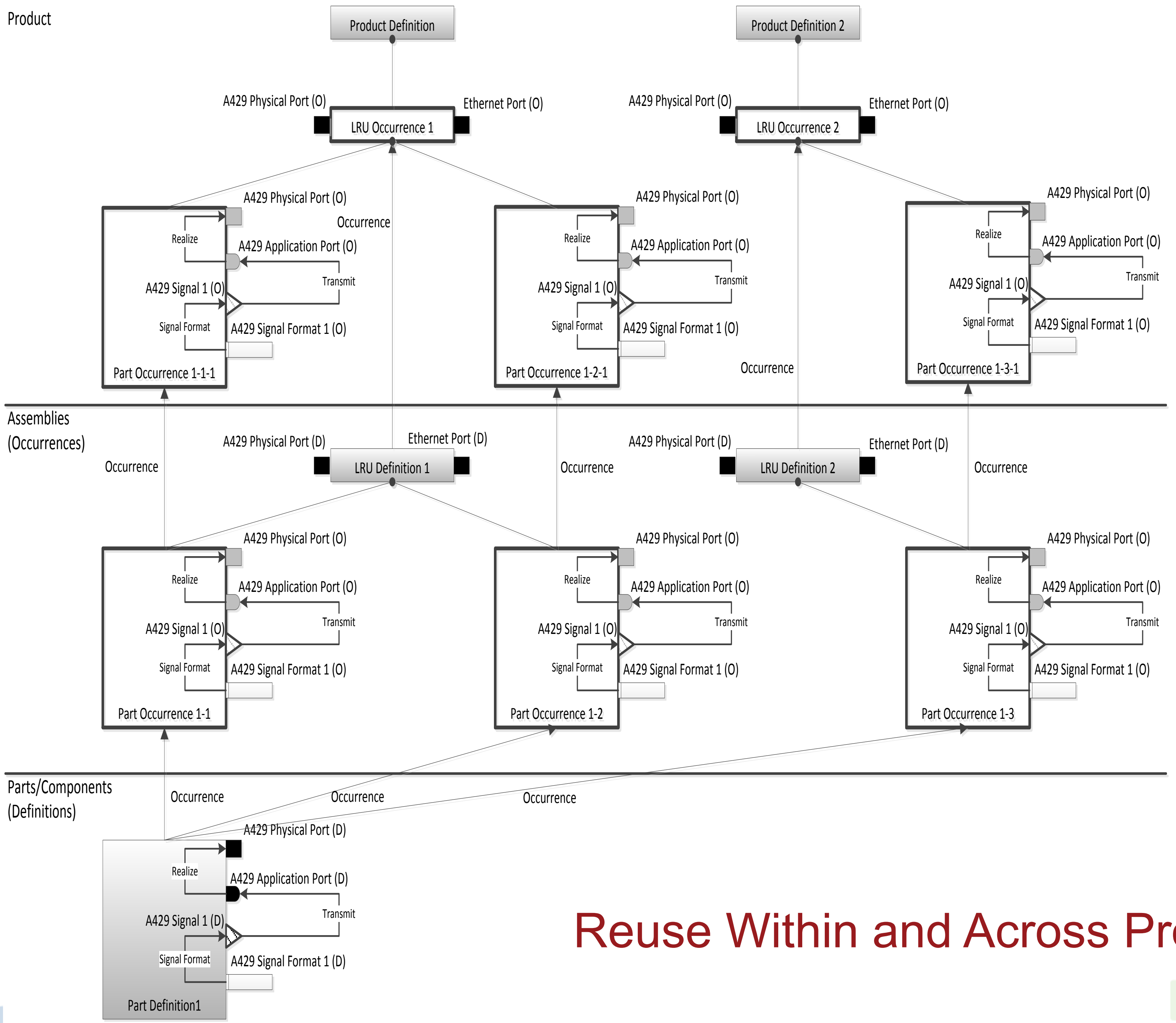
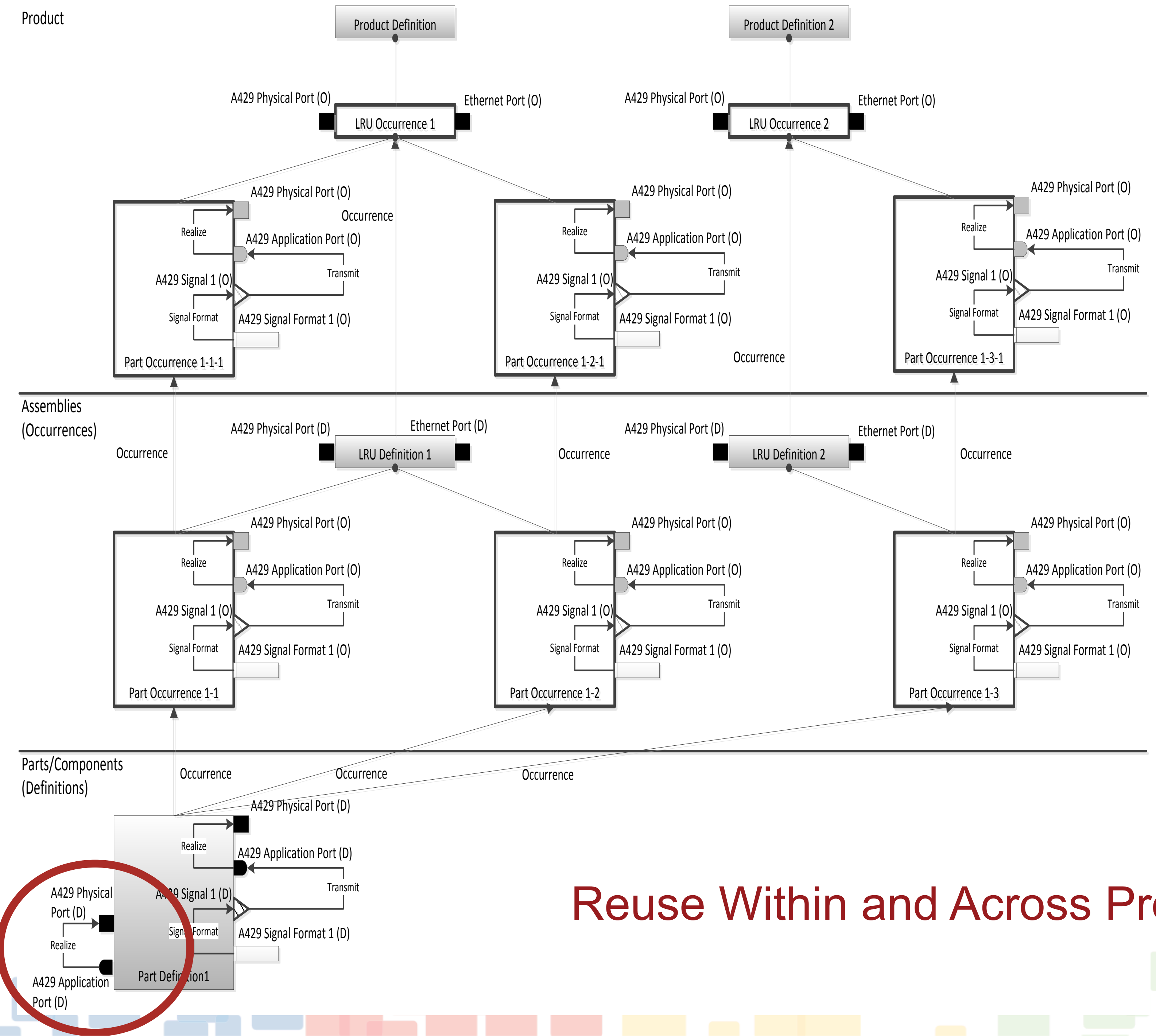


