

# SysEng 6542

## Model Based Systems Engineering

Systems Modeling Language  
(SysML)

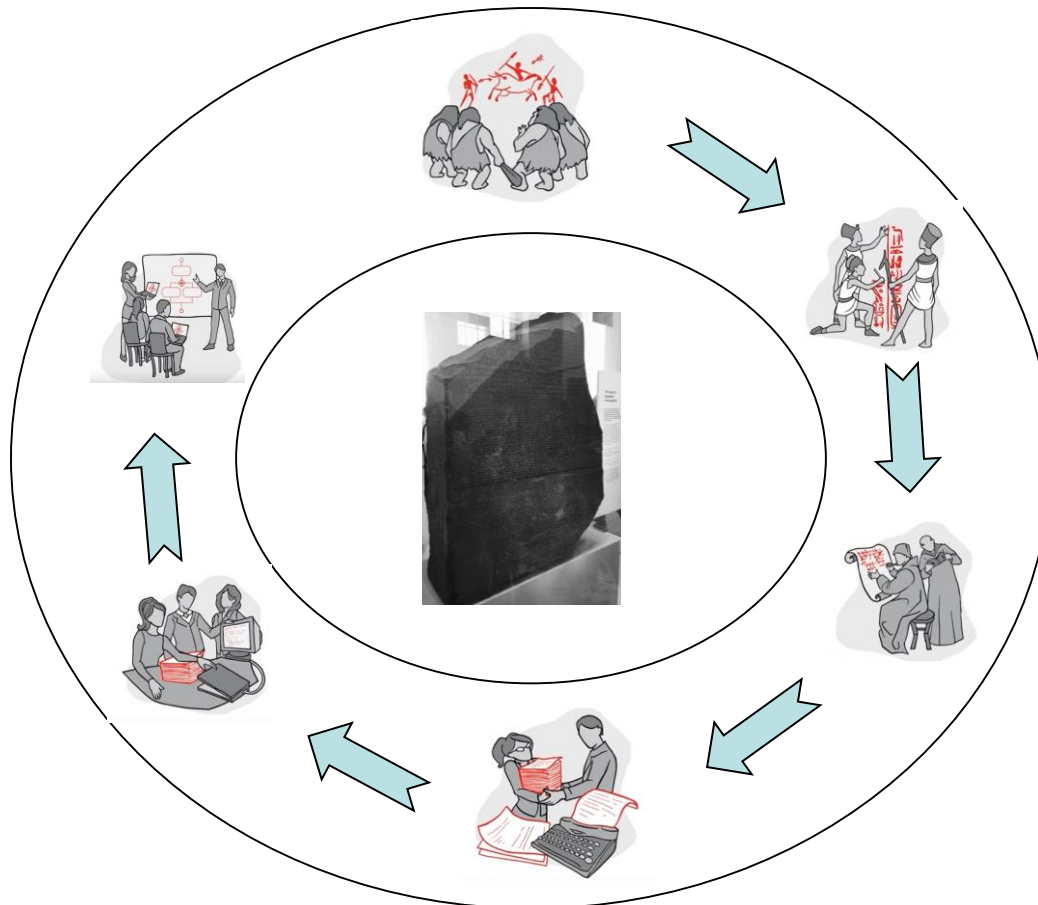
Dr Quoc Do

# MBSE Methodology

- A Systems Engineering Language - SysML
- A set of SE Processes
- A Systems Engineering Tool(s)

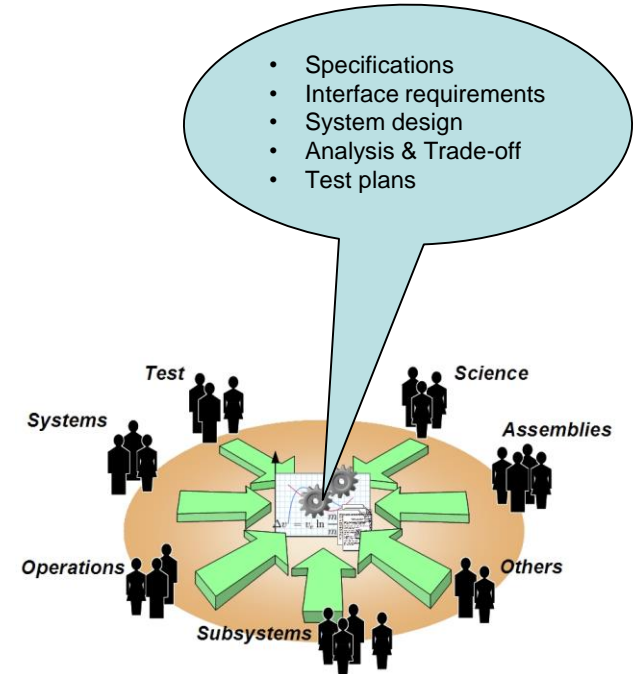
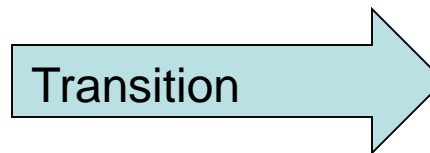
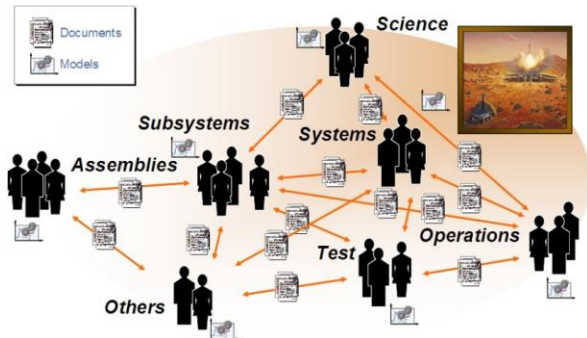
# Systems Modeling Language

- Graphical representation of system information
- Diagrams used to contain information



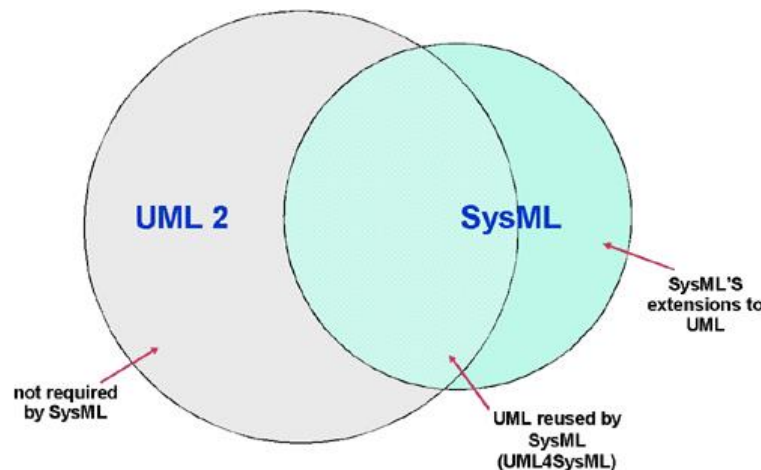
# Systems Modeling Language

- Systems modelling language enables model-centric Systems Engineering practice



# SysML and UML

- SysML is a general-purpose graphical modeling language for specifying, analyzing, designing, and verifying complex systems that may include hardware, software, information, personnel, procedures, and facilities.
- SysML is an extension of UML and has four key pillars:
  - Requirements
  - Structure
  - Behavior
  - Parametric



