Modeling System Interfaces with SysML v1.3

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Topics

- Background
- SysML v1.2 Interface Modeling
- SysML v1.3 Interface Modeling (draft)
- Examples
- Summary

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Background

- Interface definition is critical aspect of systems engineering
  - Many system problems result from inadequately defined interfaces
  - Problems often surface during integration and test
- Typical interface documentation include ICD, IRS, IDD, …
- Many different types of interfaces
  - Electrical
  - Mechanical
  - Software
  - Man-Machine
  - …
- SysML must support effective interface modeling

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Complex Interface Challenges

- Example: Airbus A380 Electrical Harness
  - Why isn't the Airbus A380 taking off on time? According to a variety of media, it's tangled in a bunch of electrical wire harnesses -- *530km of cables, 100,000 wires and 40,300 connectors*, to be exact.

Source: Cadalyst magazine article

What Grounded the Airbus A380?

December 6, 2006 By: Kenneth Wong

http://www.cadalyst.com/management/what-grounded-airbus-a380-5955

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Interface Control Document Example

A Diverse Set of Interfaces

Interface Control Document NASA 932 C-9B
Aircraft Operations Division February 2011
Source: http://jsc-aircraft-ops.jsc.nasa.gov/Reduced_Gravity/docs/AOD_33912.pdf

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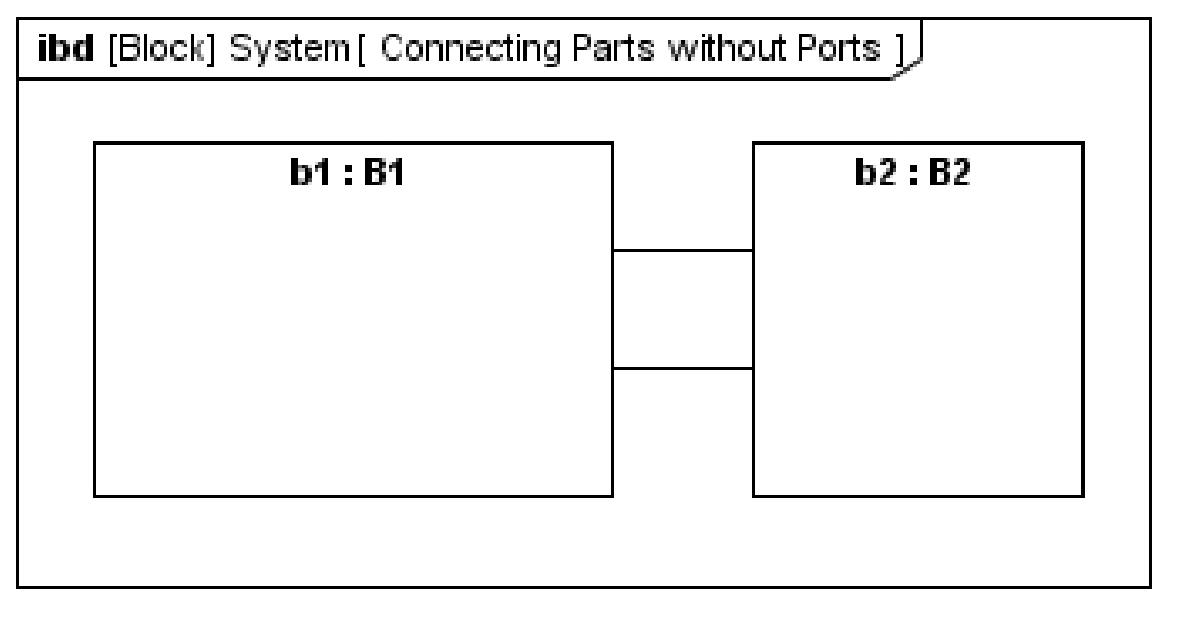
SysML v1.2 Interface Modeling

Connecting Parts W/O Ports

- Connectors can connect parts without ports, but cannot specify details about the interfaces between b1 and b2



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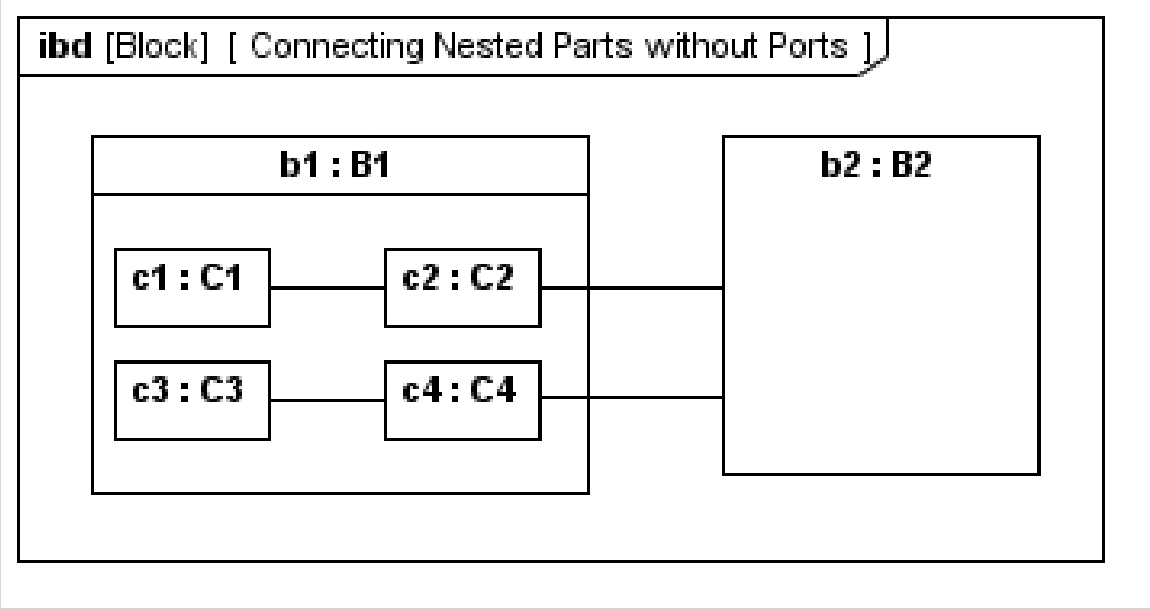
Connecting Nested Parts W/O Ports

- Connectors can be used to connect nested parts without imposing a black box interface specification on b1:B1
  - This is sometimes very useful, particularly when outer block (i.e., b1:B1) is only a logical aggregation of parts



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SysML v1.2 Ports

- Specifies interaction points on blocks
  - Flow ports
    - Specifies what can flow in or out of a block
  - Standard ports
    - Specifies a set of required or provided interfaces

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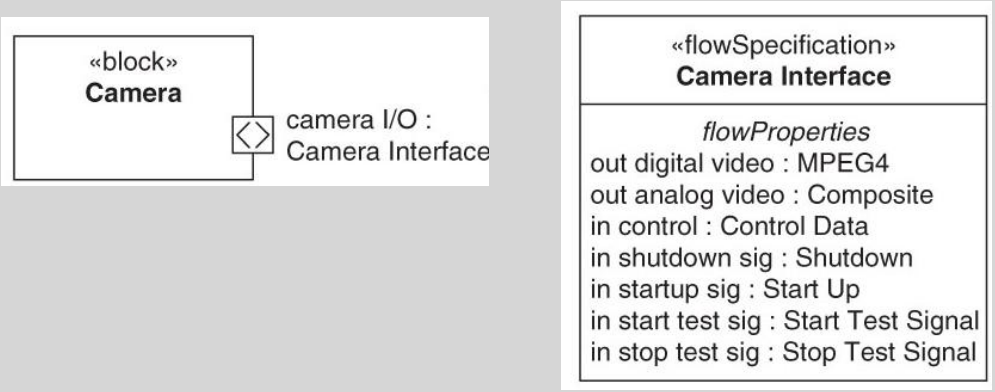
SysML 1.2 - Flow Ports

- Flow port typed by a flow specification
- Flow specification contains flow properties
- Flow properties specify types of items that can flow in and out of Camera block



Source: FIGURE 6.26 A Practical Guide to SysML

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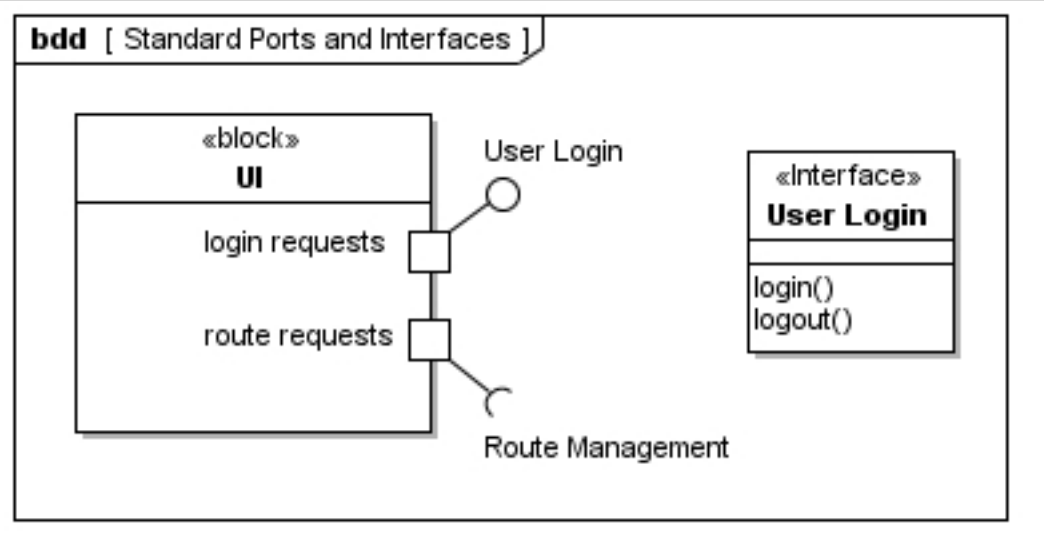
SysML 1.2 - Standard Ports and Interfaces

- Specify the services that a block either provides or requires
- Provided Interface – specifies operations that a block provides
  - Depicted by a ‘ball’
- Required Interface – specifies operations required by the block
  - Depicted by a ‘socket’



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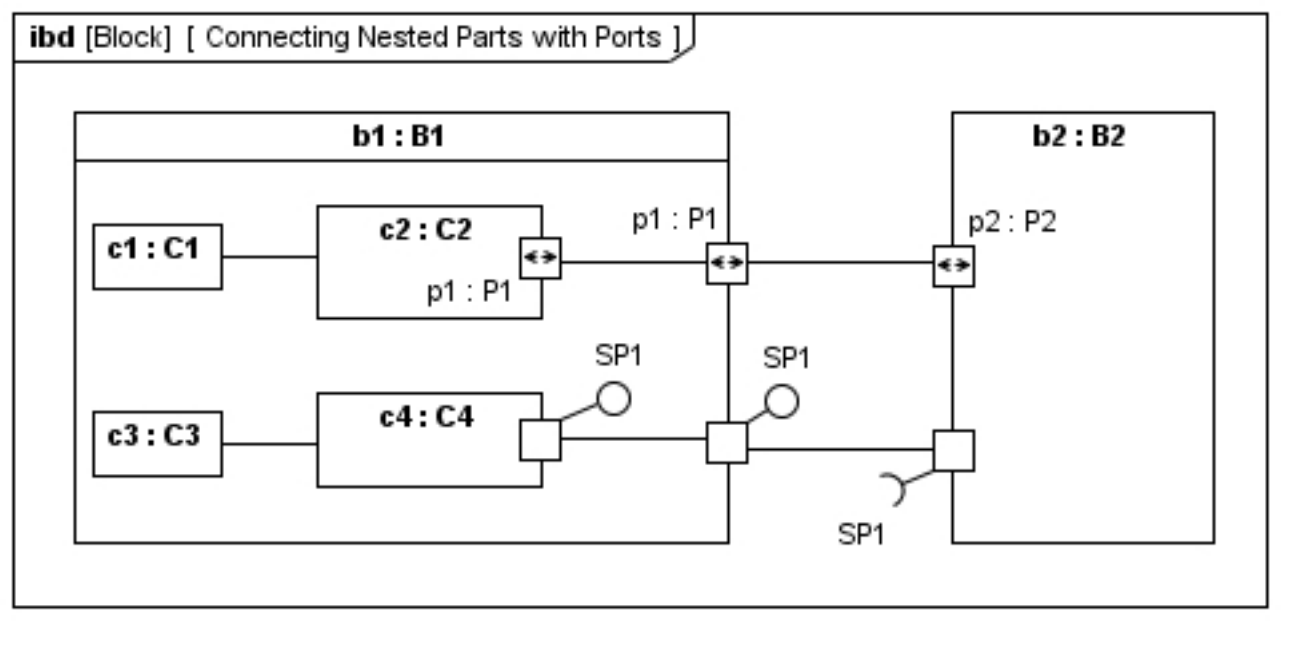
Connecting Nested Parts with Ports

- Provides ability to delegate black box interface to internal structure



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SysML v1.3 Interface Modeling

SysML v1.3 Interface Modeling Requirements

- **Relay semantics.**
  - Provide support to model ports that relay items to/from their owning block and/or its internal parts. Include the ability to define what items can be relayed by each port and how: how a behavior of a block sends and receives items via its ports, and which connector(s) the items are conveyed from the sender part to the receiver part(s) (via the ports)
- **Diversity of system interfaces.**
  - Provide support for modeling a diverse set of system logical and physical interfaces, including electrical, mechanical, software, and operator interfaces, as well as supporting interface modeling paradigms such as those used by Modelica.
- **Complex/hierarchical interfaces.**
  - Provide support for modeling complex interfaces that include multiple levels of hierarchy via composite port types and composite connector types.
- **End compatibility.**
  - Provide support for specifying compatibility rules between the ports/parts at the connector ends. This includes constraints on the features of the port type that specify what can be accessed.
- **Binding to features of the owning block.**
  - Provide mechanisms to bind the features of the port type to the accessible features of the owning block.
- **Layered abstractions.**
  - Provide support for layered descriptions of item flows such as messages that include description of logical data, encoding in bits/bytes, and signal characteristics (e.g., voltage levels, response times, ..)
- **Access point identification.**
  - Identification of access points so that identical flow/requests exchanged at two distinct access points can be distinguished.