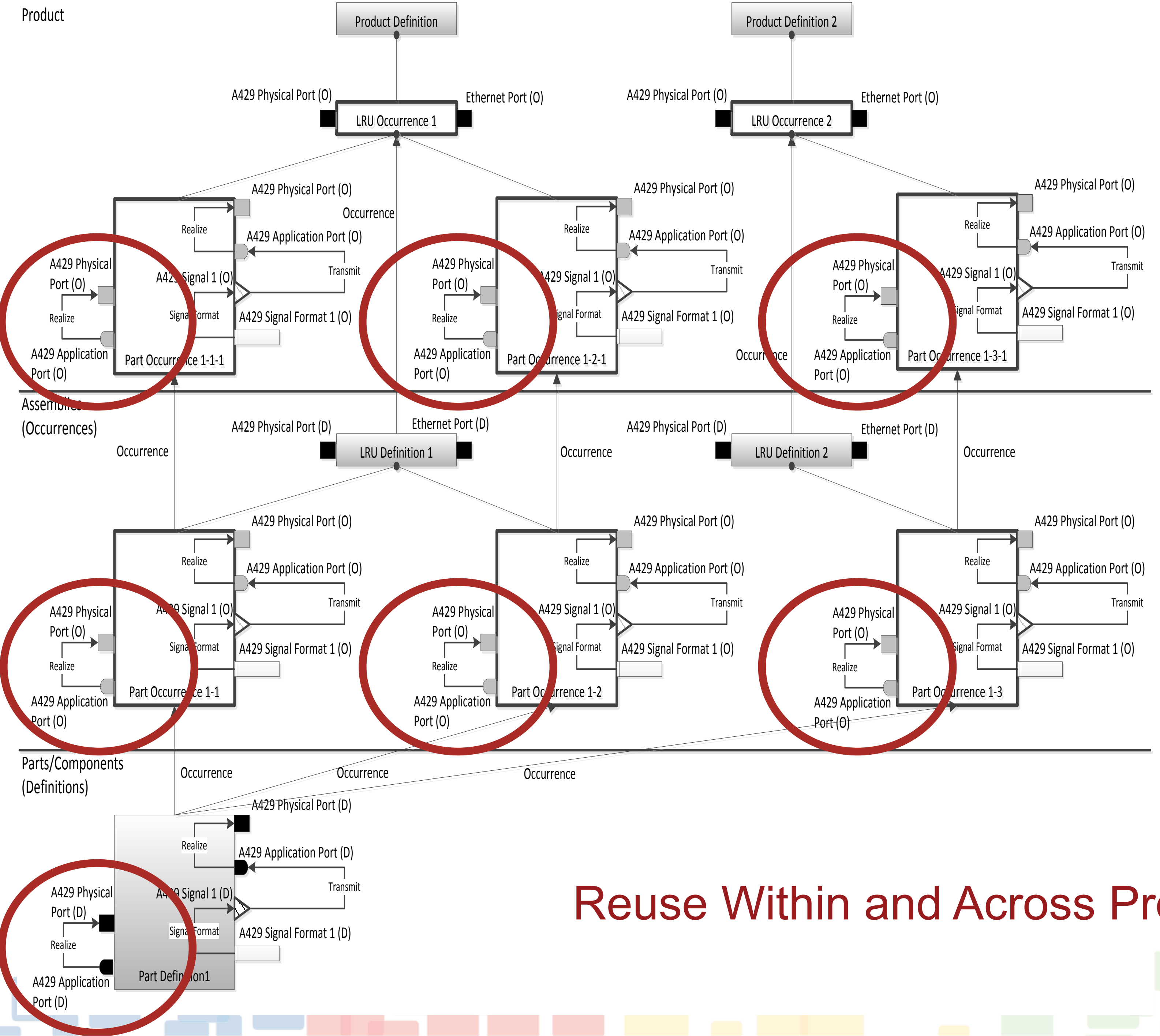
Logical Architecture
Occurrence Model

Reuse Within and Across Products



Logical Architecture
Occurrence Model

Reuse Within and Across Products



Logical Architecture
Occurrence Model

Reuse Within and Across Products

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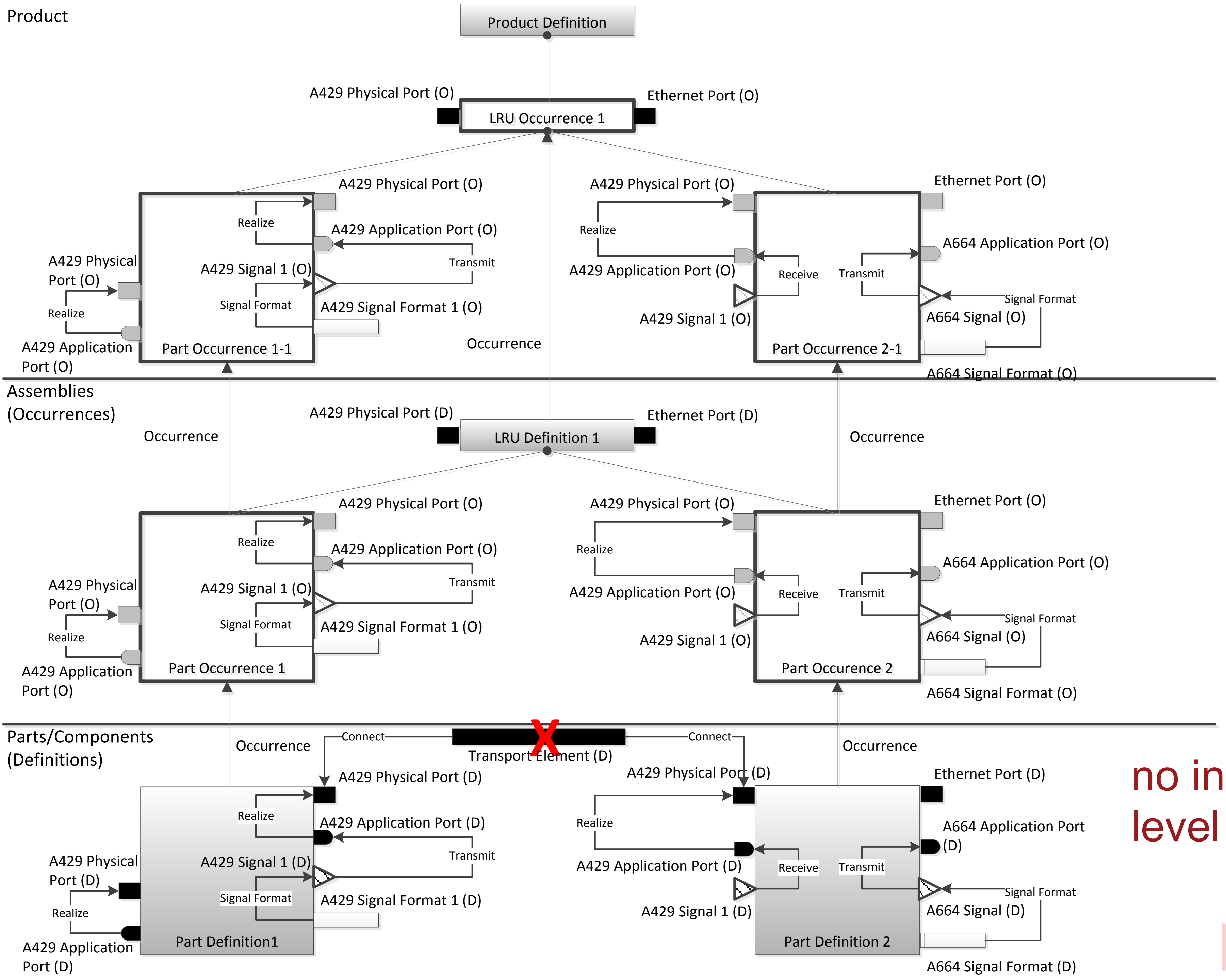
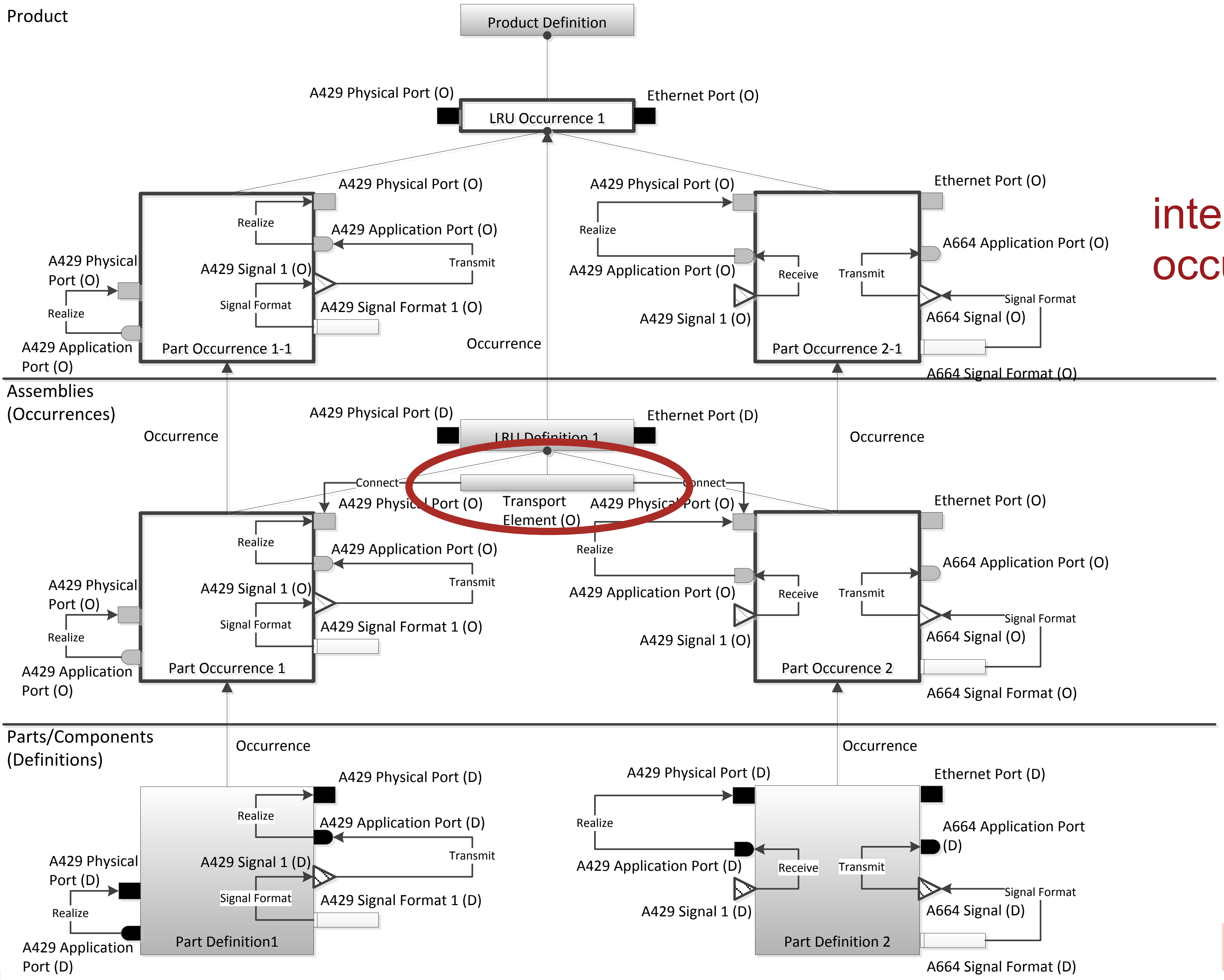