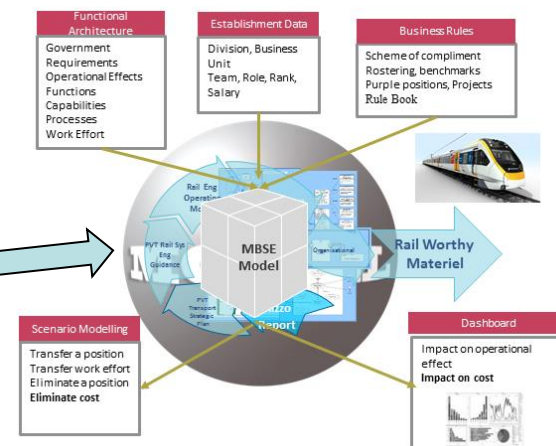
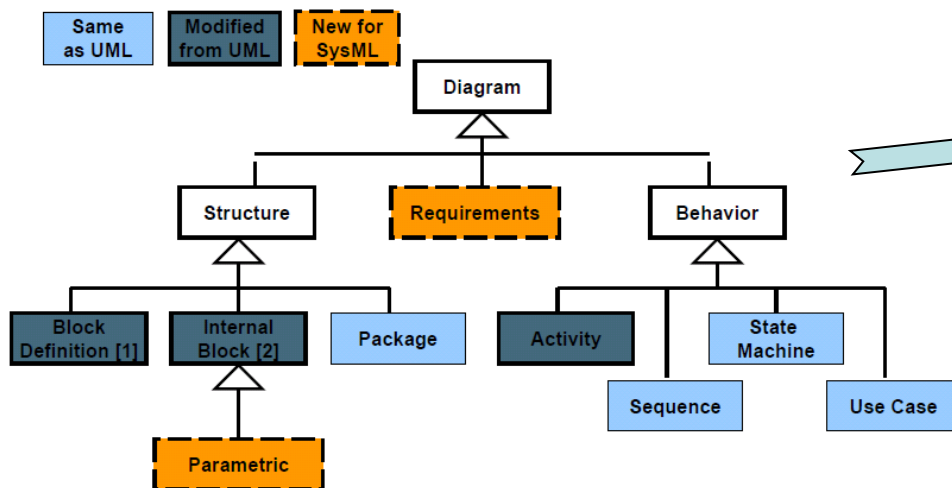
# The SysML Architecture

- This architecture provides a means to transfer systems engineering domain information into a metamodel
- This allows for the representation of systems in a uniform model representation
- Enable reuse of models
- Adoption of standards ensures interoperability (...)
- Complexity management

# Diagrams

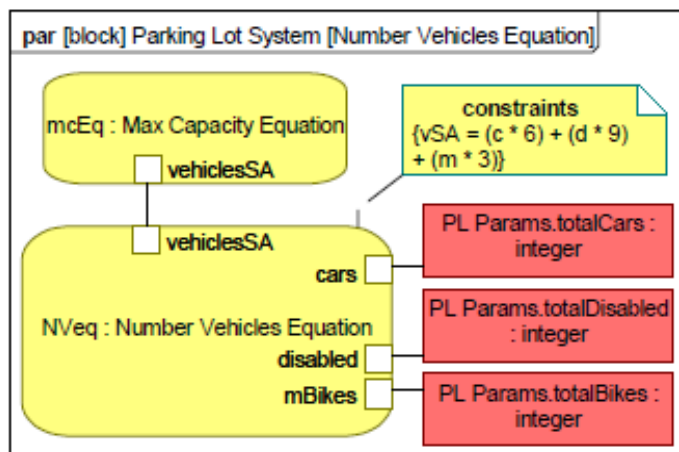
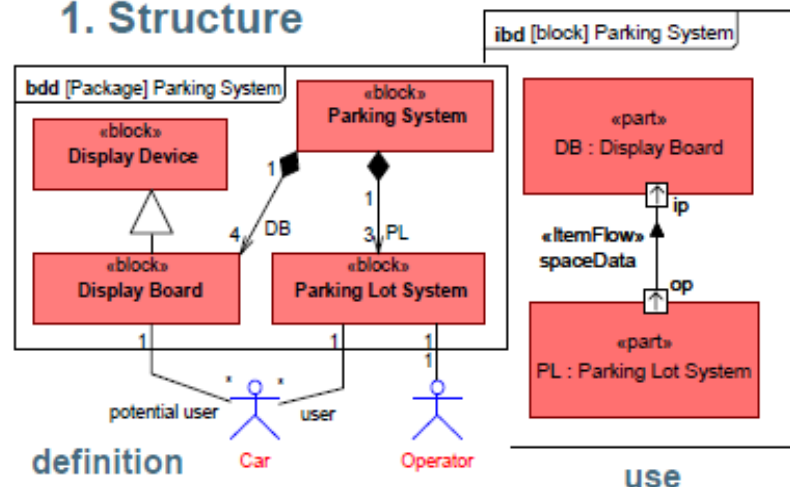
- Graphical representation of the system information
- 9 types used in SysML
- Classified by the type of data they contain

## SysML Taxonomy of Diagrams



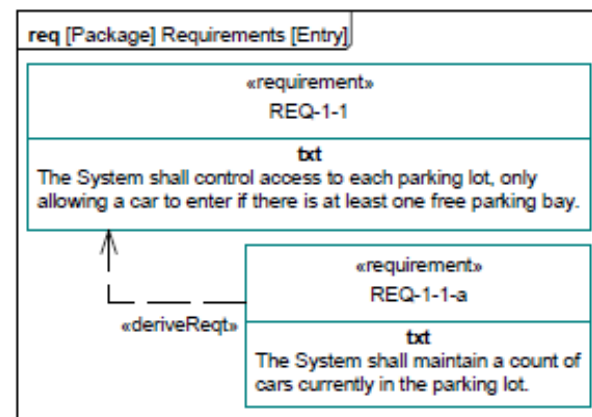
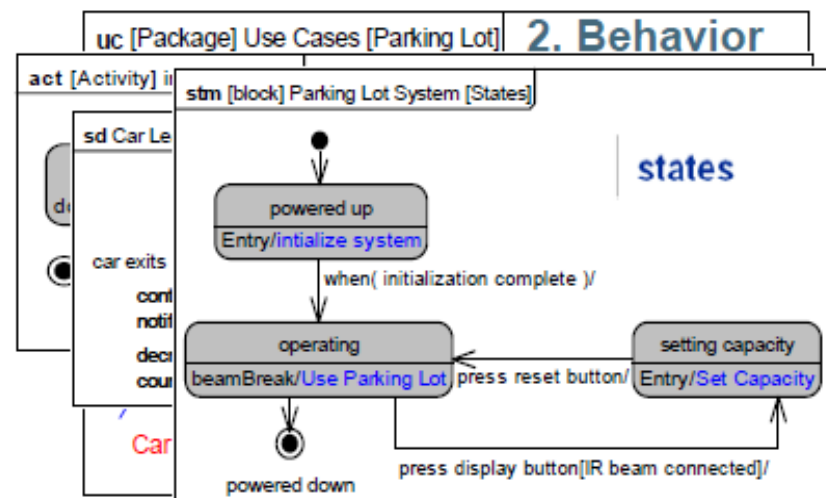
## The Four Pillars of SysML