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SysML v1.3 Interface Modeling Capability

- Retain capability of v1.2 ports (standard port, flow port)
  - However, deprecate Flow Ports and Flow Specification and replace with new ports
- Provide additional capability
  - Nested ports and flows
  - Interface specification beyond flows and services to include more diverse interfaces (e.g. mechanical mating)
  - Required and provided features
  - Ability to specify compatibility between connected ports

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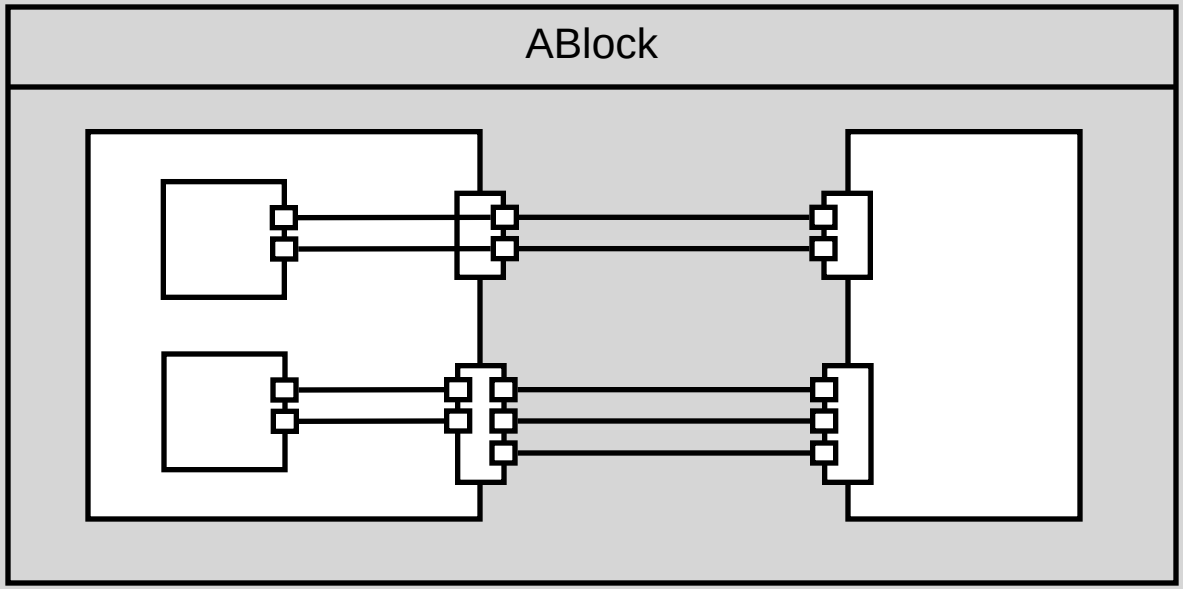
Nested Ports

Source: Draft Ballot Presentation by C. Bock

- Ports can be shown with nested ports, recursively
- Connectors can link to nested ports
- Connectors decomposed by typing them by an association



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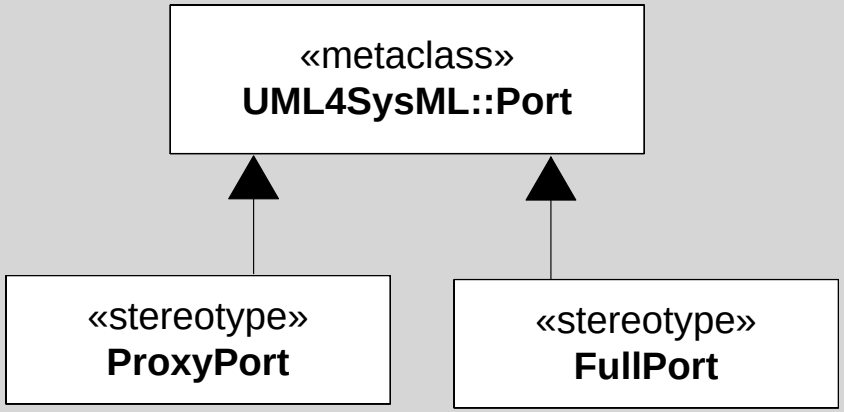
SysML v1.3 Port Types

- Port without stereotype (uncommitted)
- Stereotyped ports
  - Full port
  - Proxy port



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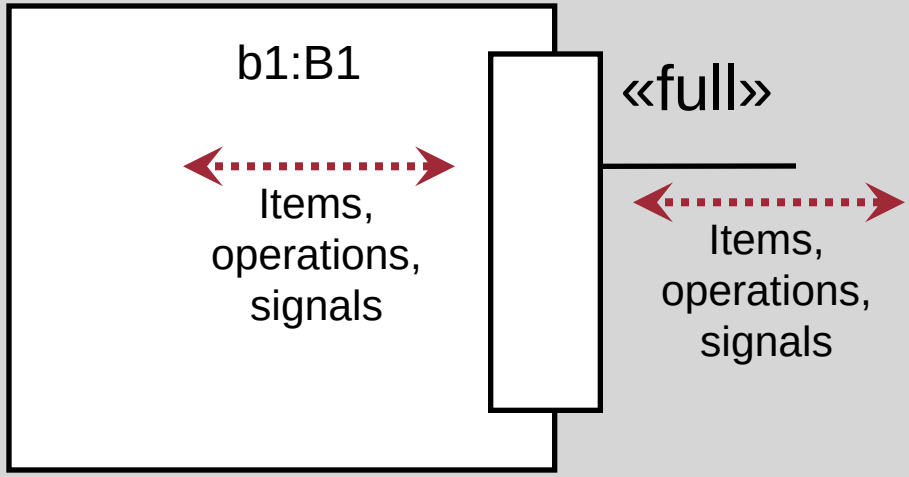
Full Port

- Similar to a part on a boundary
  - Represents a part of the system
- Generally typed by a block
- Can have behavior and nested parts
  - Full ports handle incoming items, operations, and signals themselves, and can send out items, etc.



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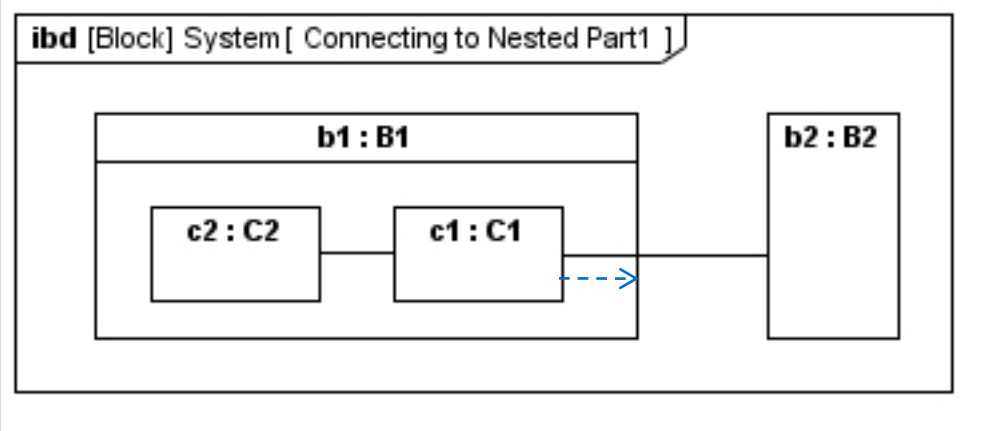
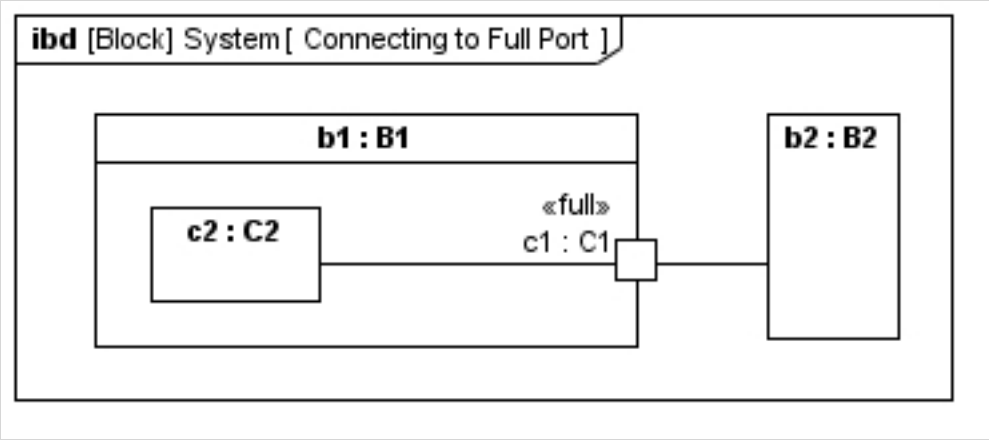
Full Port (cont.)

- The full port c1:C1 in the lower figure is similar to a part c1:C1 on the boundary in the upper figure





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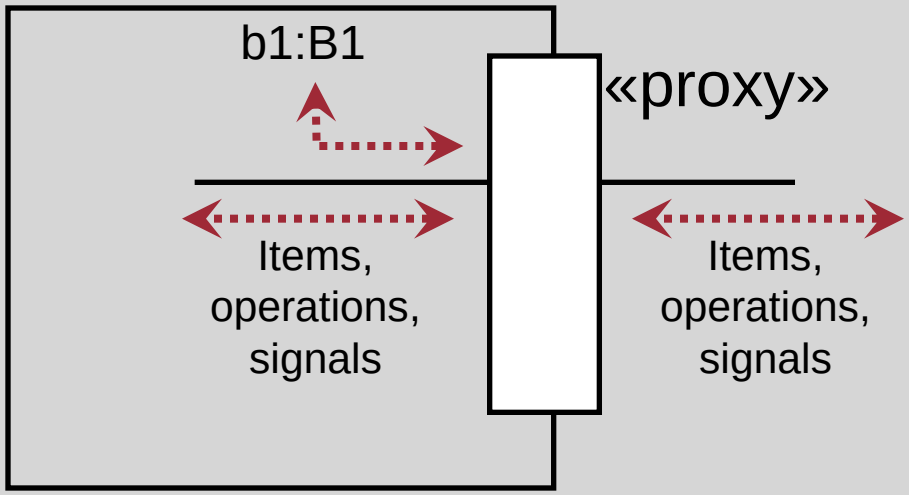
Proxy Port

- Provides access to/from features of its owning block or its nested parts to the outside world
  - No behavior and not a part of the system
  - Serves as proxy for the owner or internal parts
  - Items, operations, and signals to and from the port are actually going to or from the owner or internal parts
- Typed by an interface block to specify which features are accessible via a connector



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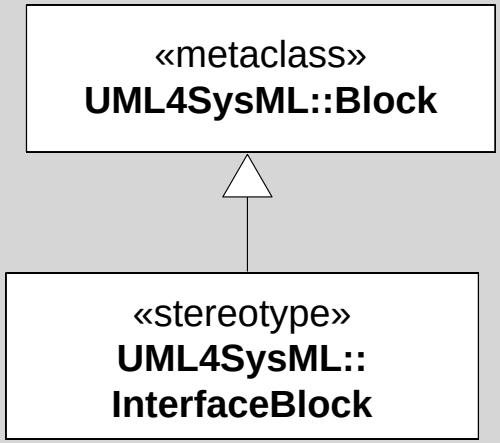
Interface Block