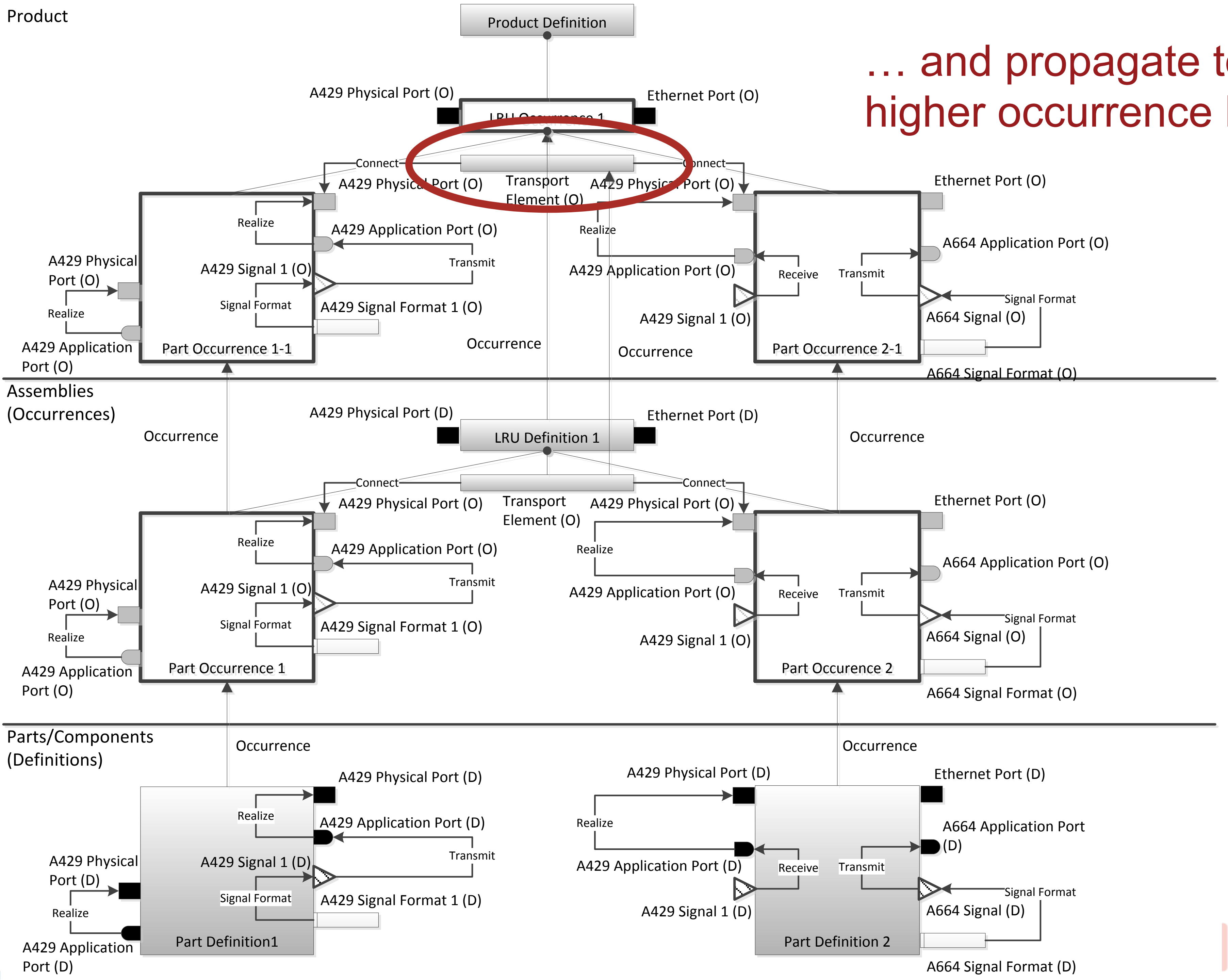
Logical Architecture Occurrence Model

no interfaces at definition level



interfaces made at occurrence level

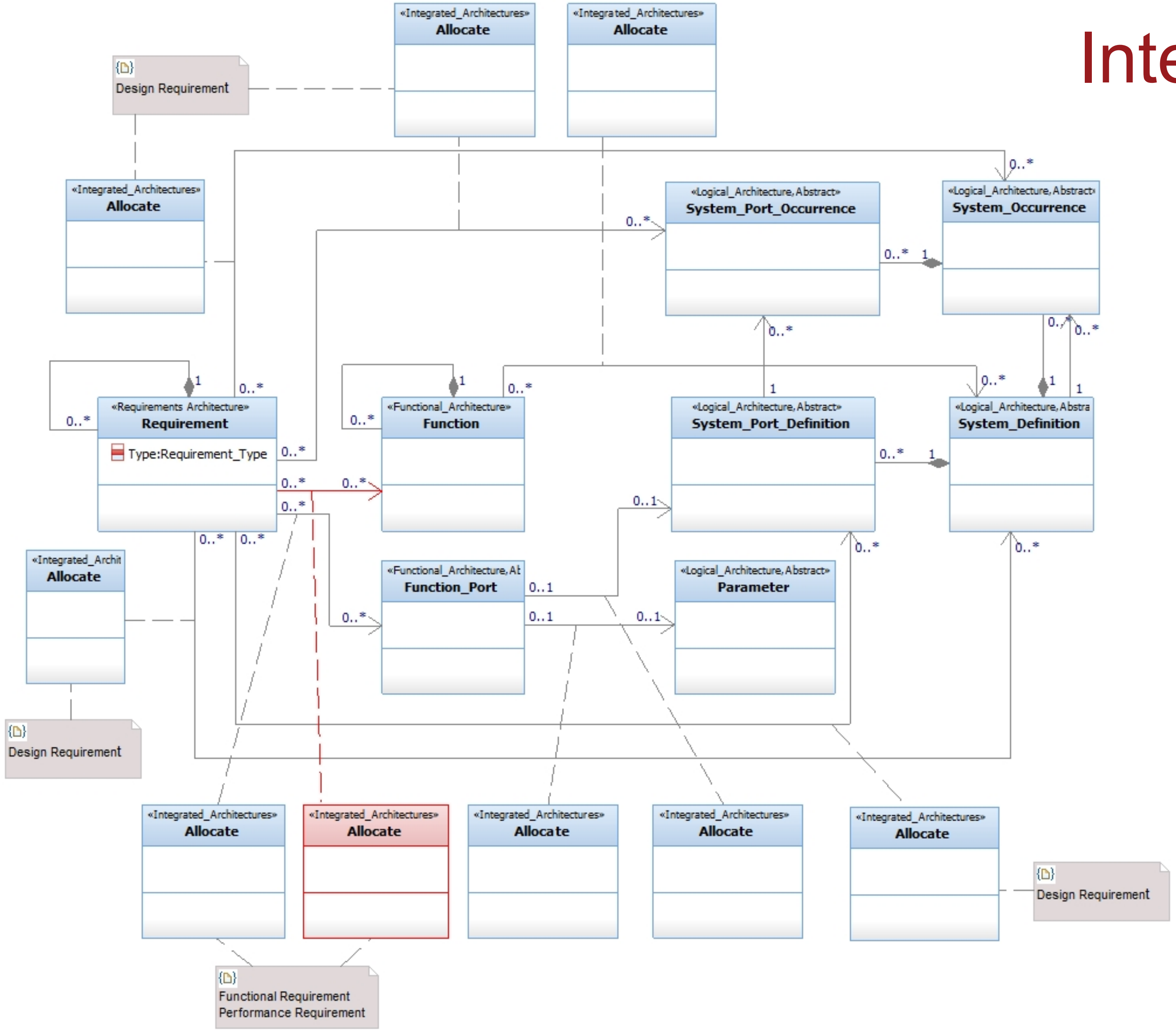
Logical Architecture Occurrence Model



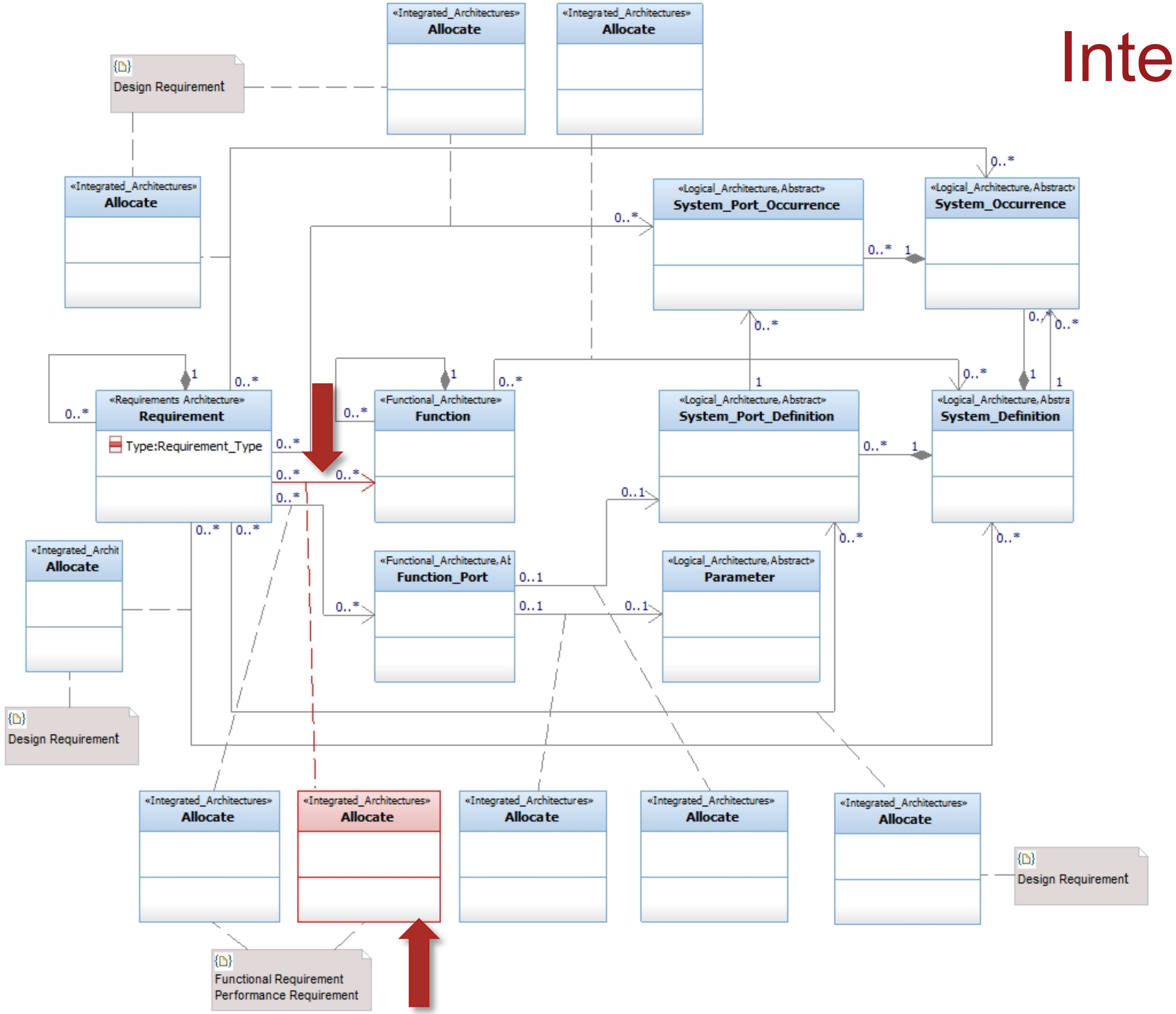
… and propagate to all higher occurrence levels