### 1. Structure



### 4. Parametrics

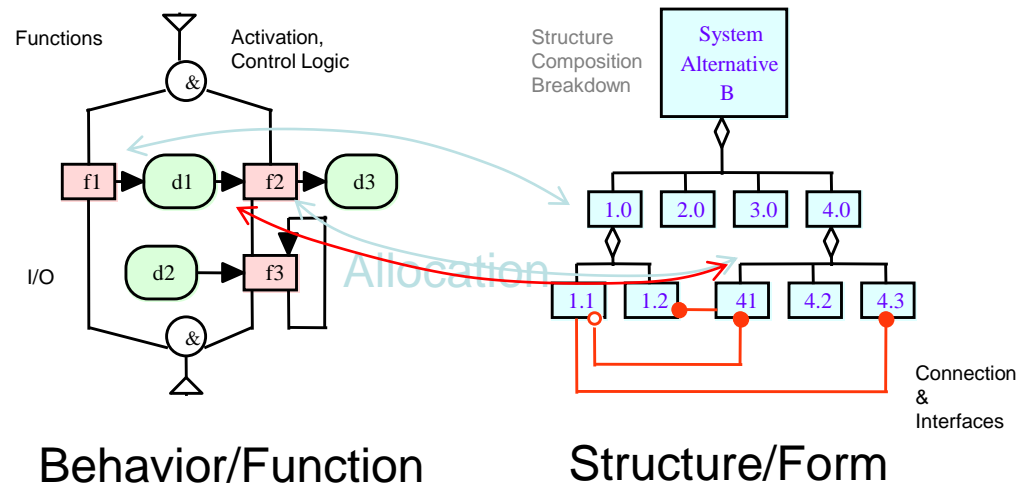
### 2. Behavior



### 3. Requirements



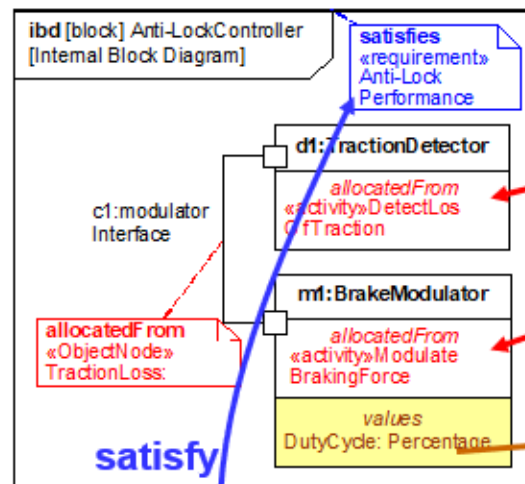
# Allocation – Function to Physical Elements



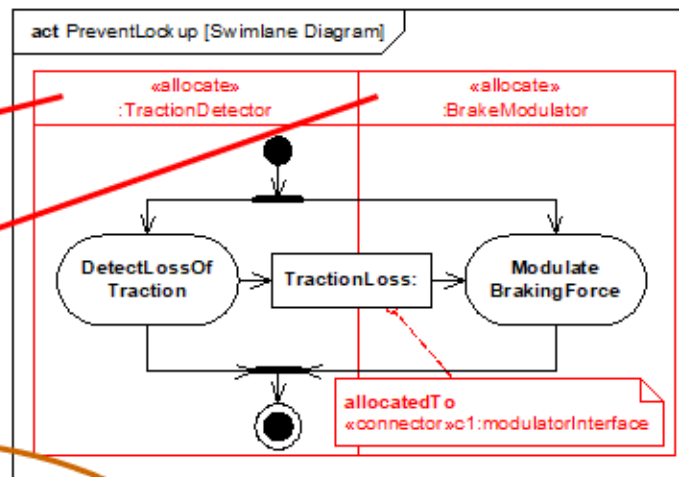
“functions” explicitly allocated to components  
“I/O” explicitly allocated to interfaces

## SysML: Cross Connecting Model Elements

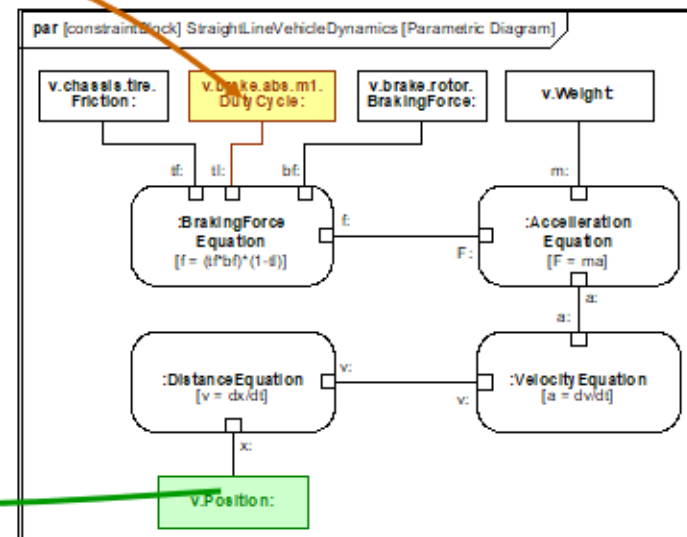
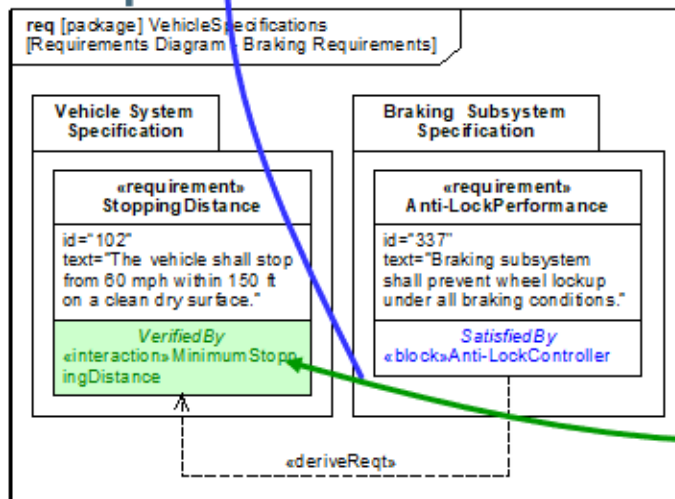
### Structure