- Used to type proxy ports
- Can have nested ports
  - But must be typed by interface blocks
- Cannot have behavior or internal parts



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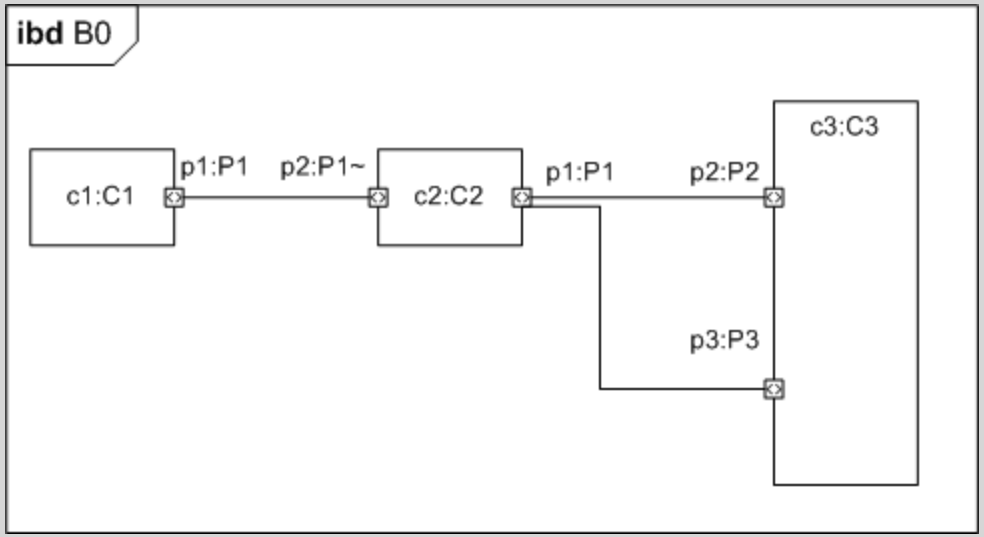
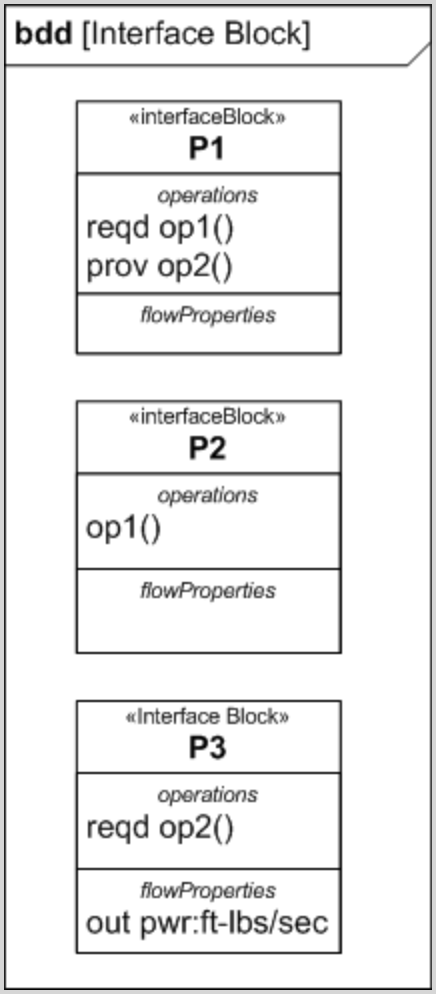
Ports Used To Request and Provide Operations





Proxy Ports with required and provided operations equivalent to ports with required and provided interfaces

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Port Compatibility

- Definition:
  - The ability to connect ports without violating constraints
- Default compatibility between ports
  - Based on feature name, type, direction matching
  - Signature matching of required/provided operations
  - Can conjugate proxy ports to reverse direction of flow properties and required/provided features
- Connectors typed by associations can assert compatibility
  - Among different port types
  - To specify protocol interactions via owned behavior of association
  - To constrain end types in support of engineering analysis (e.g. conservation laws)

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Power Plug & Socket Interface

- **AC power plugs and sockets** are devices for removably connecting electrically-operated devices to the commercial power supply.
- An electric **plug** is a male electrical connector with contact prongs to connect *mechanically* and *electrically* to slots in the matching female **socket**.

Power plug-380-x281

Source: http://en.wikipedia.org/wiki/Domestic_AC_power_plugs_and_sockets

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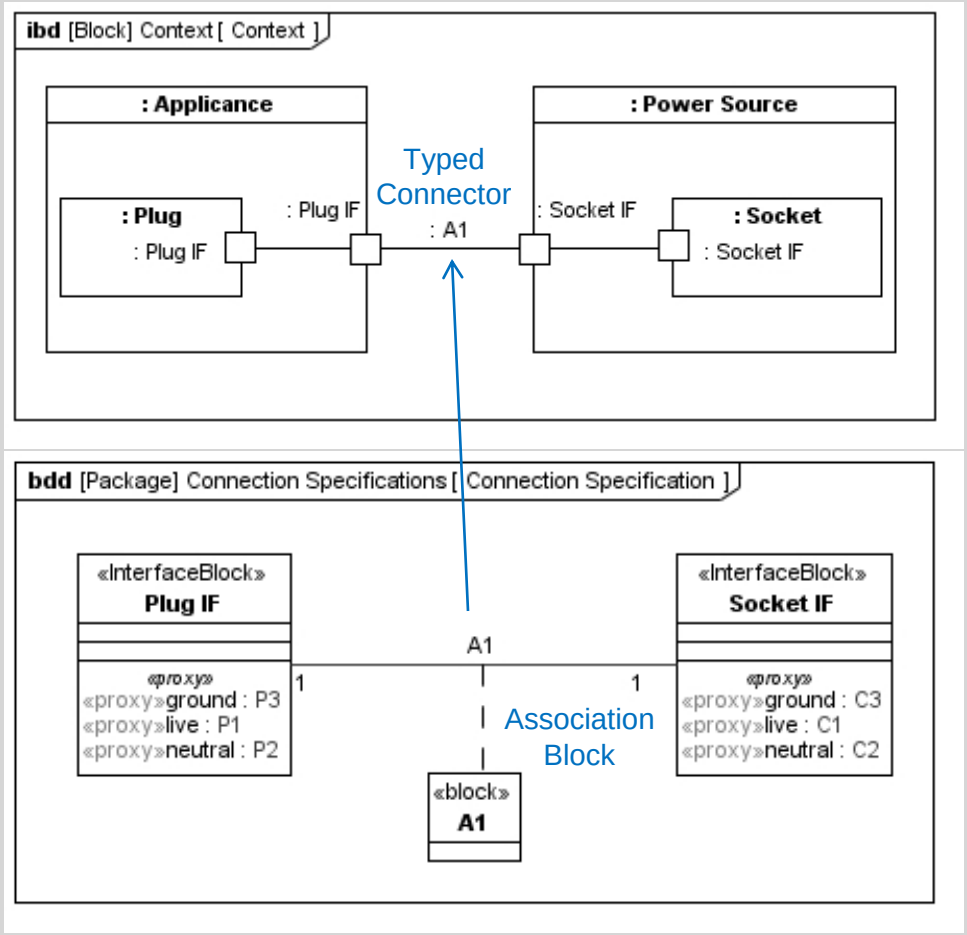
Specifying Port Compatibility with Typed Connectors



Type the connector on the ibd by the association A1

The ports on the ibd are compatible if their types match the ends of A1

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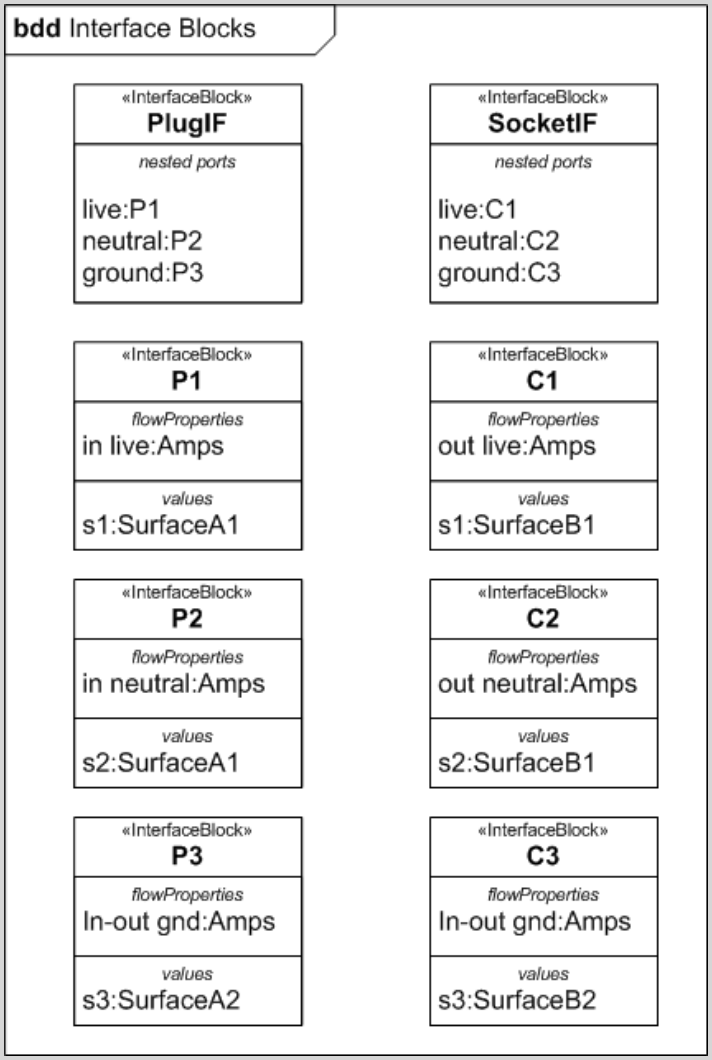
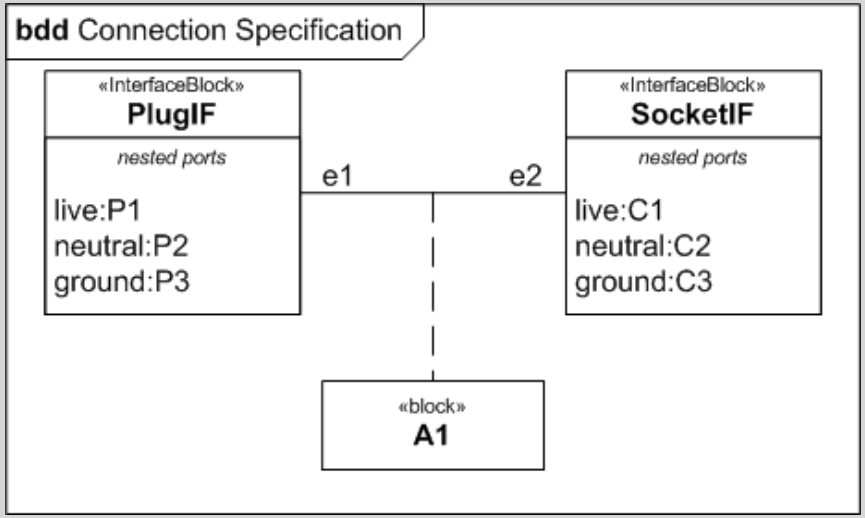
Compatible Port Types