Logical Architecture
Occurrence Model

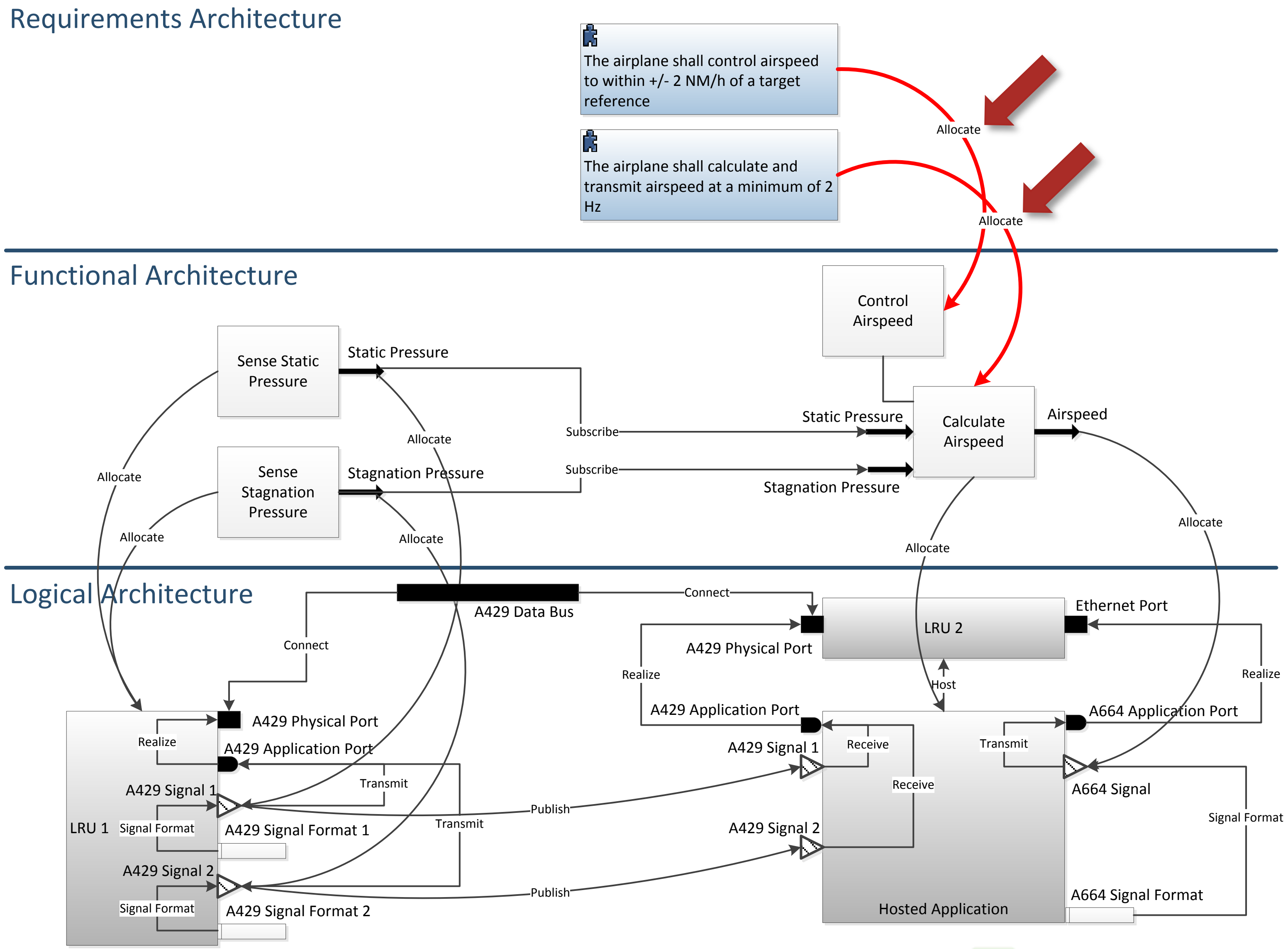
Integrated Architectures



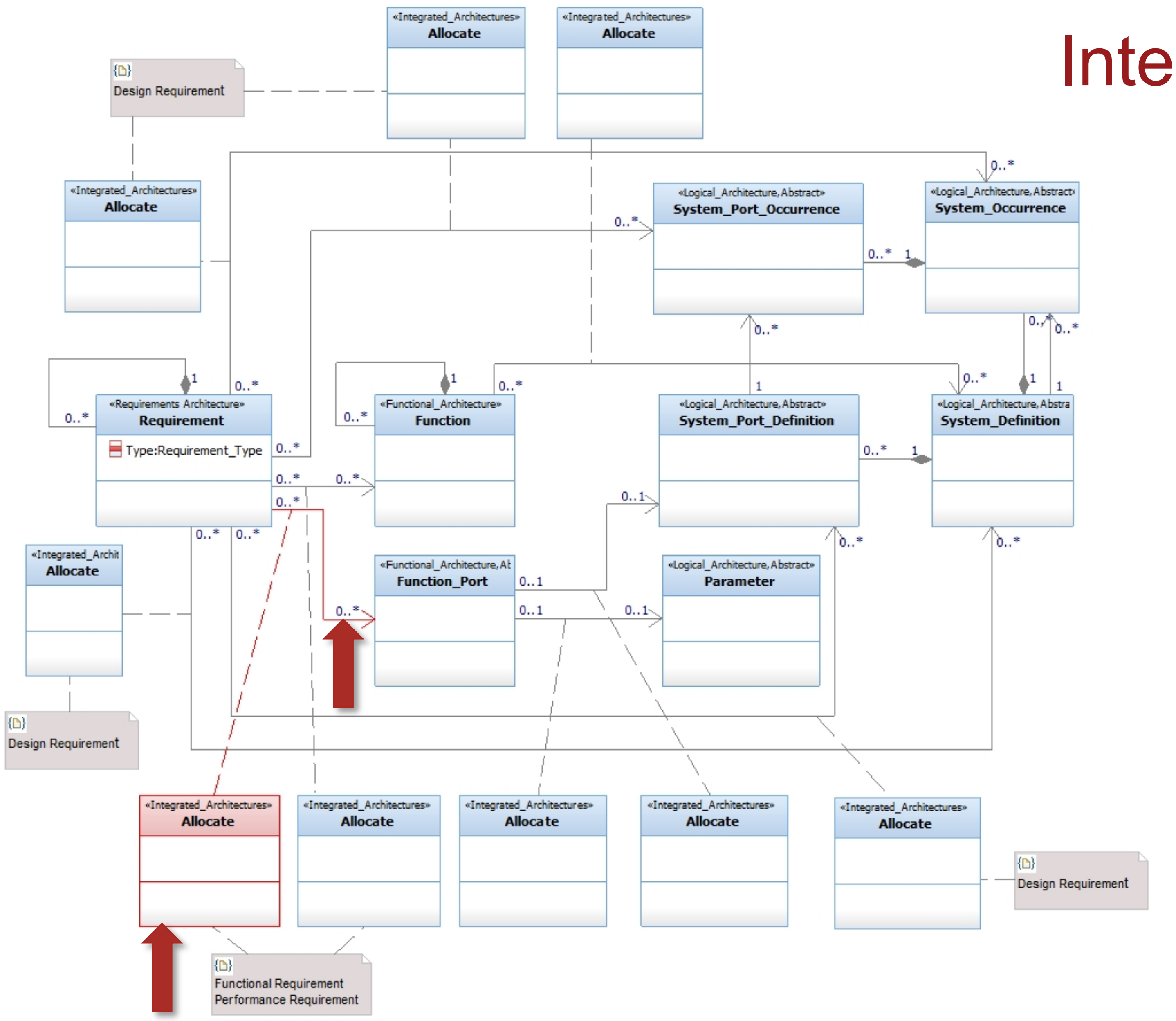
Integrated Architectures



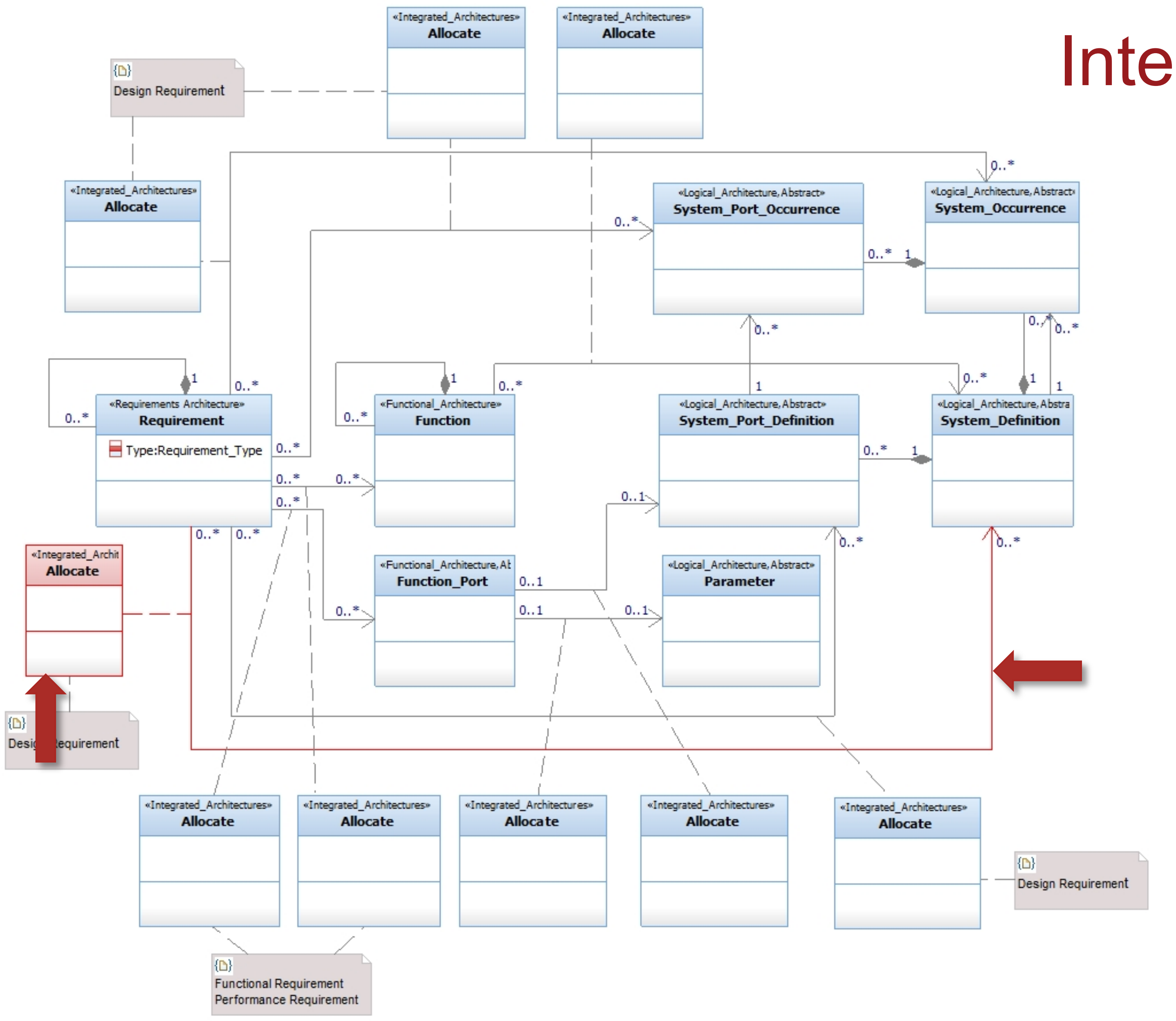
Integrated Architectures