### Behavior

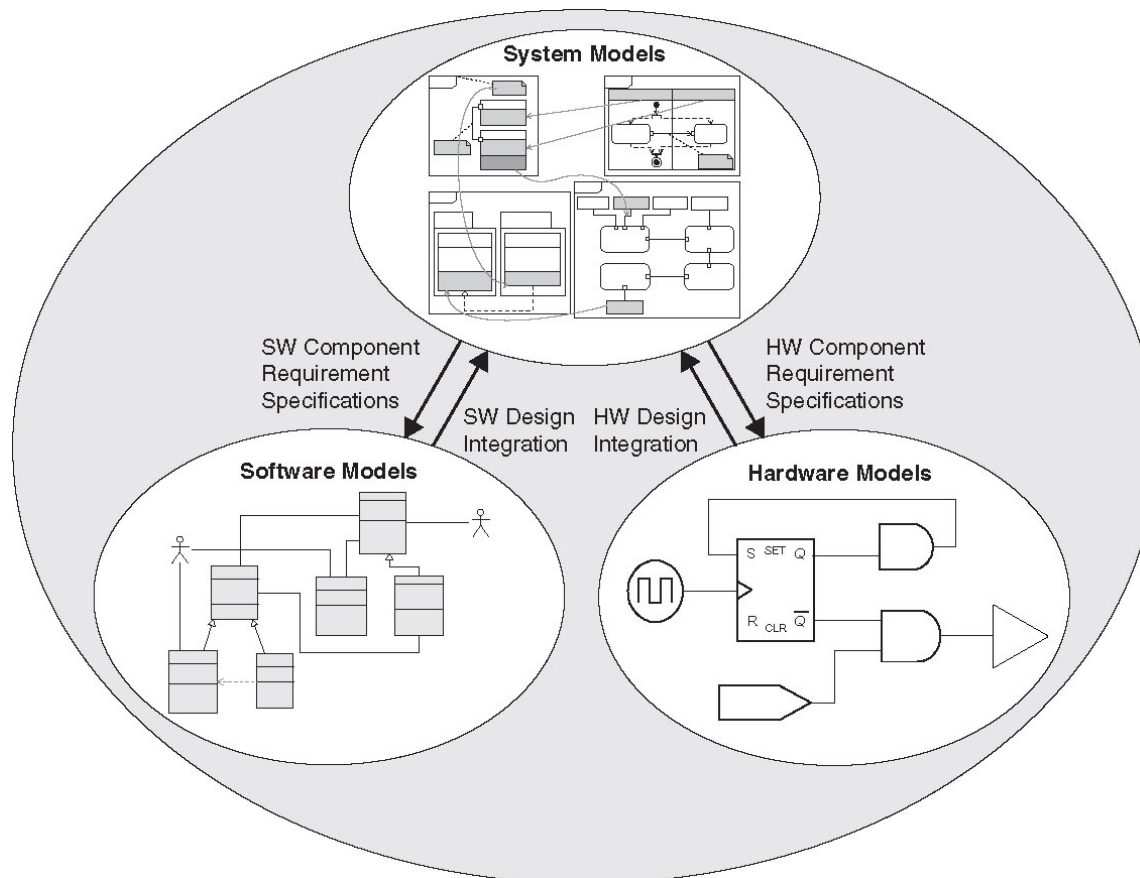


### Requirements



### Parametrics

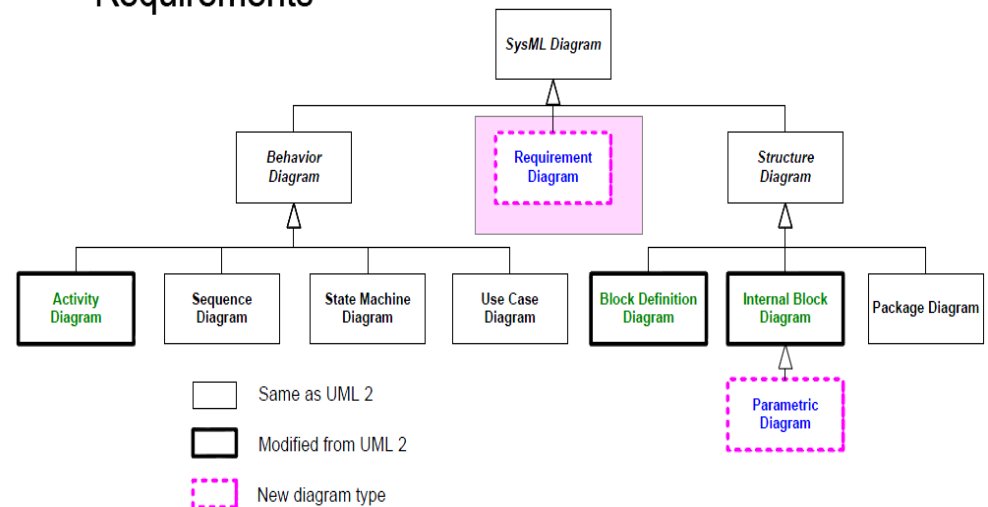
# Connecting Models Cross Disciplines



# Overview of SysML Diagrams

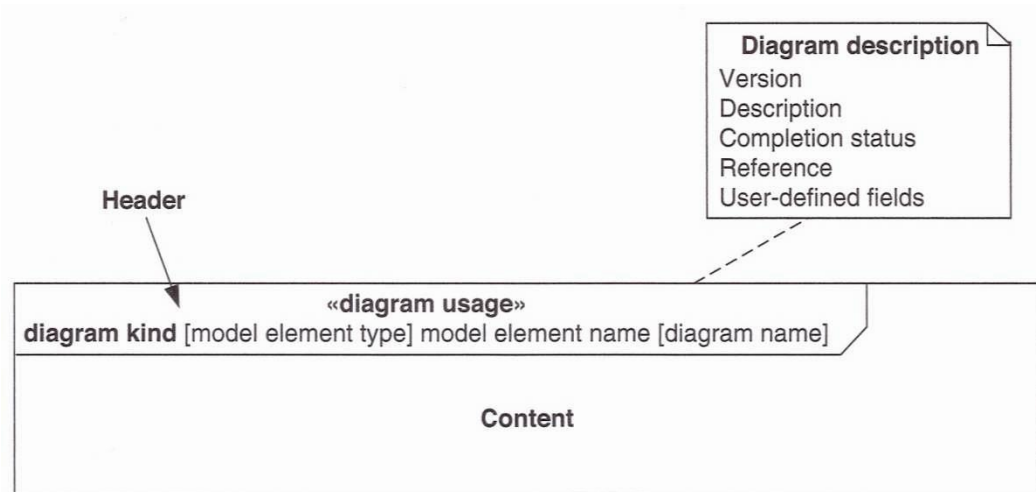
- Anatomy of a Diagram
- Diagram Types:
  - Requirement (req)
  - Structure
    - Block Definition (bdd)
    - Internal Block (ibd)
    - Parametric (par)
    - Package (pkg)
  - Behavior
    - Activity (act)
    - Sequence (sd)
    - State Machine (stm)
    - Use Case (uc)

- Allocations
- Requirements



# Anatomy of a Diagram

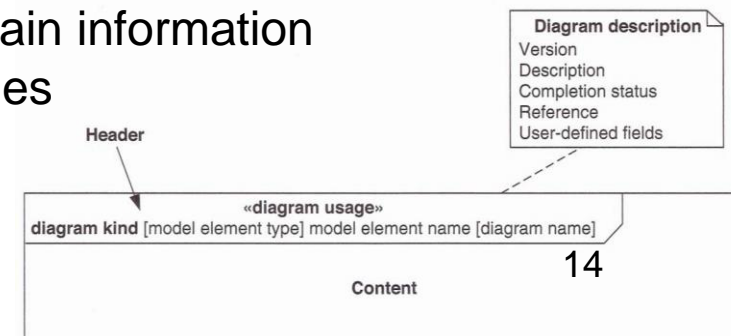
- Frame
- Header
  - Name
  - Usage
- Description
- Content



*A Practical guide to SysML, Friedenthal et al.*

# Anatomy of a Diagram

- Frame – Visible context of the diagram content
- Header/Name – Includes the information to identify the diagram
- Header provides:
  - Diagram kind, Model element type, Model element name, Diagram name, Diagram usage
  - Diagram kind – diagram classification
  - Model element type
    - Model element name
    - Diagram name
    - Diagram usage
- Description – Optional note that provides ‘bookkeeping’ information (version, status, etc.)
- Content – The actual information on the elements of the model.
- The content area contains the graphical elements representing model elements: Node: Contain information (symbols, icons, etc.) describing system entities

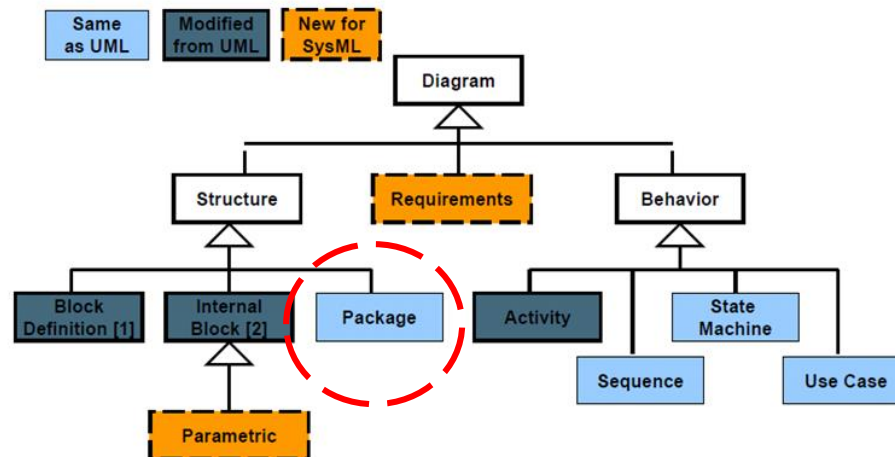


# SysEng 6542

## Model Based Systems Engineering

### Modelling Physical Systems

SysML Taxonomy of Diagrams



# Organizing the Model

- Model elements are placed in containers
- Containers can be nested
- Containers can be thought of as component entities.
- Ease of access and navigation between elements
- Reuse of elements
- Assists configuration management
- Reuse – Libraries
- Views and Viewports
- Import relationships