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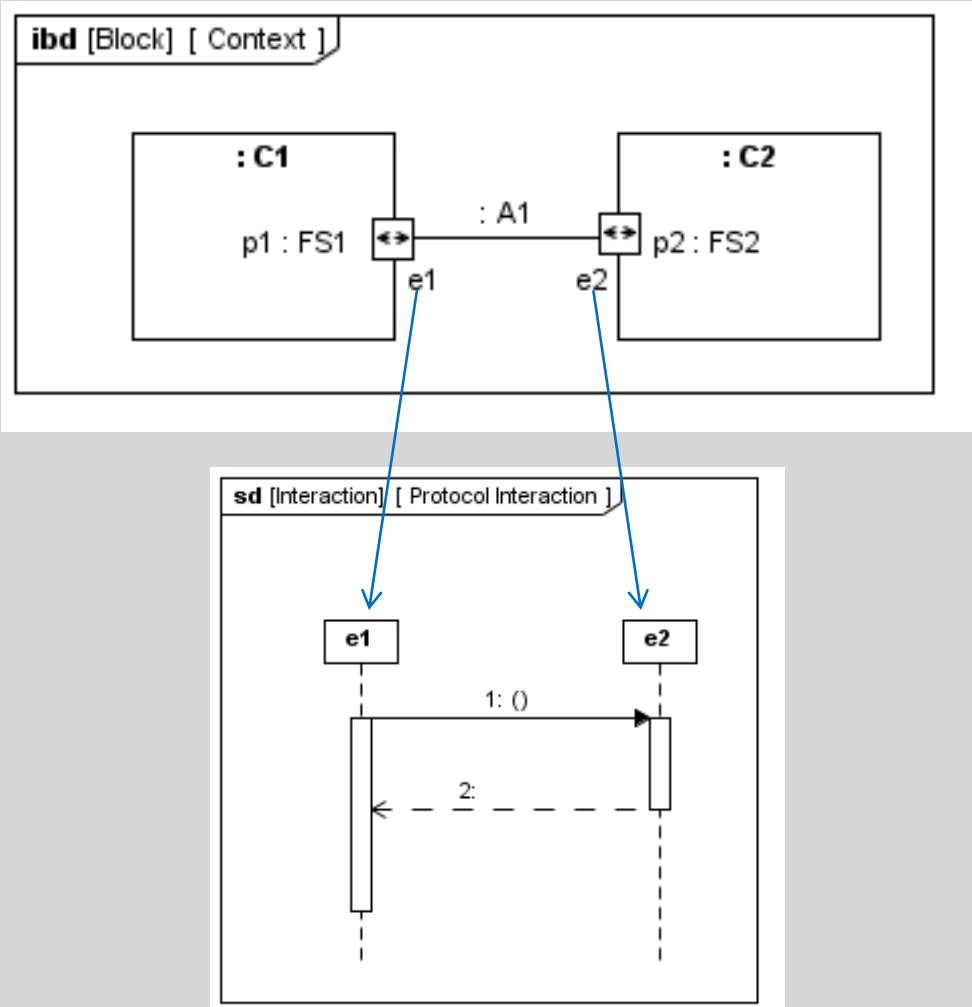
Protocol Interactions



- Behavior specified between ends of association block A1

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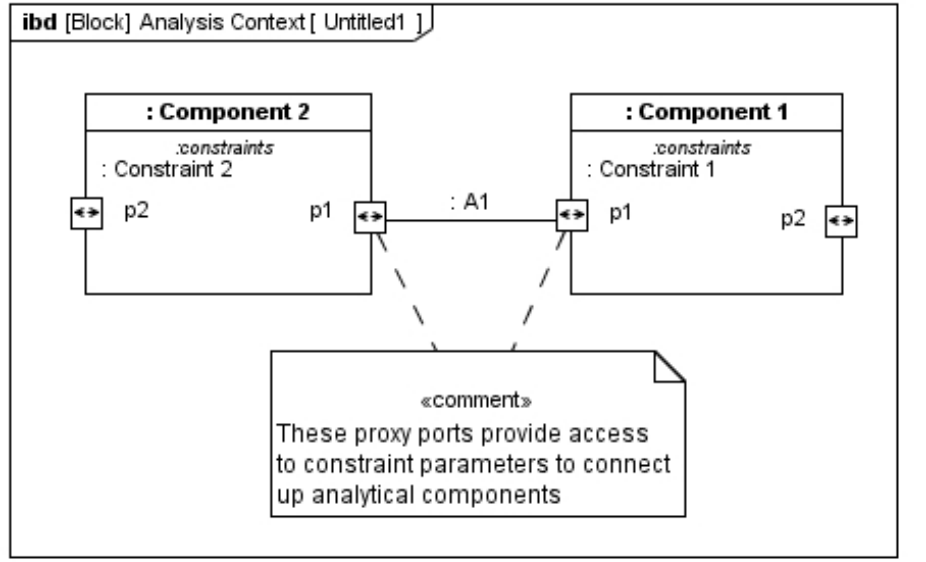
Constrained Ports to Support Engr Analysis

- Modelica-like interfaces support engineering analysis
  - Refer to SysML-Modelica Transformation Specification
- Integrate ibd with parametrics
  - Use of binding connectors on ibd
  - Binding connector typed by association A1 contains conservation laws
  - Proxy ports provide access to value properties and constraint parameters



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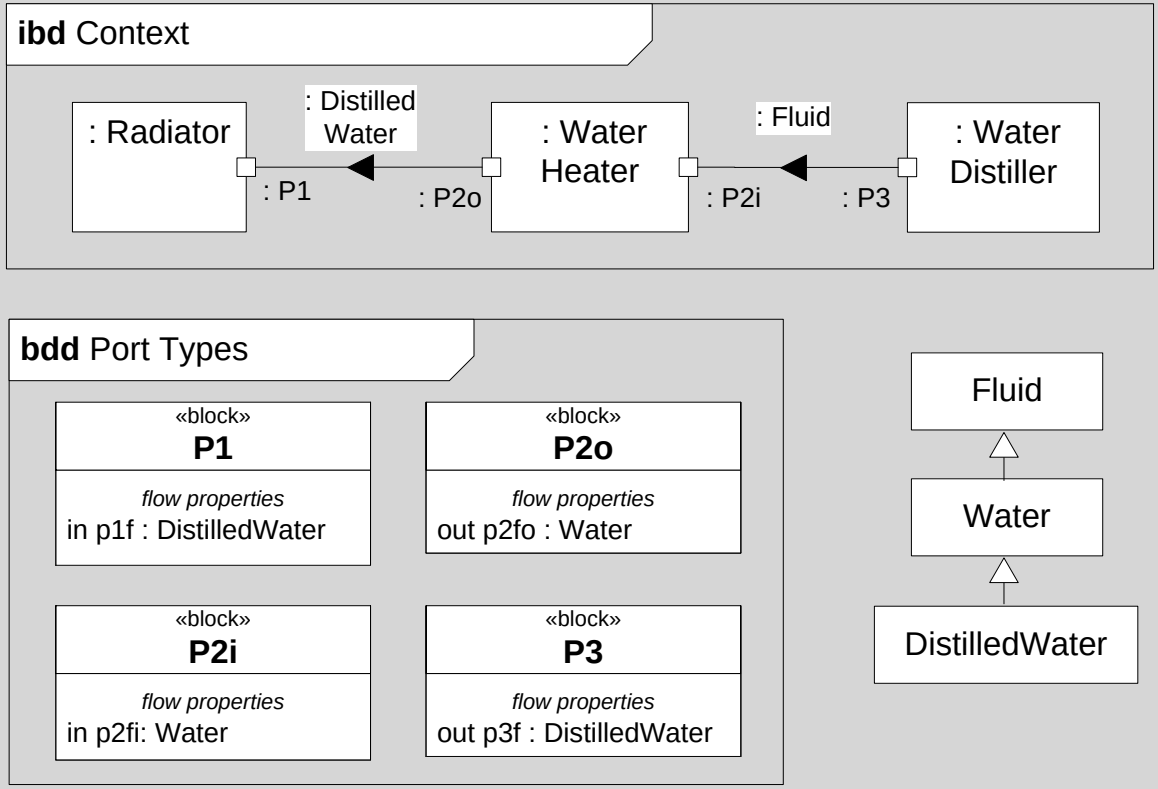
Item Flow End Compatibility

Source: Draft Ballot Presentation by C. Bock



- Type of item flowing must be same, supertype, or subtype of a source flow property type. Cannot be unrelated.
- Target flow properties must be the same or supertype of either the type of item flowing or a source flow property type.

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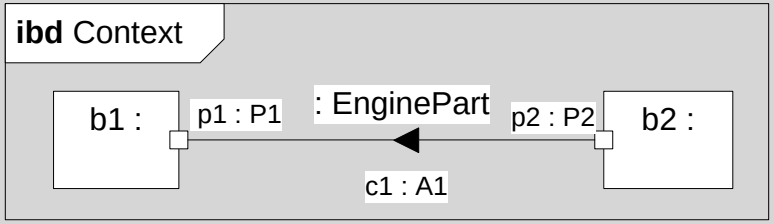
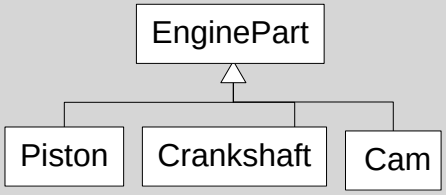
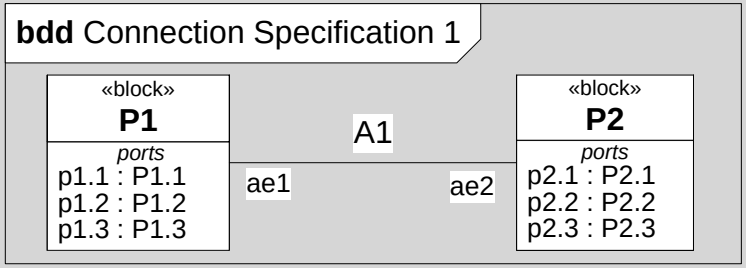
Item Flow Decomposition

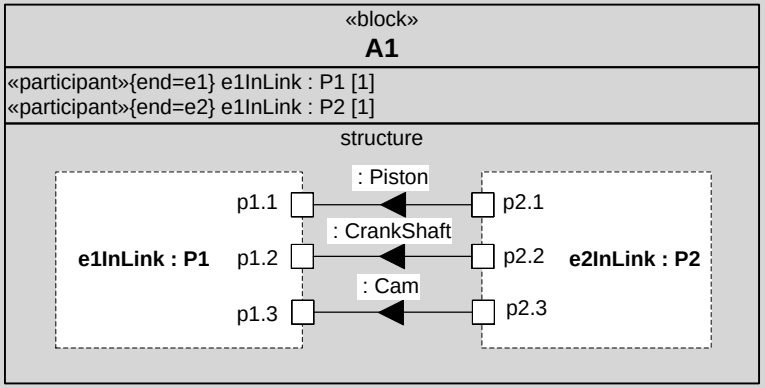
Source: Draft Ballot Presentation by C. Bock

- Relationship of item flow to sub-item flows is up to modeler
- This example, sub-flows are subclass of composite item flow









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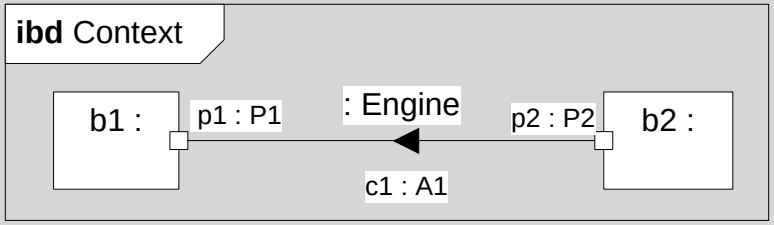
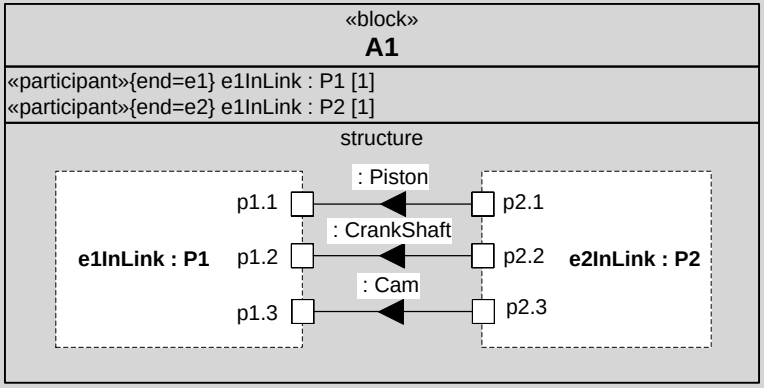
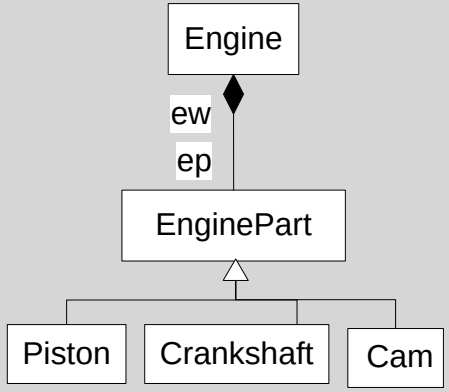
Item Flow Decomposition