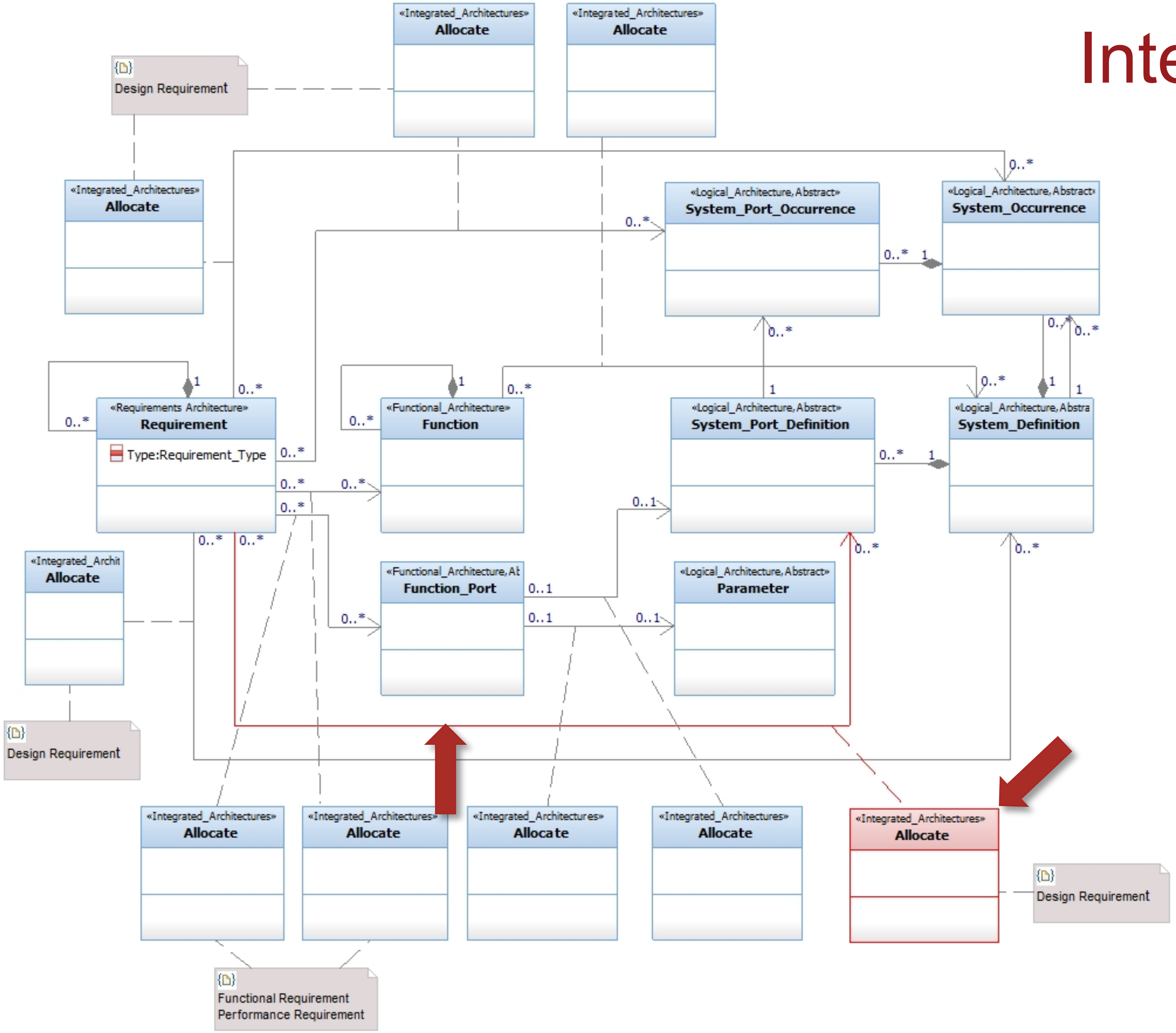
Integrated Architectures



Integrated Architectures



Integrated Architectures



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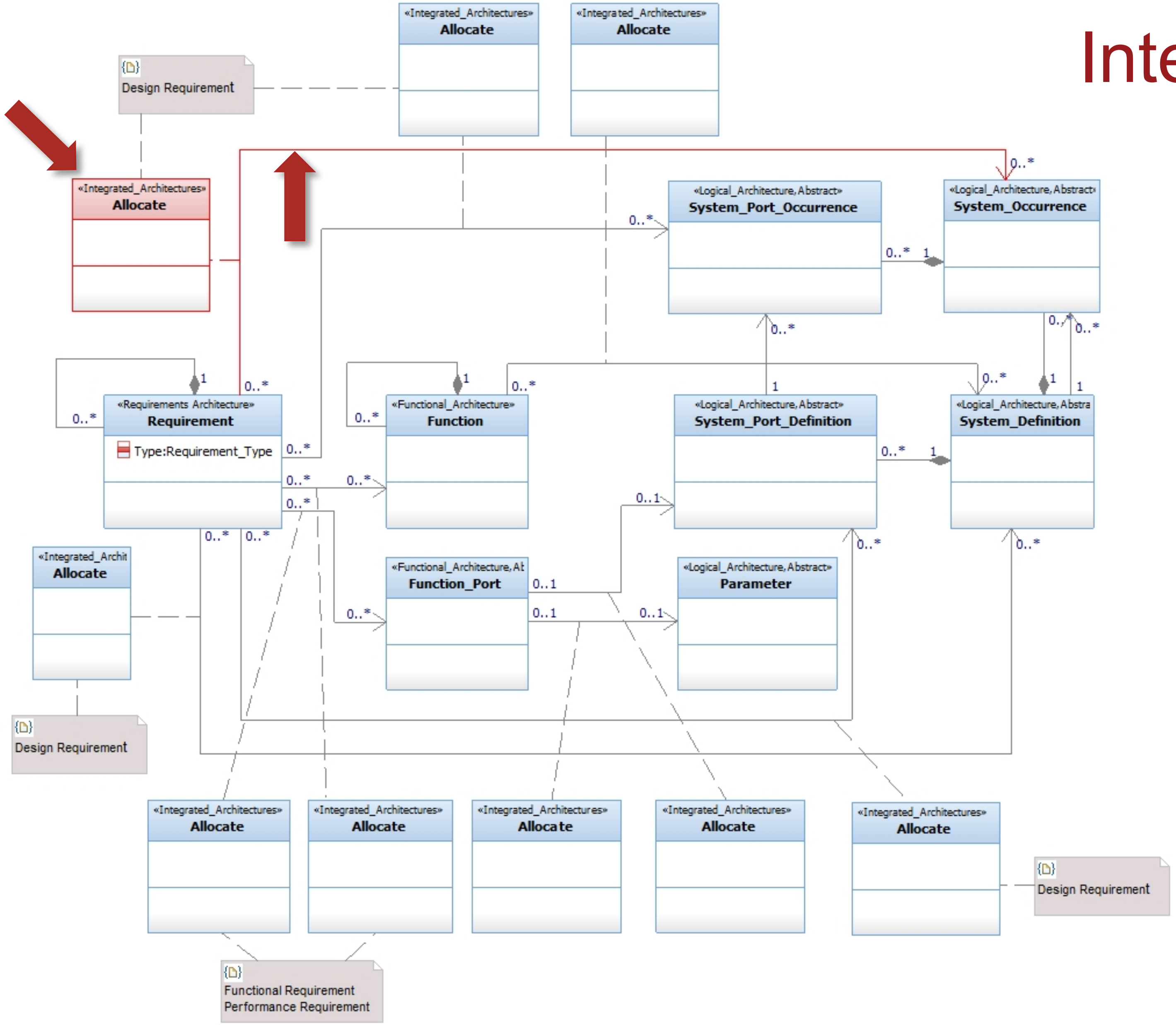
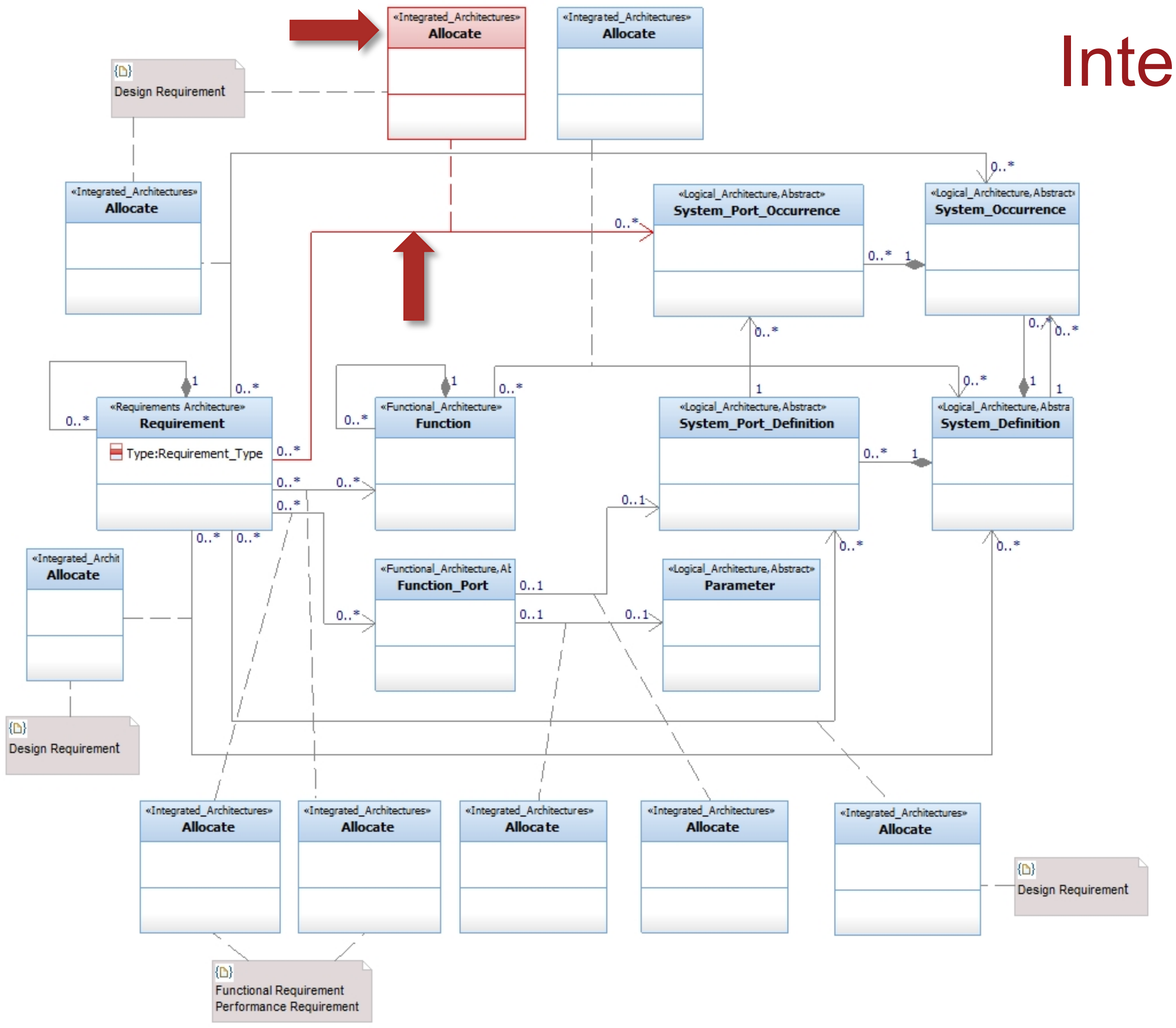