# Model Libraries

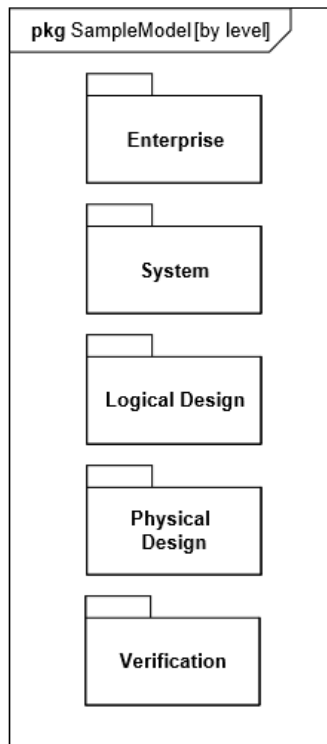
- Package hierarchy constructed with the intent for it to be reused.
- Libraries can be used for
  - COTS items
  - Standard definitions
  - Company specific products
  - Etc.

# Package Hierarchy

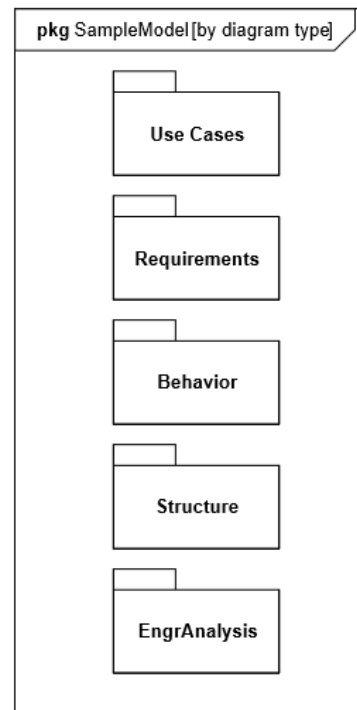
- Gives a standard organization of model data
- Allows data to be arranged in domain specific methods
- Critical to access control, configuration management, data exchange, etc.

# Package Diagrams

- Provide a means to organize system model data
- The SysML model is a top-level package