Source: Draft Ballot Presentation by C. Bock

- Composite item flow composed of sub-flows







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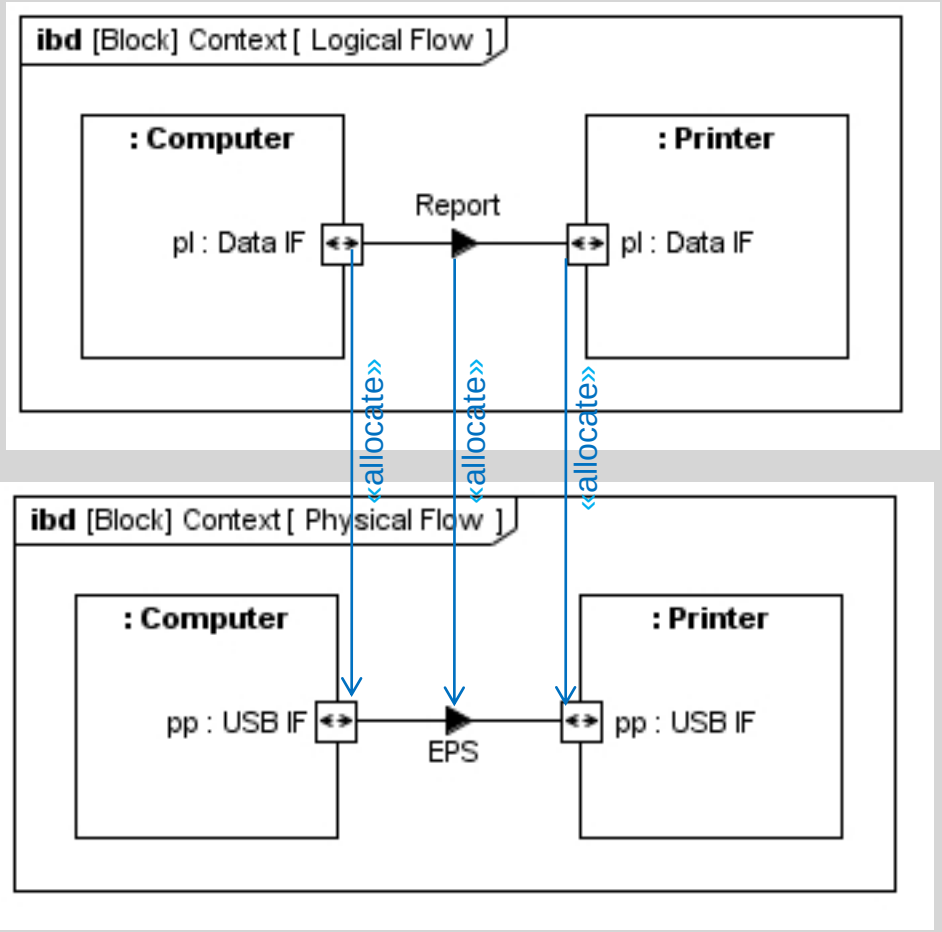
Logical to Physical Interface Allocation

- Can allocate logical to physical ports and item flows



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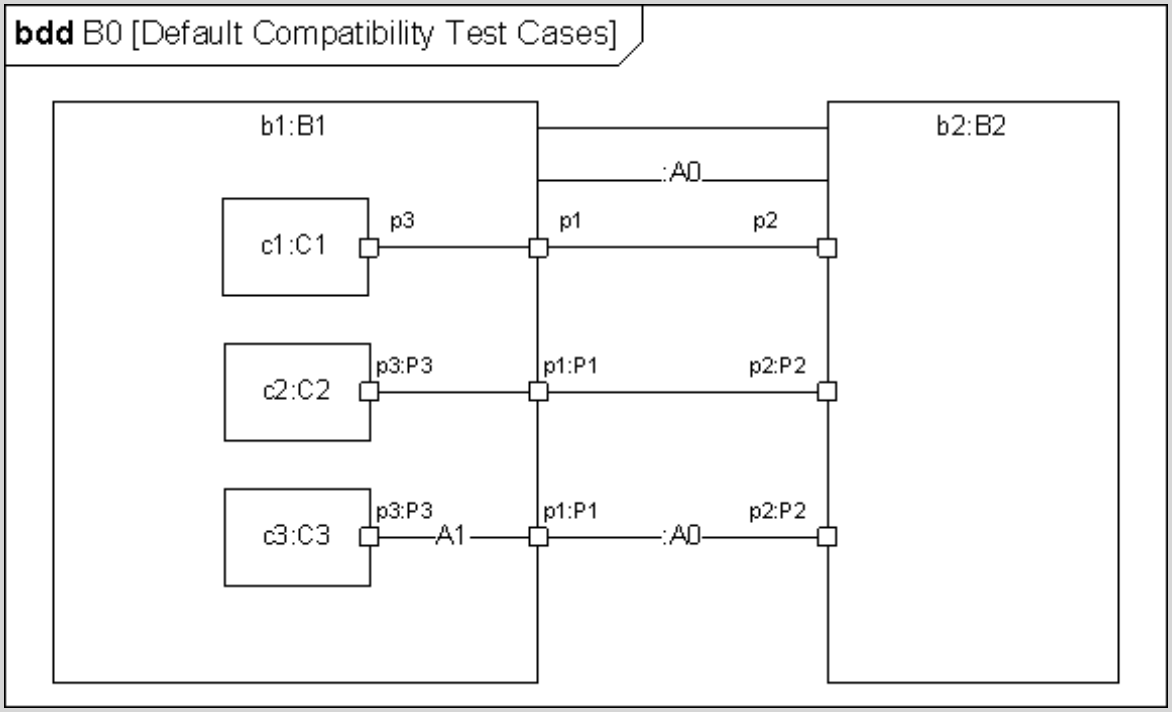
Port Compatibility Test Cases

Permutations

Connectors
- Typed, Untyped
- External, Internal
- Nested, Unnested

Ports
- No port, Generic,
- Full, Proxy
- Typed, Untyped
- Nested, Unnested

Item Flows
- With, Without



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Examples

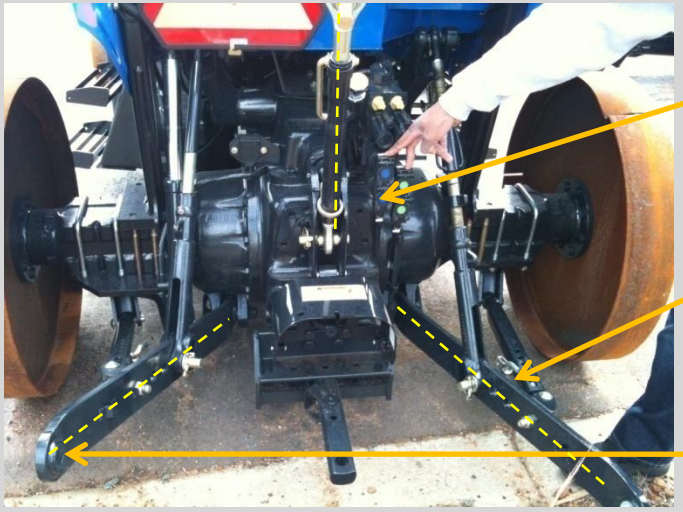
Tractor-Attachment Interface Example

Source: Axel Reichwein (date: 101030)