Integrated Architectures



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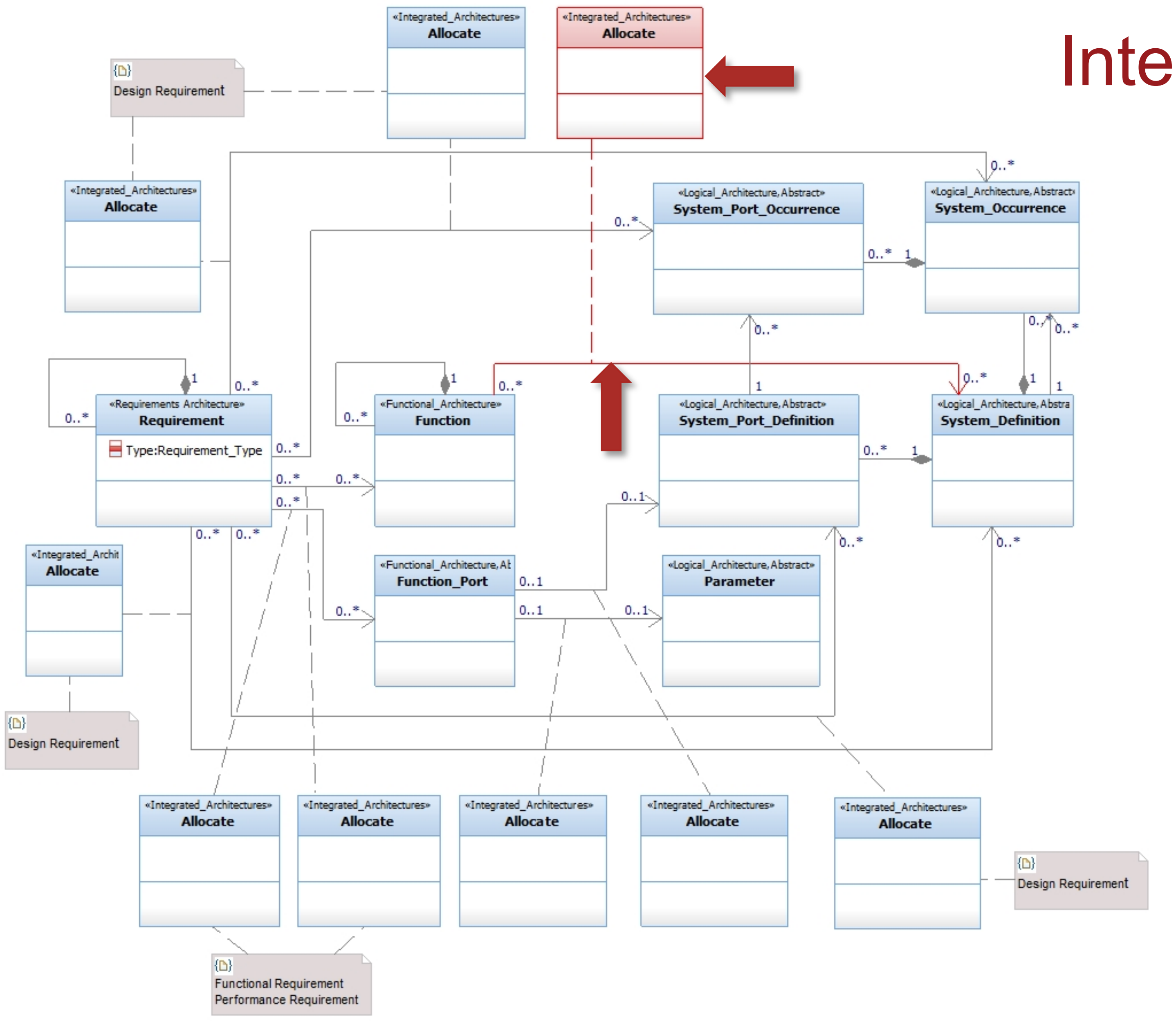

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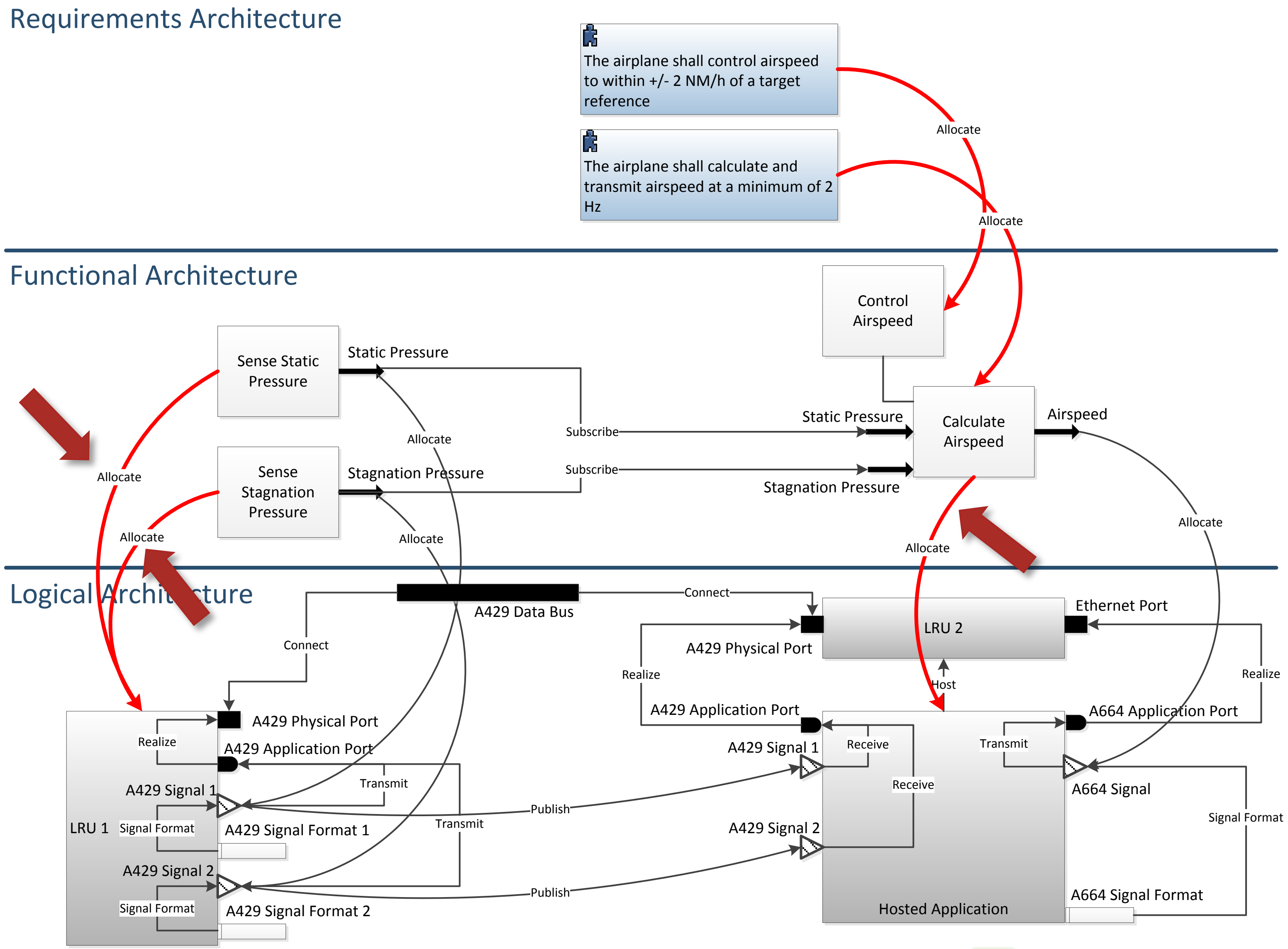