OR

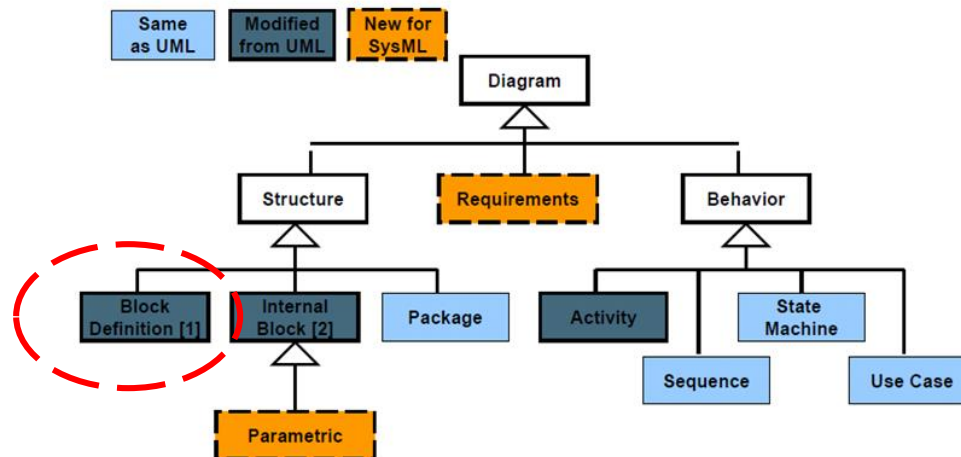


# SysEng 6542

## Model Based Systems Engineering

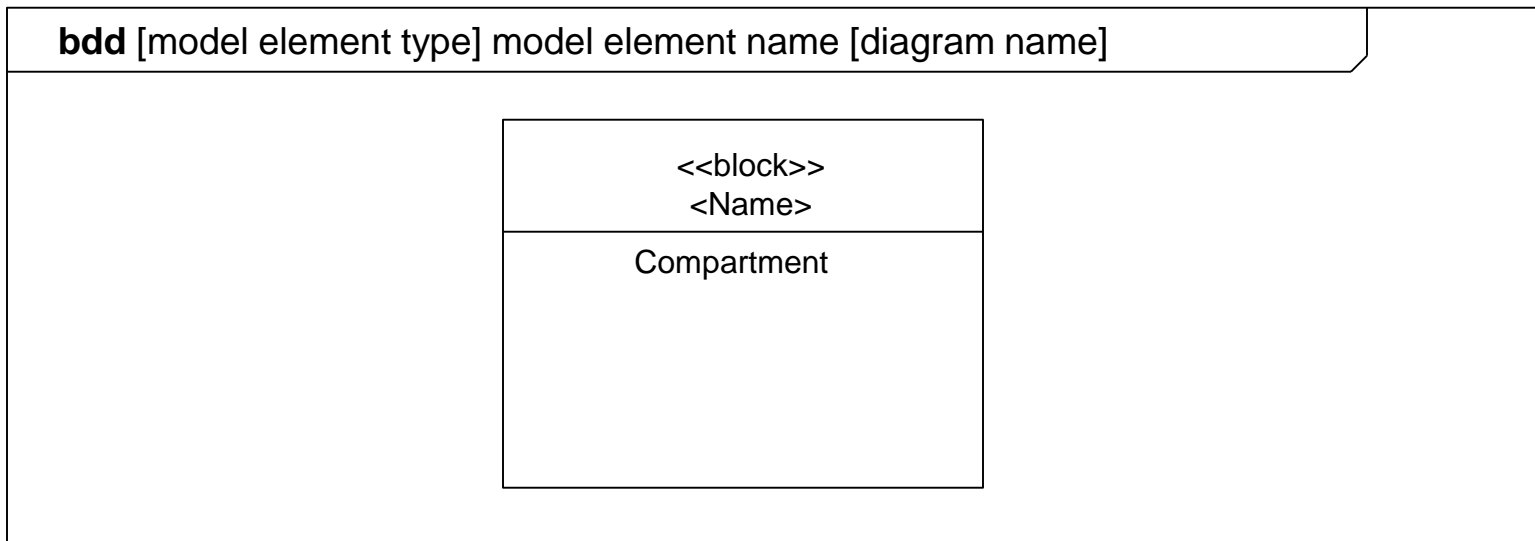
### Modelling Physical Systems

SysML Taxonomy of Diagrams

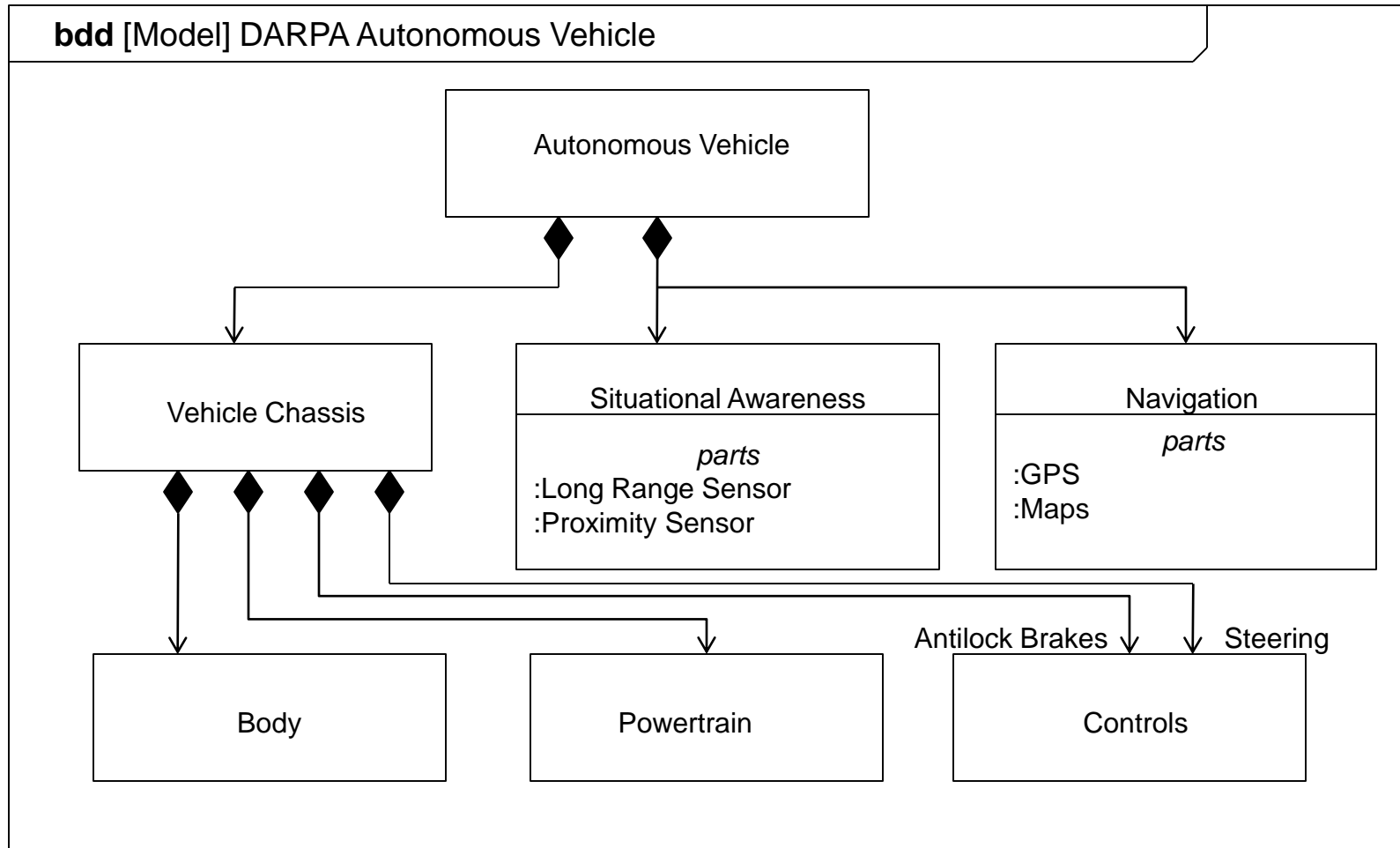


# Block Definition Diagram

- Modified UML Structure (Class) Diagram
- Used to define blocks and their structural relationships with other blocks (HW, SW, system, facility, etc....)
- Describes the pieces used to construct the model
- Describe a set of similar instances
  - “Engineering objects”

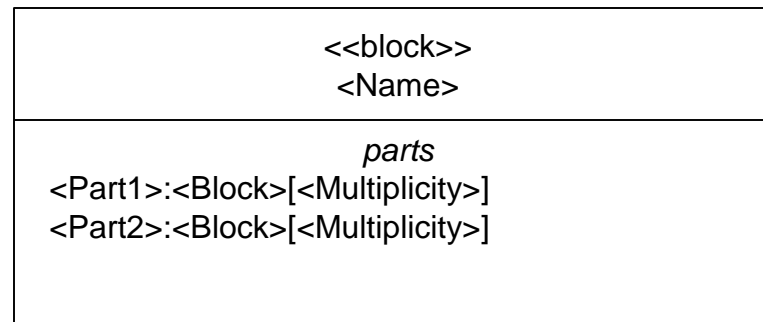


# Blocks showing hierarchy



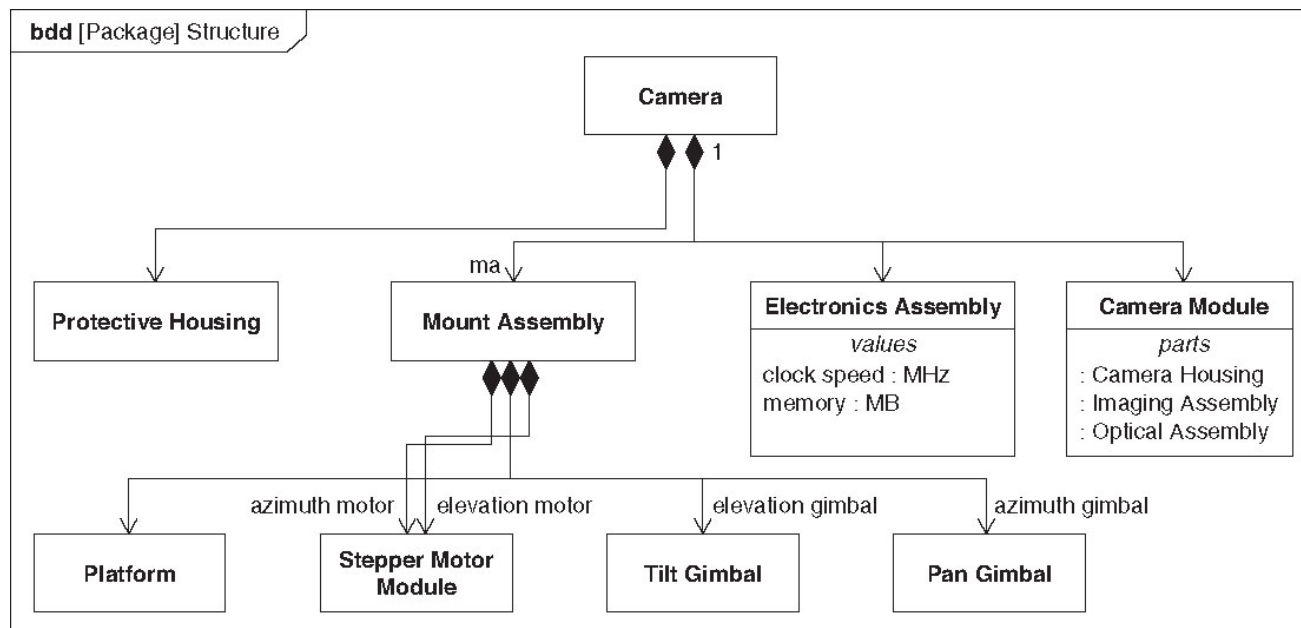
# Blocks

- Compartments: hold additional information about the node
  - Part properties
  - Reference properties
  - Value properties
  - Operation
  - Reception
- Part properties (*part*)
  - Describe composition relationships between blocks
  - Contains part name, block, and number of instances (multiplicity)