Tractor

Attachment

Note: Updates made to reflect change in port names



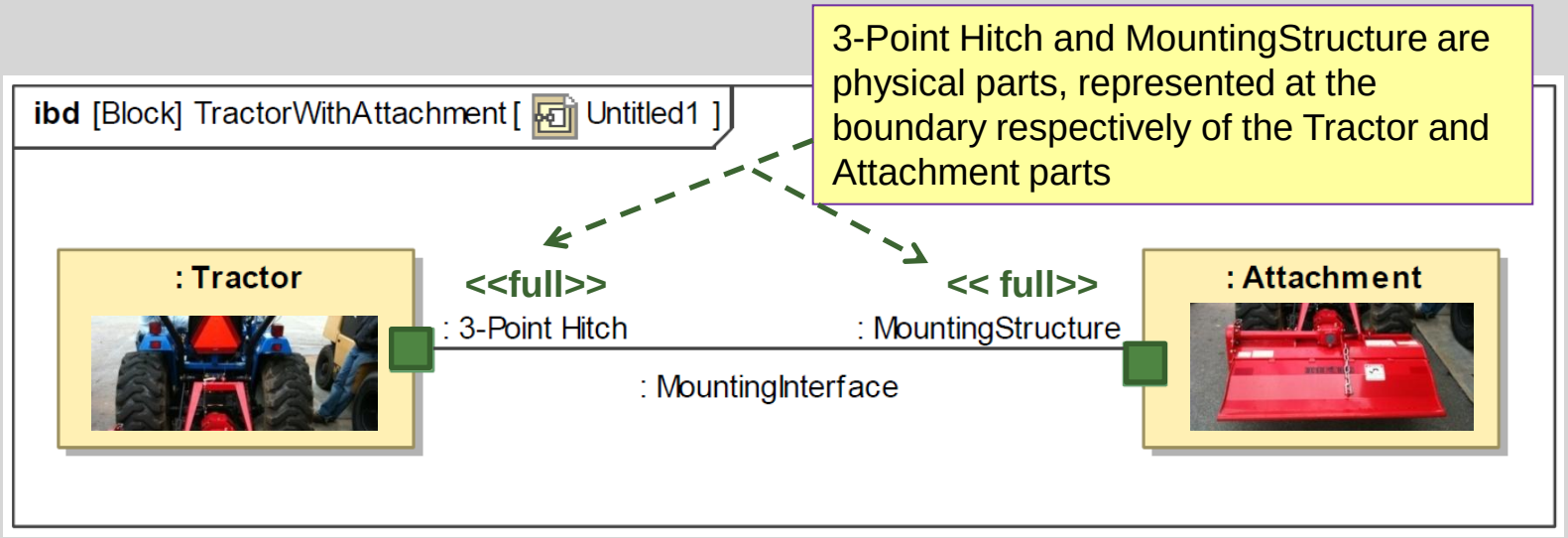
Tractor 3-Point Hitch

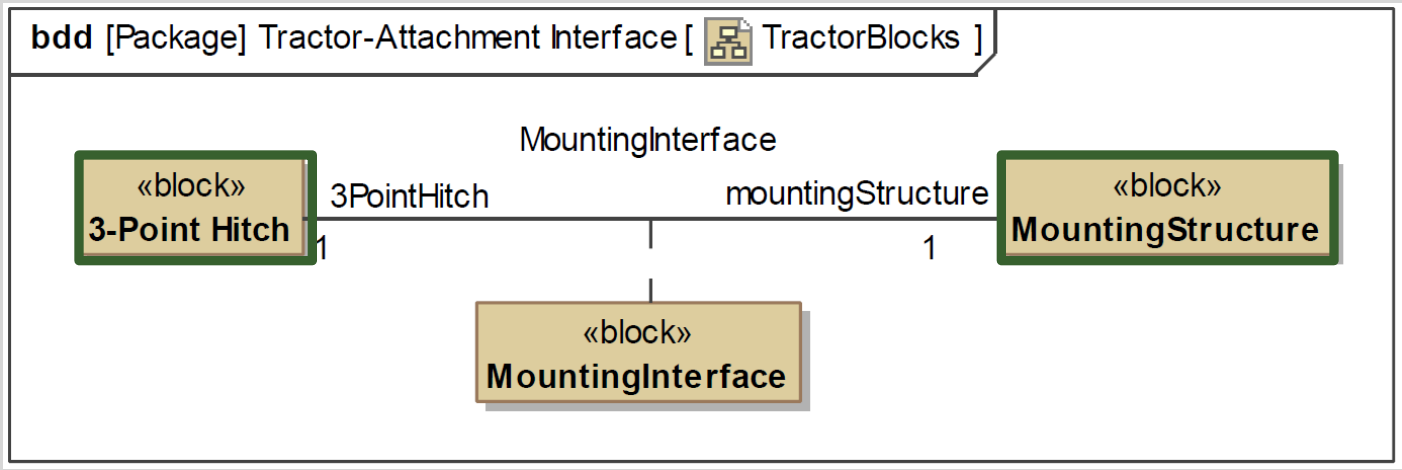
Link Arm

Bore Hole

Example with *Full Ports*

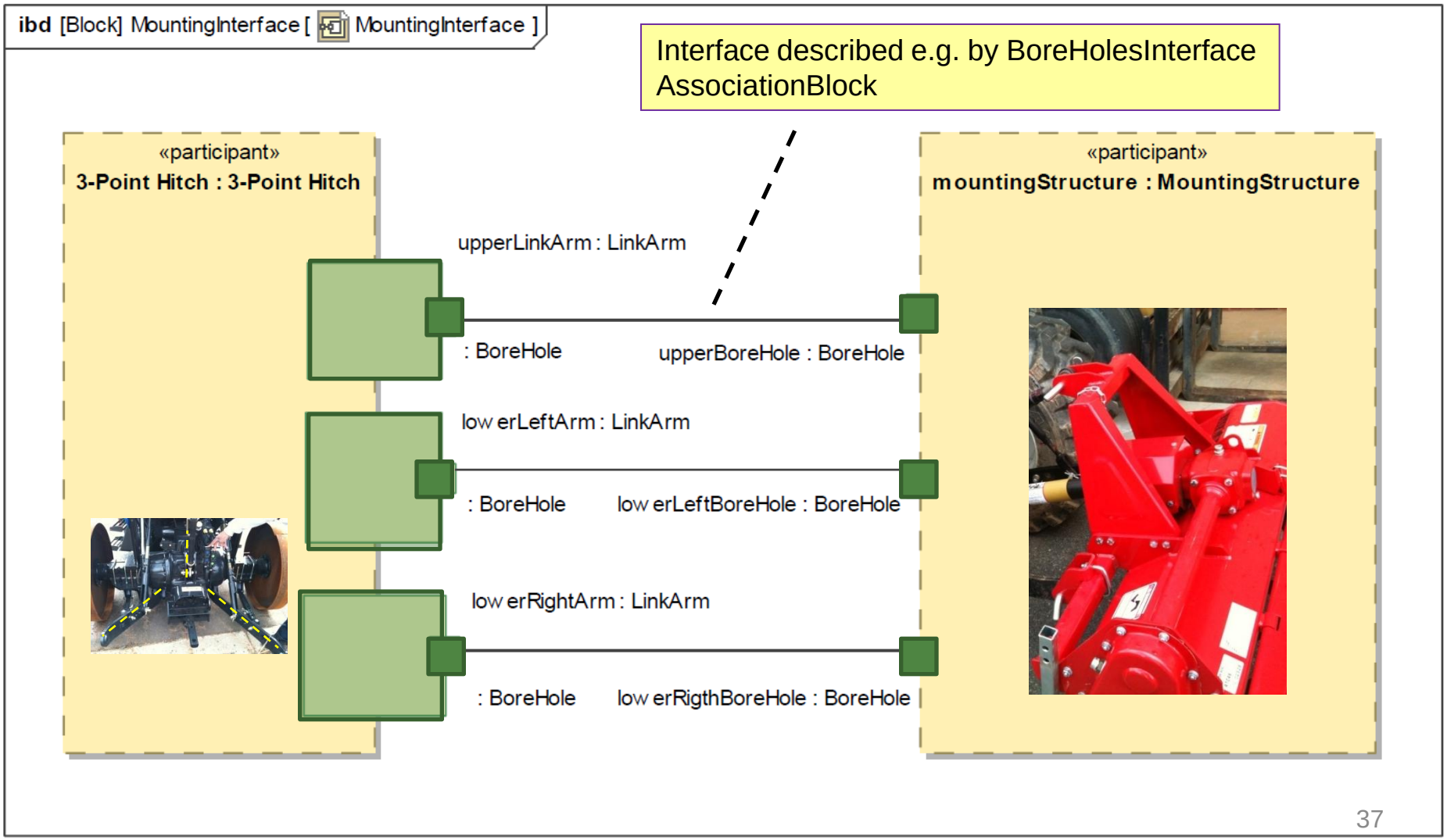
Source: Axel Reichwein (date: 101030)





Example with *Full Ports (cont.)*

Source: Axel Reichwein (date: 101030)



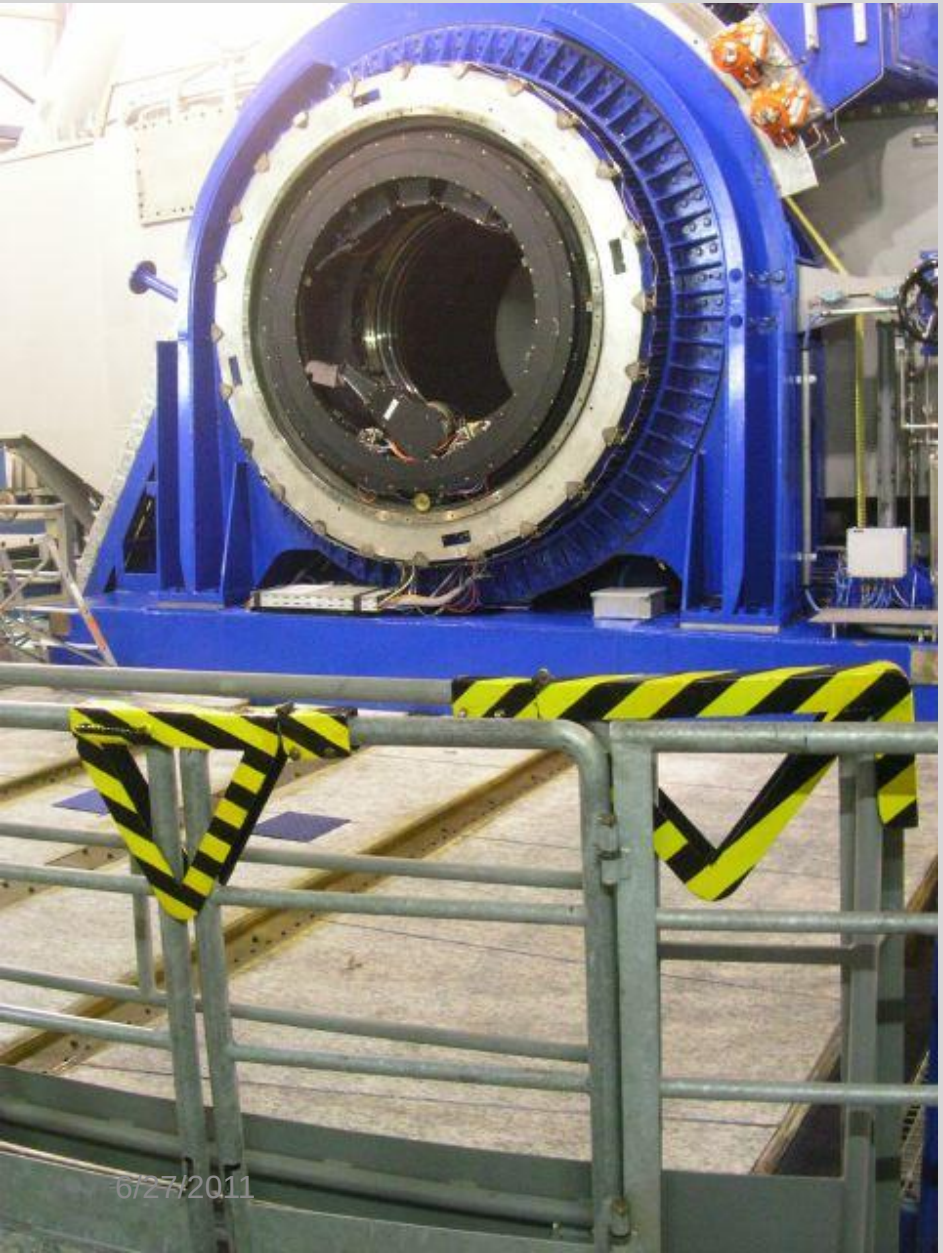
Telescope Interface Modeling Example

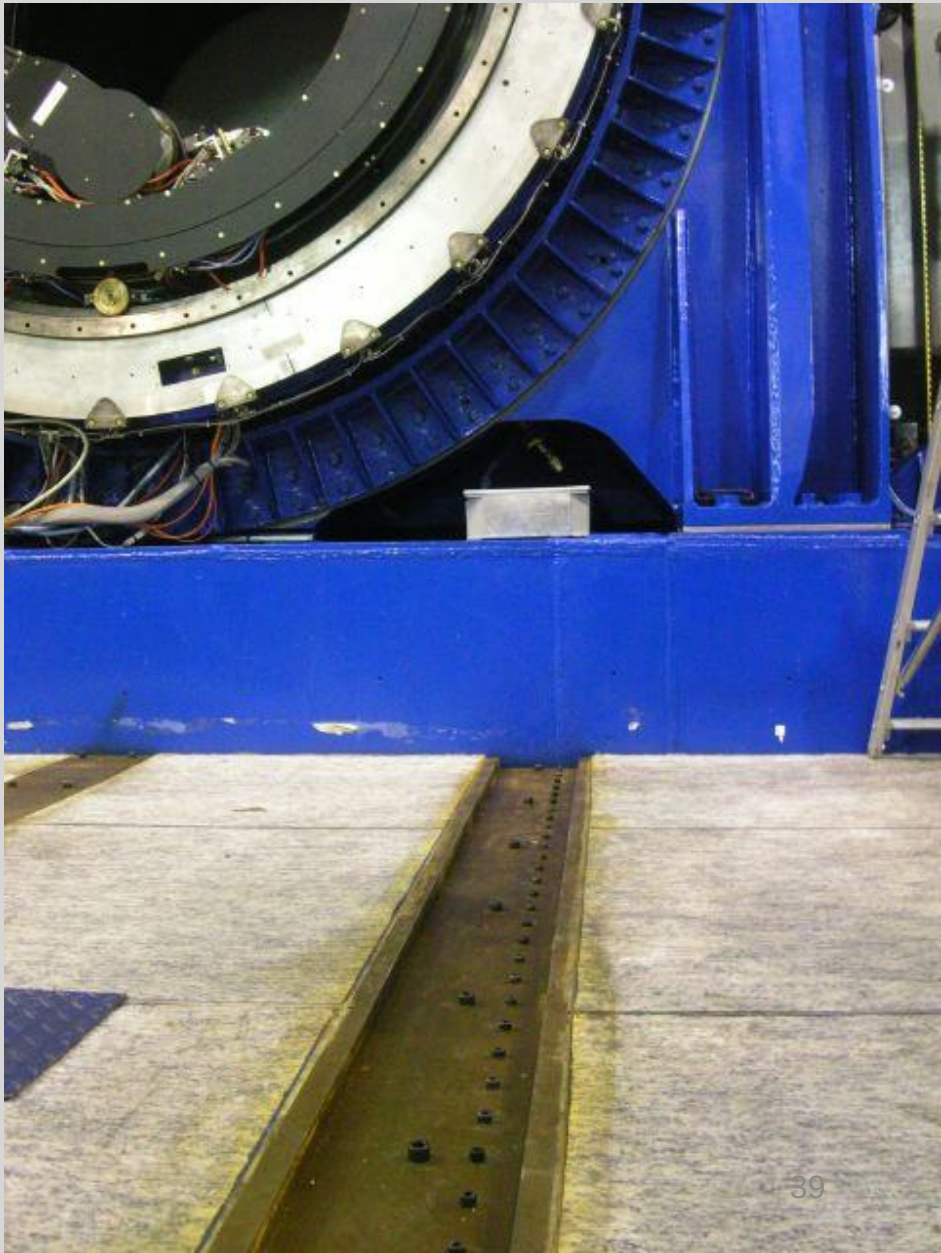
Source: Robert Karban (date: 110223)

- Mounting an instrument on a telescope
  - A telescope provides power and mechanical interfaces (among others) for attaching instruments
  - Power interfaces are bundled in Service Connection Points (SCP)
  - SCPs are distributed around the telescope's main structure and dome
  - Instruments are mounted with their flange on a rotator flange which is part of the main structure, using reference pins
  - Instrument electronics are screwed to the main structures platform
  - The rotator flange, platform, and SCPs are parts of the Main structure
  - From the Instrument point of view the Telescope is seen as a black box with certain exposed interfaces (<<proxy>>)
  - There are maximum power and load requirements for instruments