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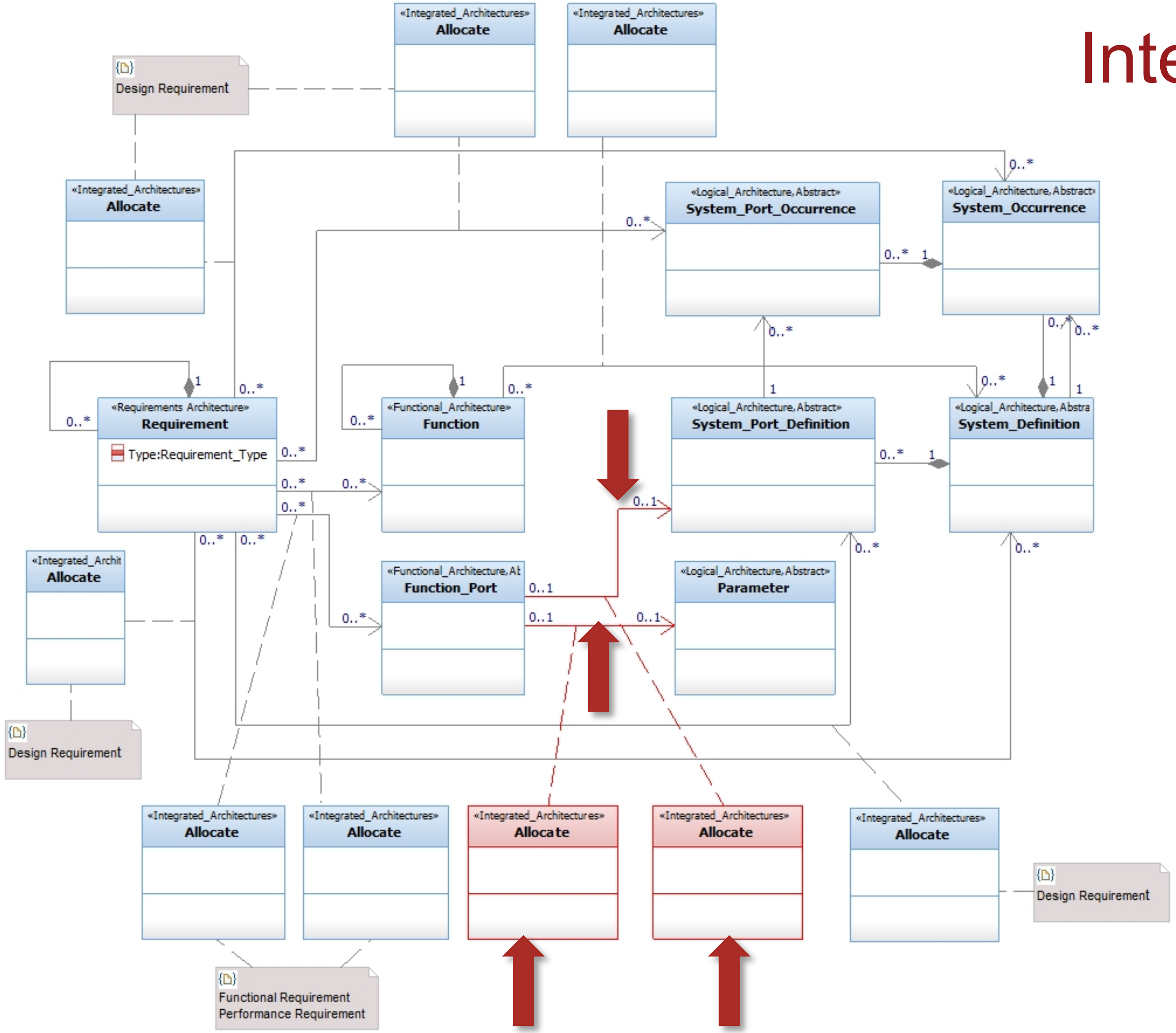
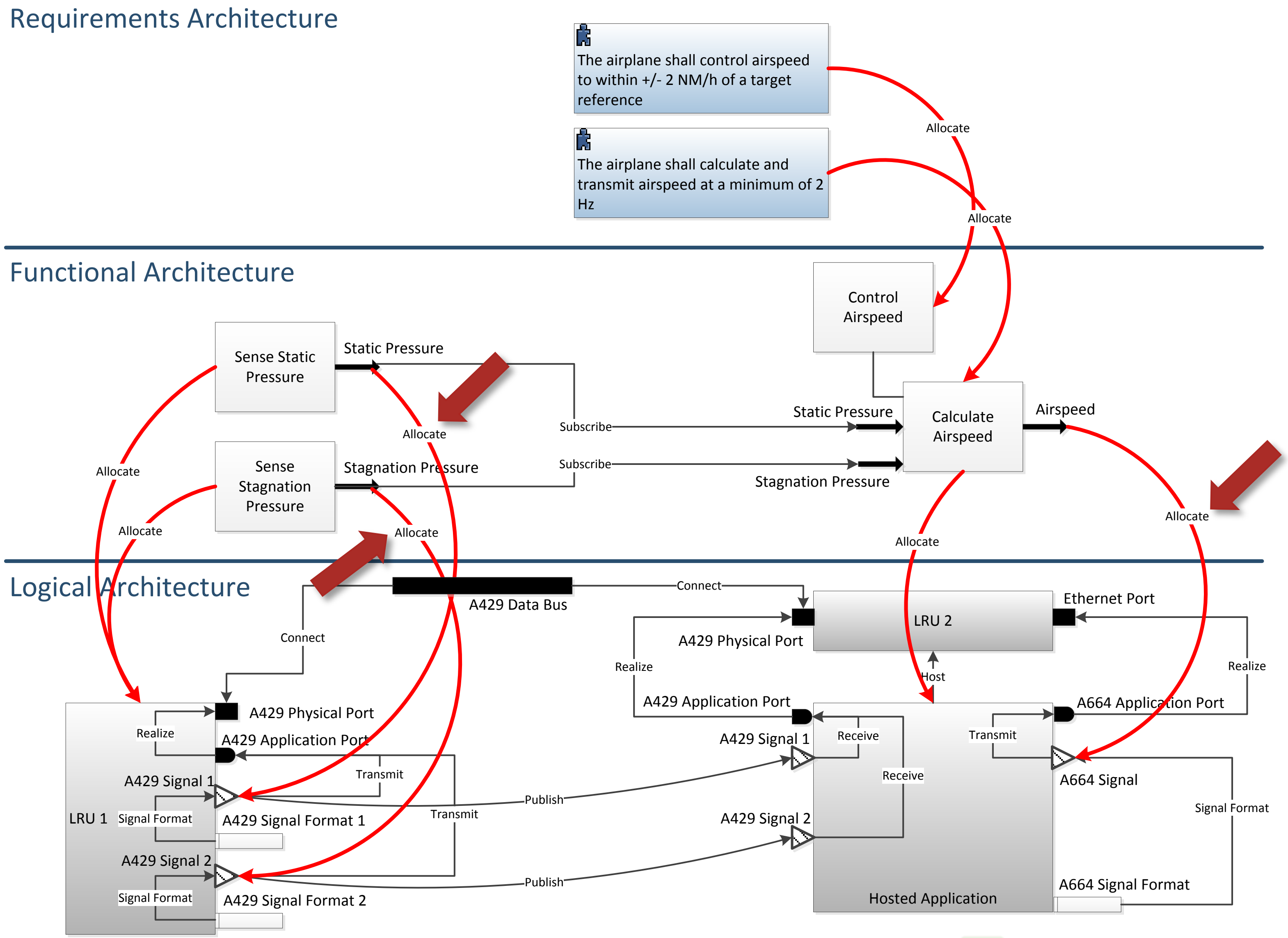
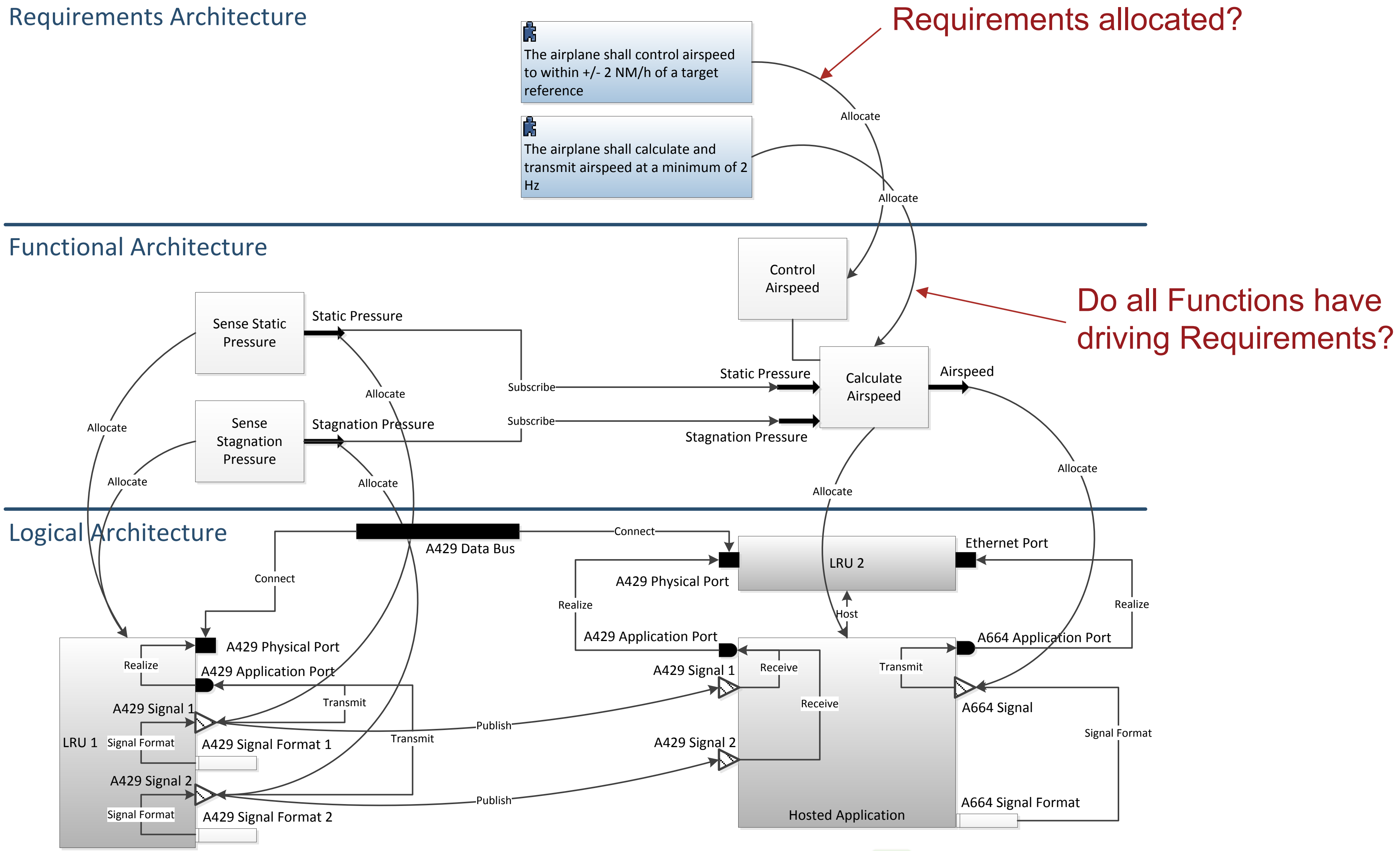