# Composite Associations

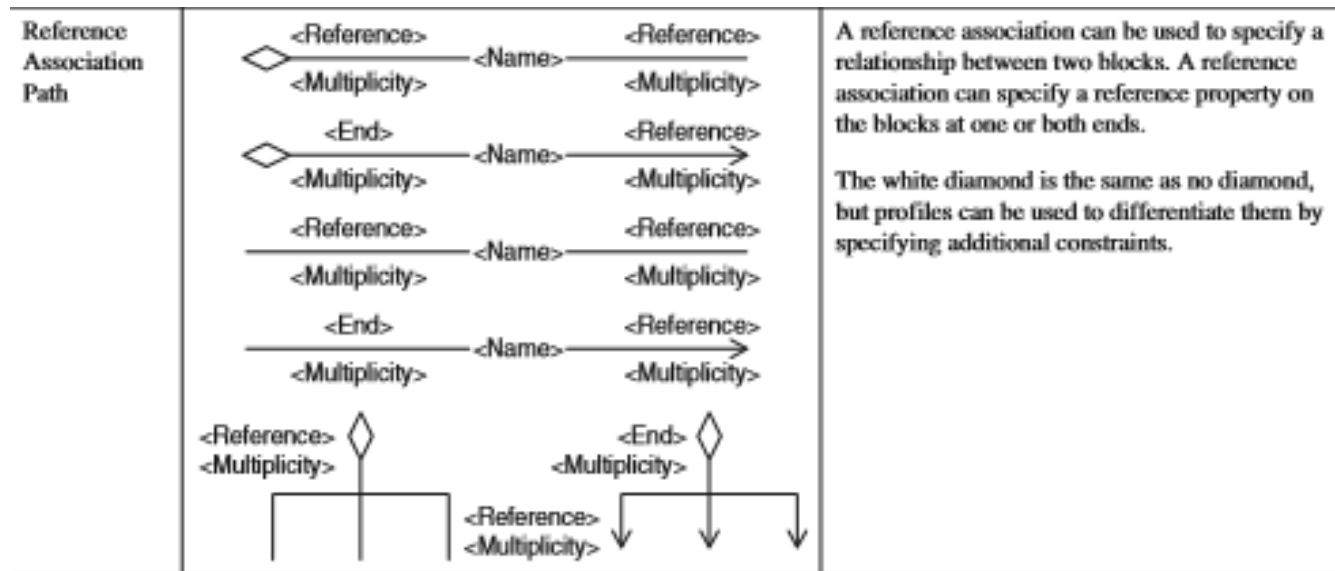
- Describes whether the part can exist without the block it is associated with
- Multiplicity at whole end is either 1 (needed by part) or 0..1 (not needed)



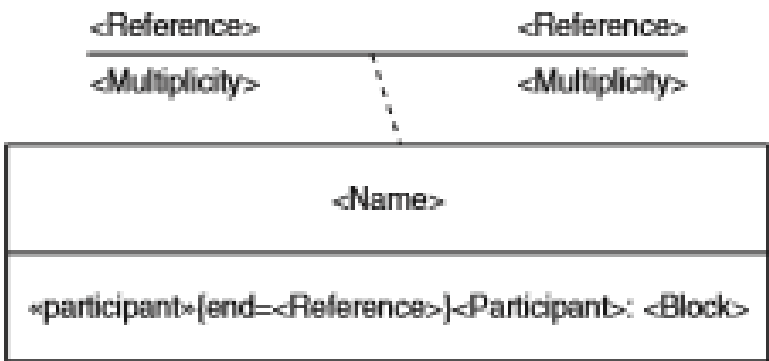



# Reference Properties

- Reference properties (*reference*) describe additional relationships
- They describe additional associations between blocks
- Can be shown in a separate 'hierarchy'



# Block Associations

Association Block Path and Node		<p>An association block, as the name implies, is a combination of an association and a block, so it can relate two blocks together but can also have internal structure and other features of its own.</p> <p>Participants are placeholders that represent the blocks at each end of the association block, and are used when it is desired to decompose a connector.</p>
Generalization Path		<p>A generalization describes the relationship between the general classifier and specialized classifier. A set of generalizations may either be {disjoint} or {overlapping}. They may also be {complete} or {incomplete}.</p>

# Value Properties

- Value properties (*value*) add quantitative properties to blocks
  - Value types describe the values for the quantities (think of it as units)
  - Can take on primitive type (integer, string, etc.), enumeration, or custom representations
  - Can read in model libraries to apply measurement systems (English, SI, etc.)
  - May also be used for derived properties
    - Value properties with values that are calculated