Platform and Rails

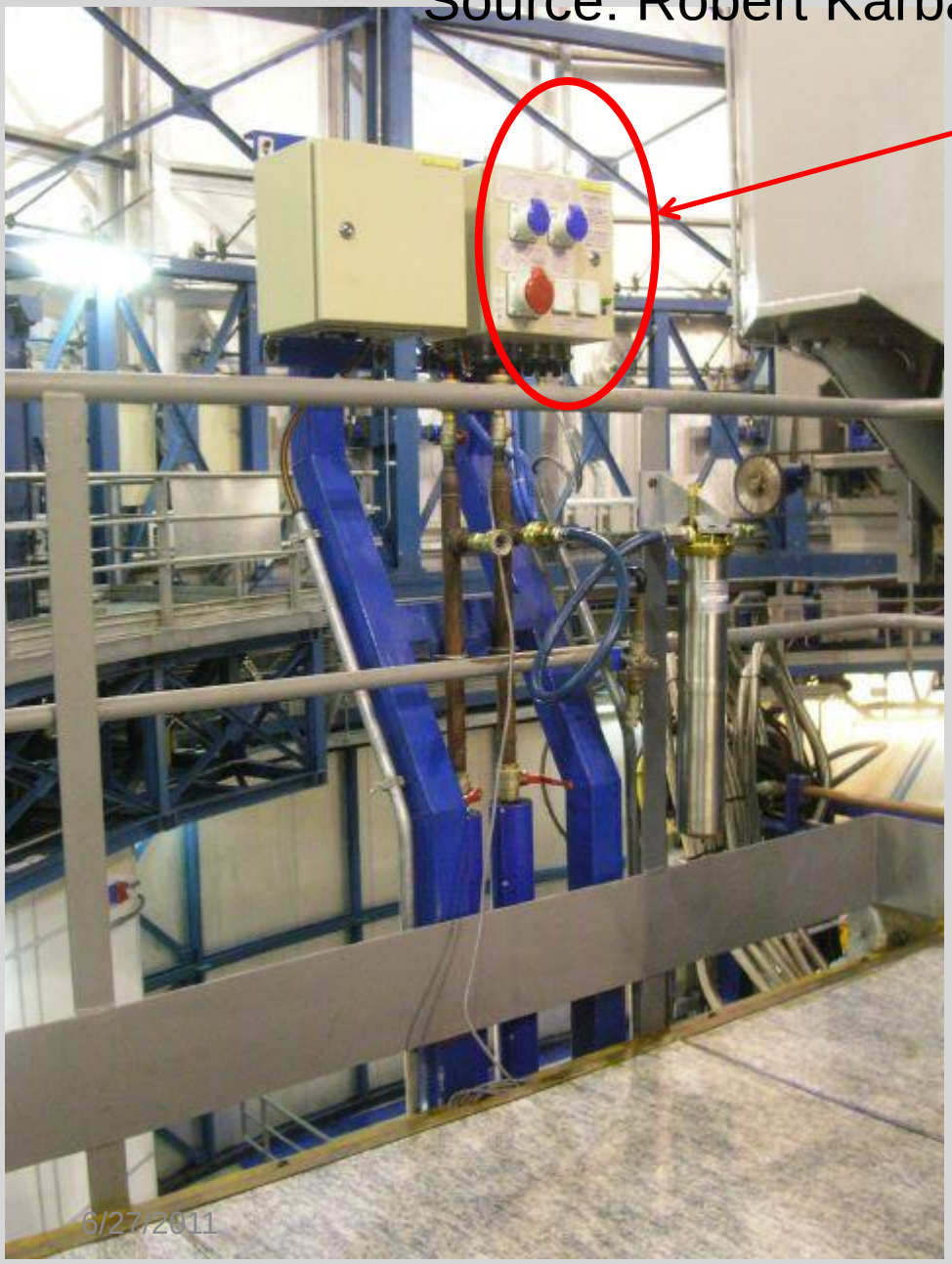
Source: Robert Karban (date: 110223)





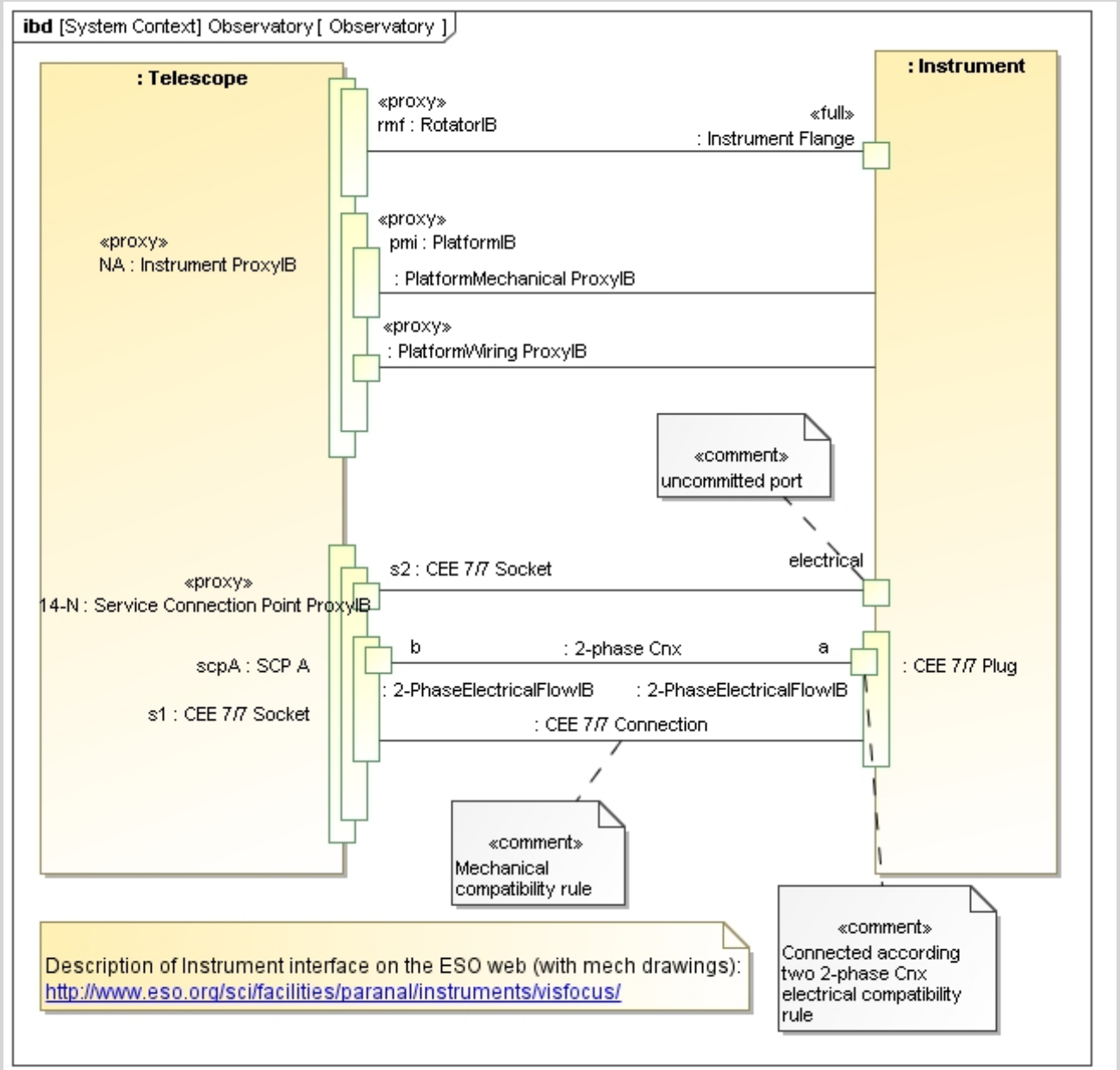
SCP on Nasmyth Platform & Wiring holes

Source: Robert Karban (date: 110223)



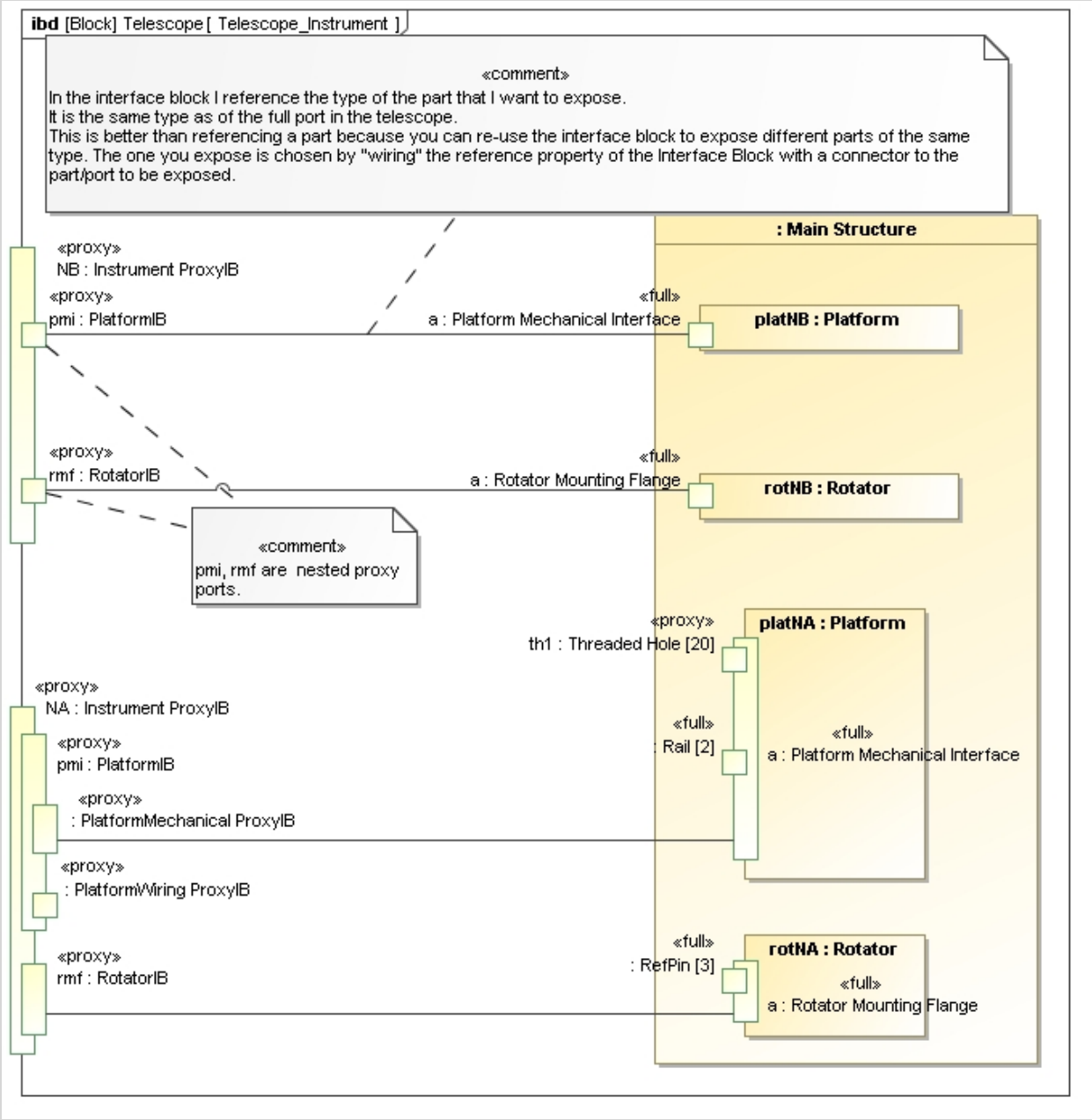
Black box view of telescope

Source: Robert Karban (date: 110223)



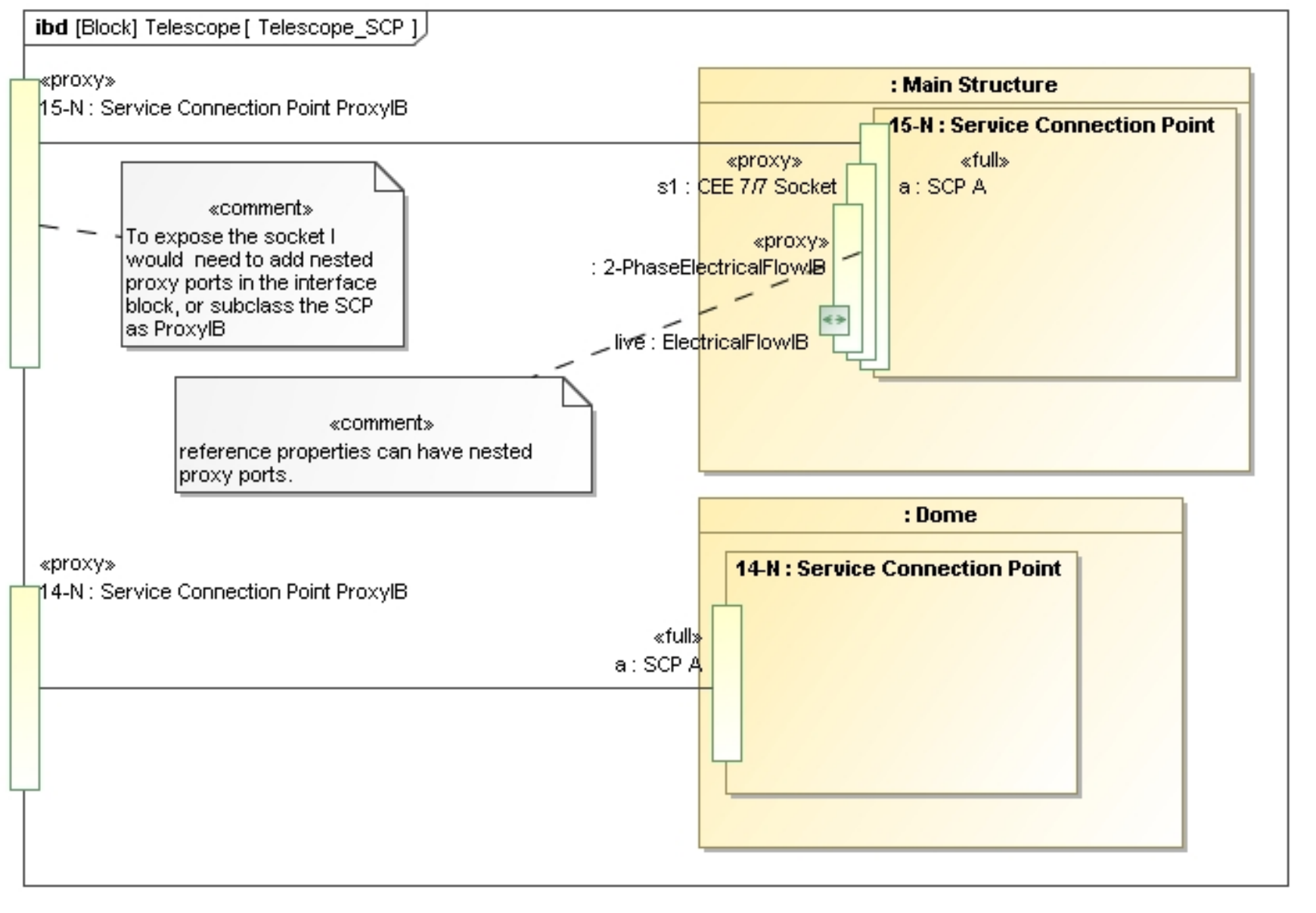
Connection External Mechanical Telescope Interfaces to its internal Interface