Integrated Architectures



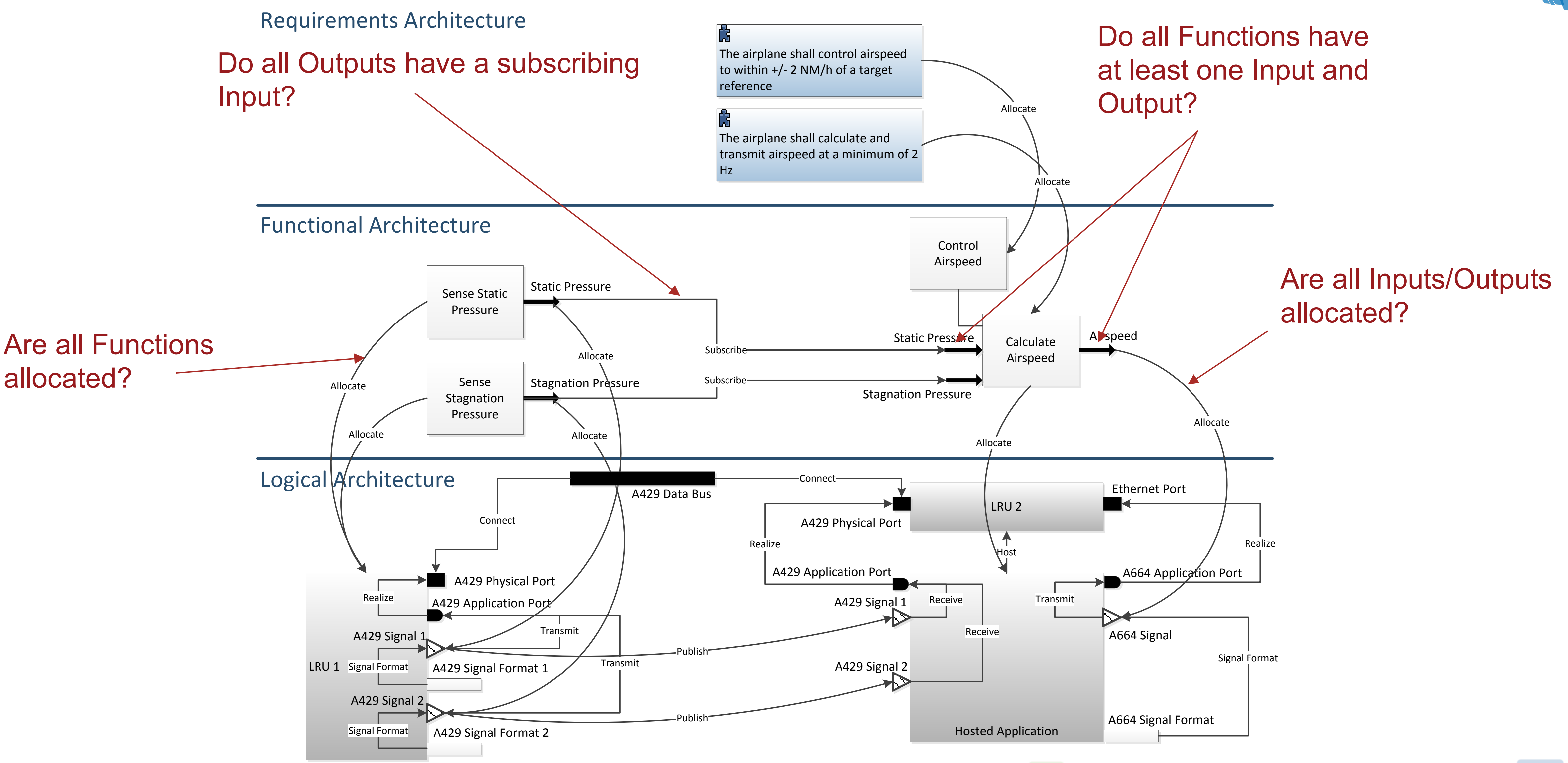
Integrated Architectures



Benefit of Modeling

Integrated Architectures

Benefit of Modeling



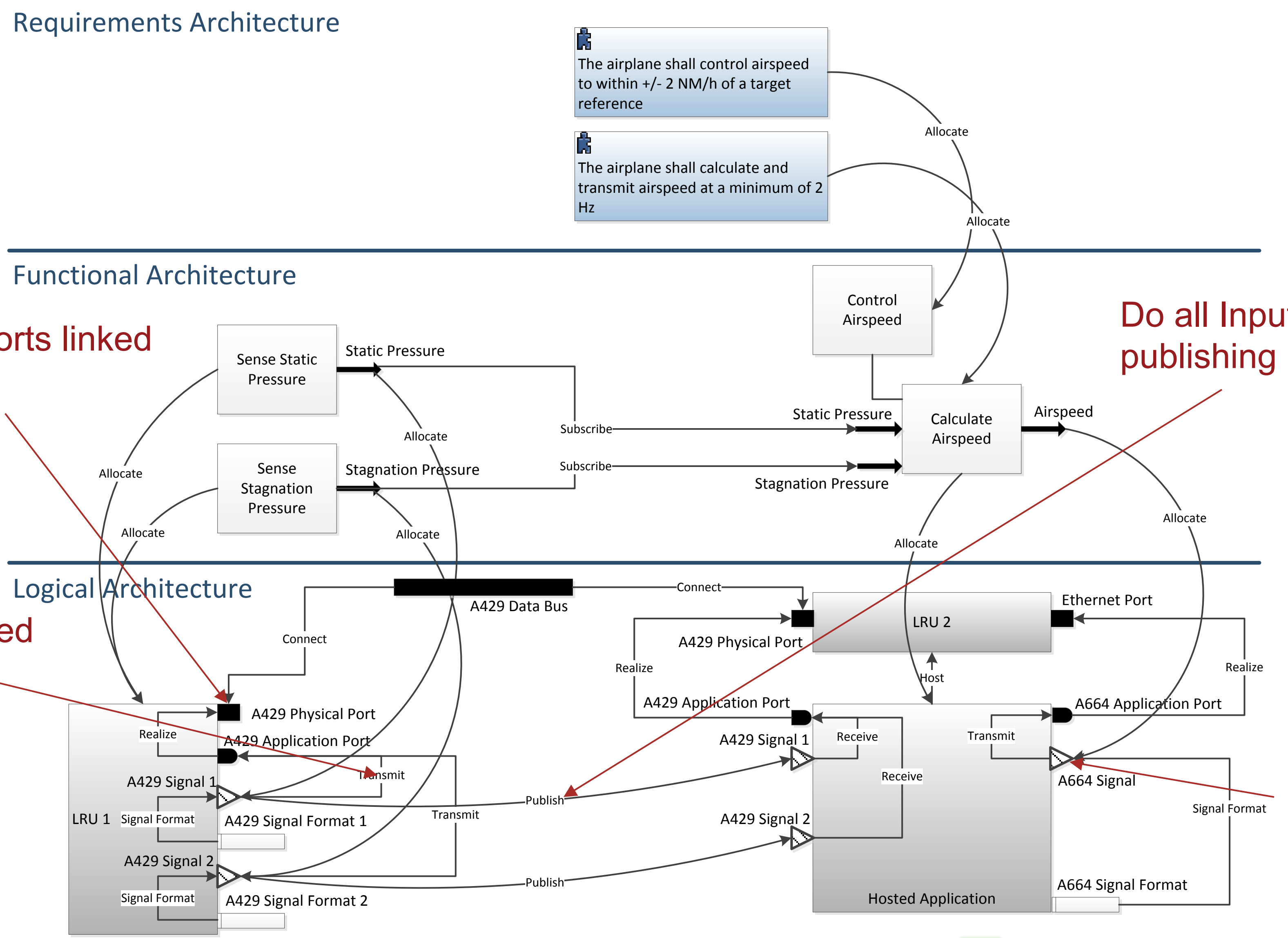
Integrated Architectures

Are all Application ports linked to a Physical port?

Are all Signals linked to an Application port?

Do all Input Signals subscribe to a publishing Output Signal?

Which Output Signals have a transmit interval shorter than 30 ms?



Benefit of Modeling

Conclusion

Conclusion

- Boeing specifies MBSE tool suites with elaborate data models and constraining rules
- Core data mode elements and rules broadly applicable across engineering domains
- Powerful features:
    - Occurrence model – reusability and model management
    - Software-Hardware Integration
    - Integration across independent architectures, requirements, functional, logical
- Objects, attributes, relationships straightforward to implement in extensible tools
- Occurrence model and business rules implementation require custom coding, requiring significant effort
- With standards, tool suites would be more capable as delivered, data exchange more straightforward (less data mapping), training reduced

Questions?

27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

ENGINEERS AUSTRALIA SESA

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robert.l.malone@boeing.com