Source: Robert Karban (date: 110223)



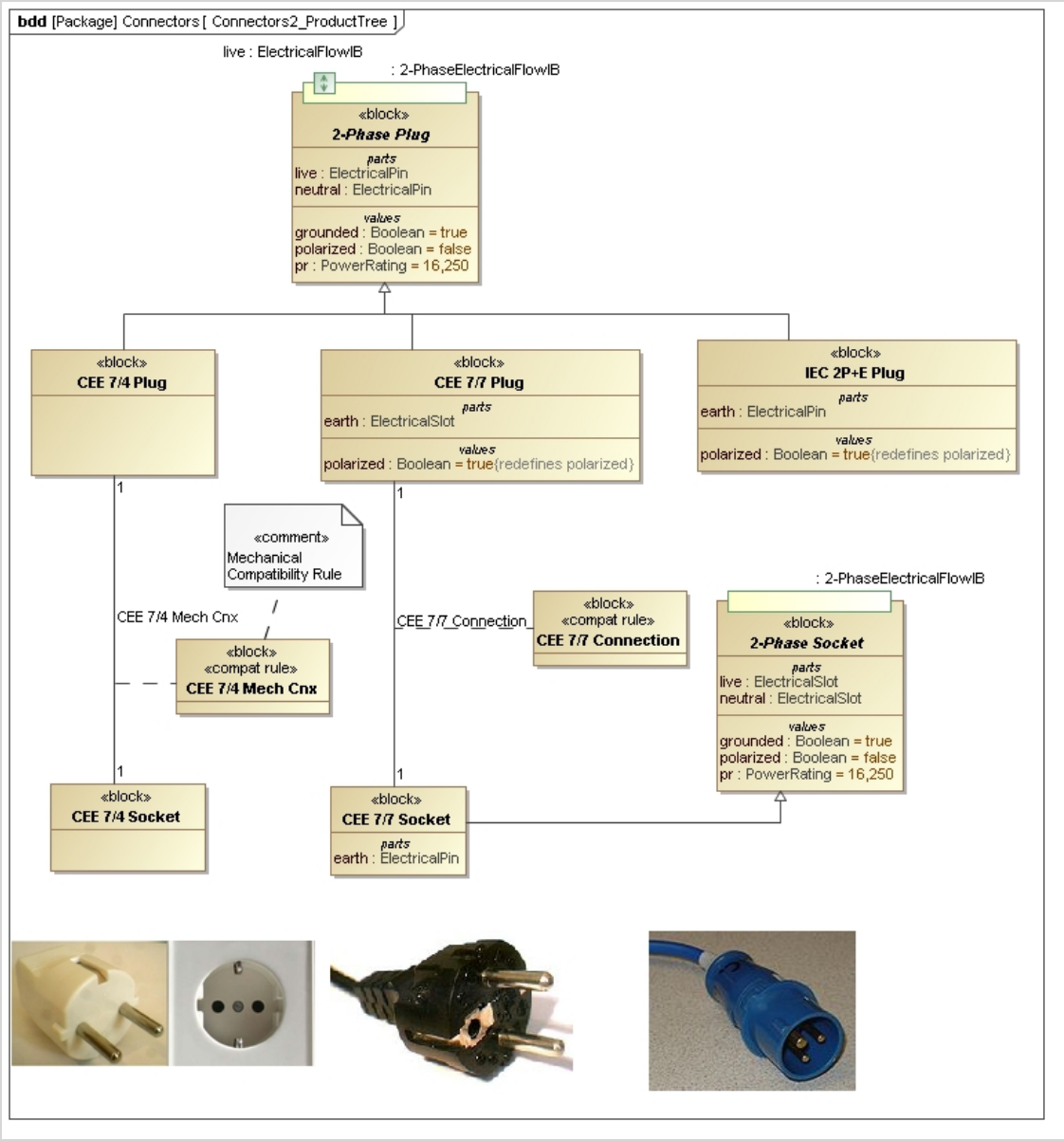
Connection External SCP Telescope Interfaces to its internal Interfaces

Source: Robert Karban (date: 110223)



Definition of 2-Phase Plugs

Source: Robert Karban (date: 110223)



Summary

- Inadequate interface modeling is a source of many system problems
- Robust interface modeling capability is an essential requirement for SysML
- SysML v1.3 capability being extended to include nested ports and flows, more diverse interfaces, and ability to specify port compatibility
- Will continue to enhance SysML interface modeling capability based on user needs

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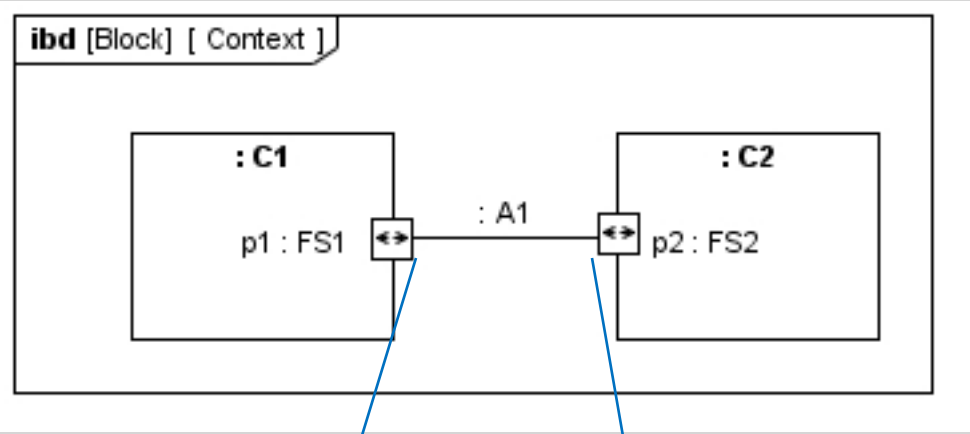
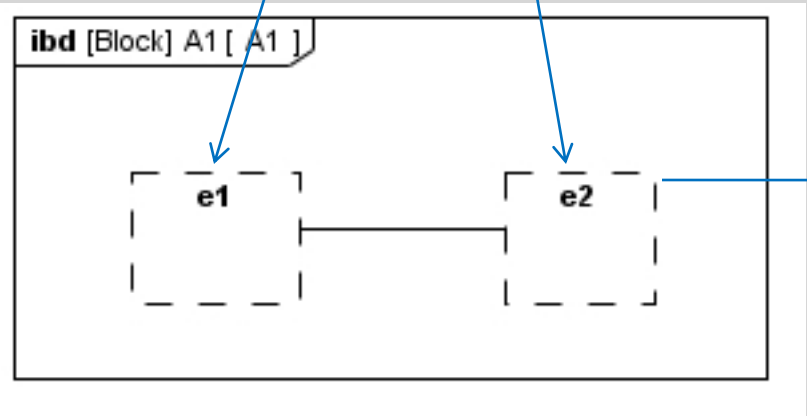
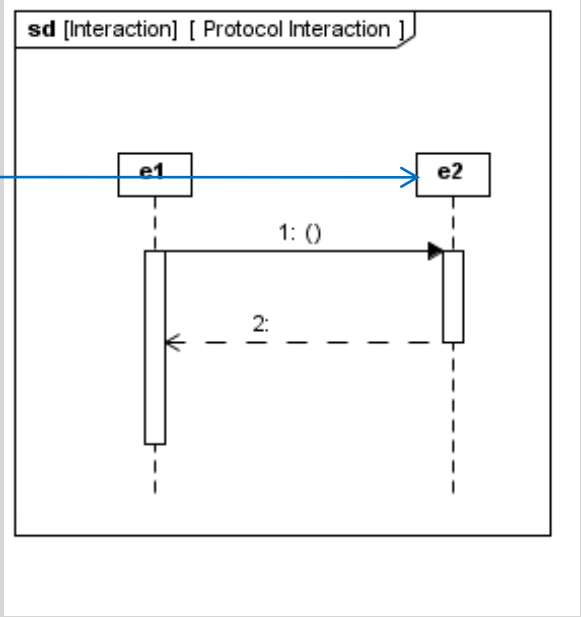
Backup

Protocol Interactions







- Behavior specified between ends of association block

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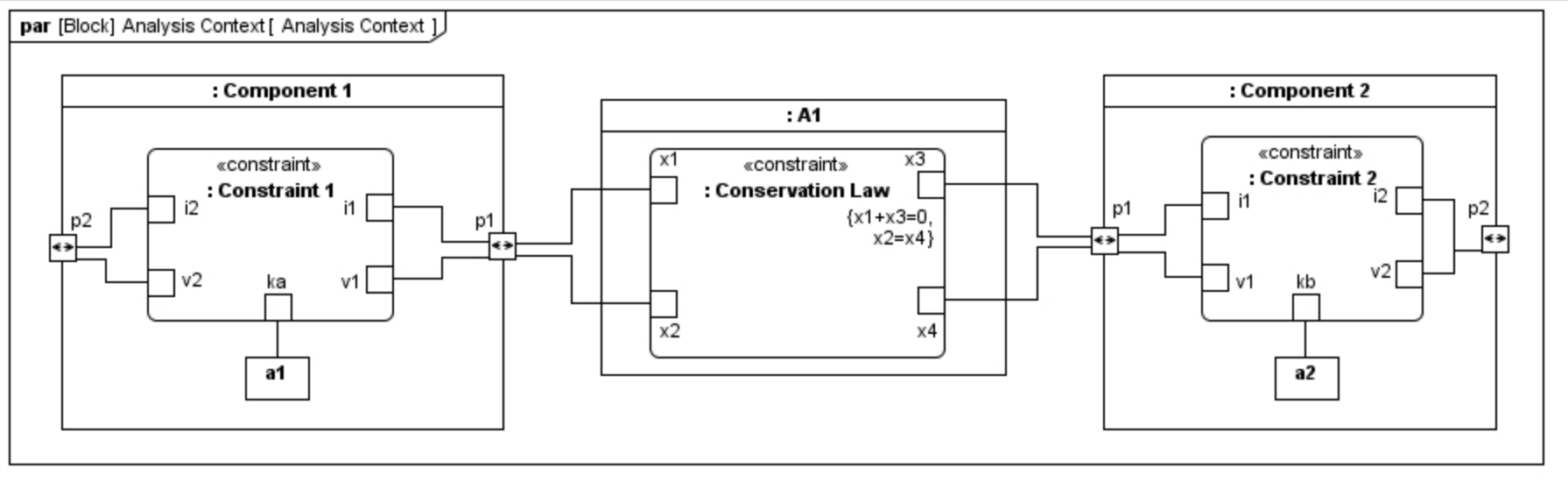
Constrained Ports for Analysis (cont.)

- Parametric diagram showing parameter and property binding
  - Association block contains Conservation Law constraint



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Required/Provided Features

- Features include
  - Operations
  - Receptions
  - Properties
- Contained in blocks and interface blocks
  - Blocks type full ports and parts
  - Interface blocks type proxy ports
- Required features on a ports and parts
  - require the feature be provided by the connected port/part
- Provided features on a port
  - Provide the feature to be used by a connected port/part
- Required and provided operations on interface blocks are equivalent to required and provided interfaces

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