# Blocks

**bdd** [model element type] model element name [diagram name]

`<<block>>`  
`<Name>`

*parts*

`<Part1>:<Block>[<Multiplicity>]`

`<Part2>:<Block>[<Multiplicity>]`

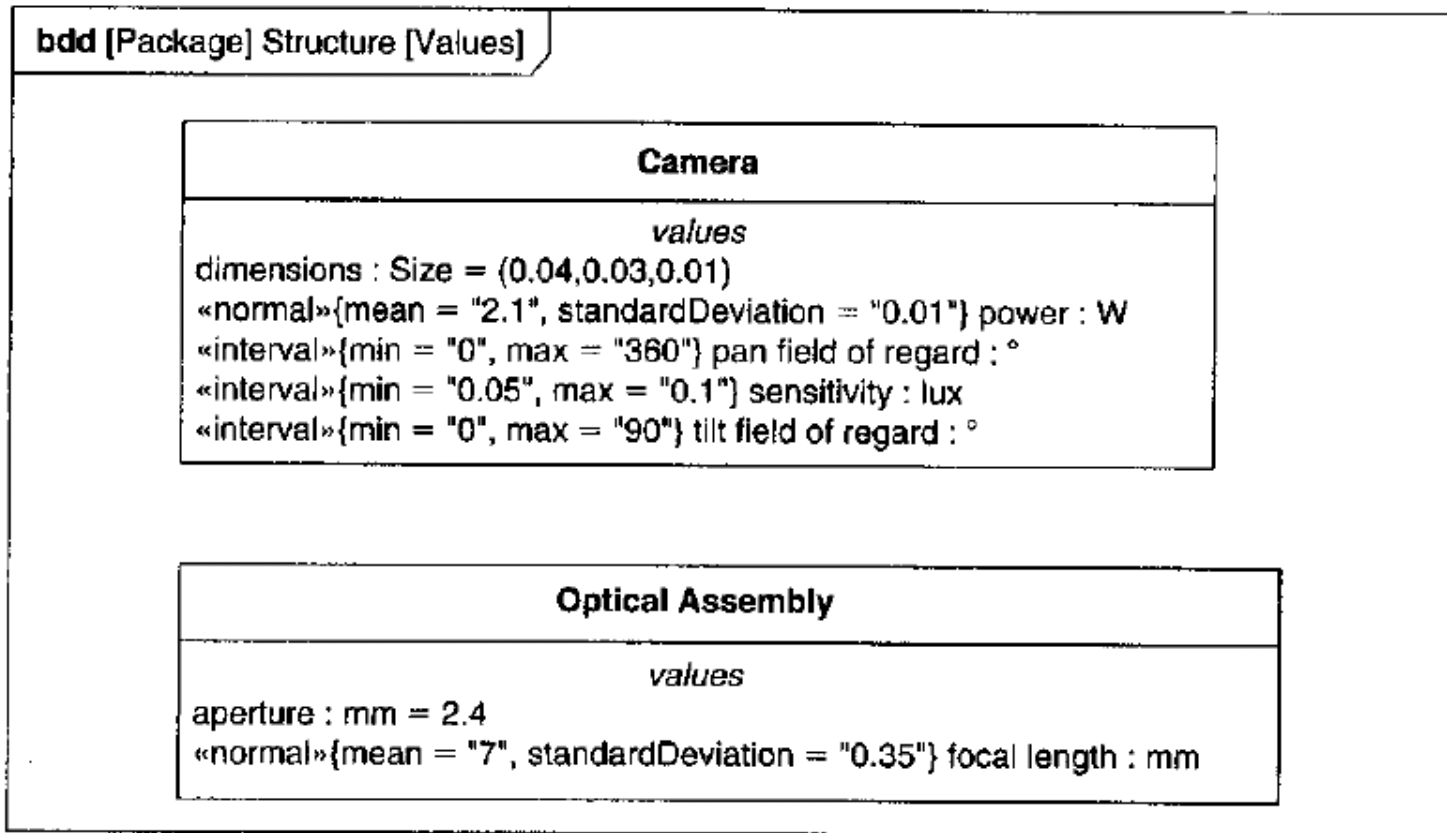
*references*

`<Reference>:<Block>[<Multiplicity>]`

*values*

`<ValueProperty>:<ValueType>=<ValueExpression>`

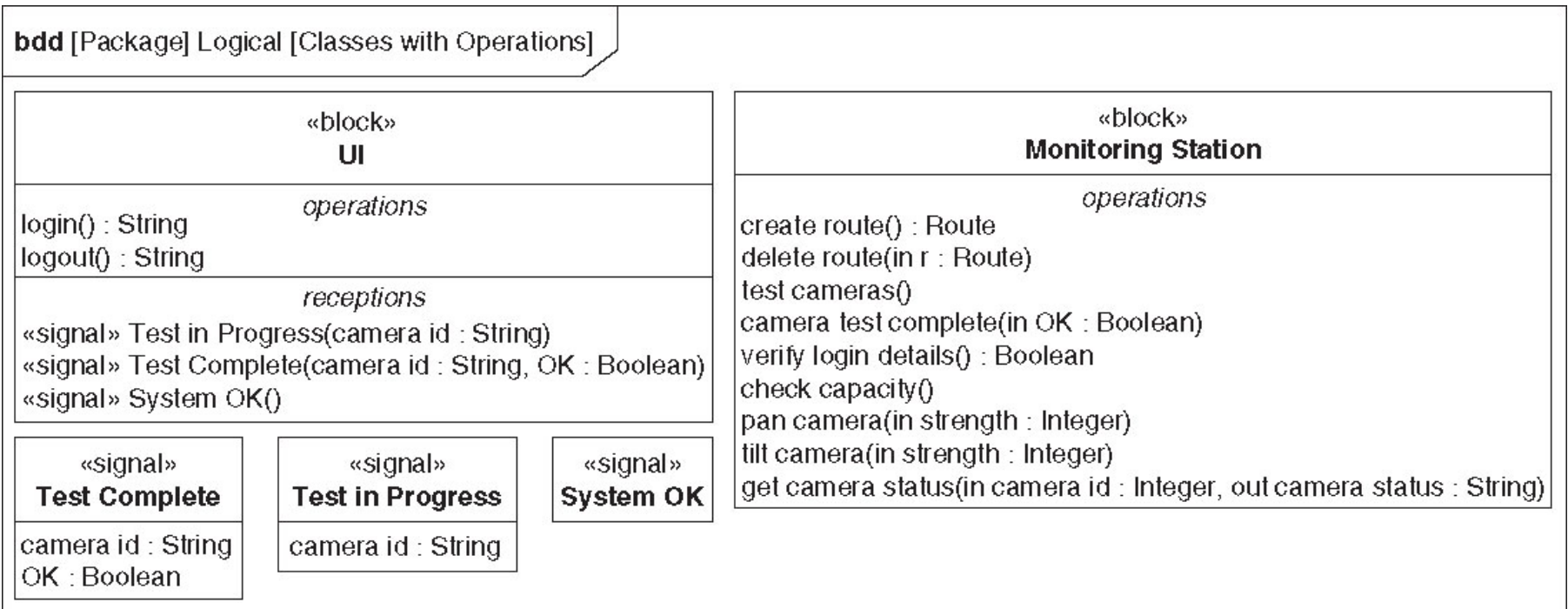
# Block - Value Properties



# Modeling Block Behavior

- Main behavior of block can be shown in behavioral features
  - Operations
  - Receptions
- Actual behavior shown in function, state machine, activities etc....
- Receptions are asynchronous requests
  - Each reception is associated with a signal
- Operations are synchronous requests
  - Parameters are defined and passed with request

# Modeling Block Behavior

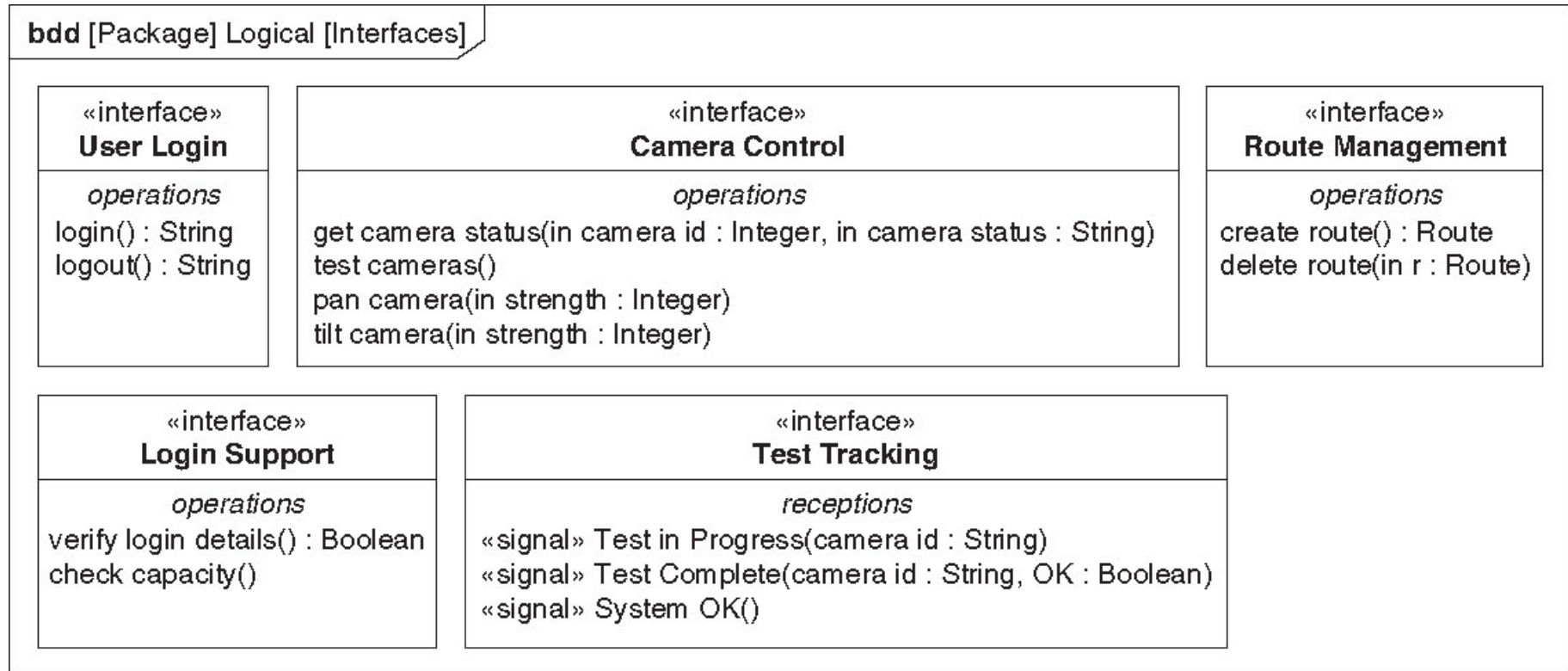


# Modeling Block Behavior

- Interface definitions for ports can also define behavior
  - Required interface: operations required by block to realize behavior
  - Provided interface: operation that a block provides

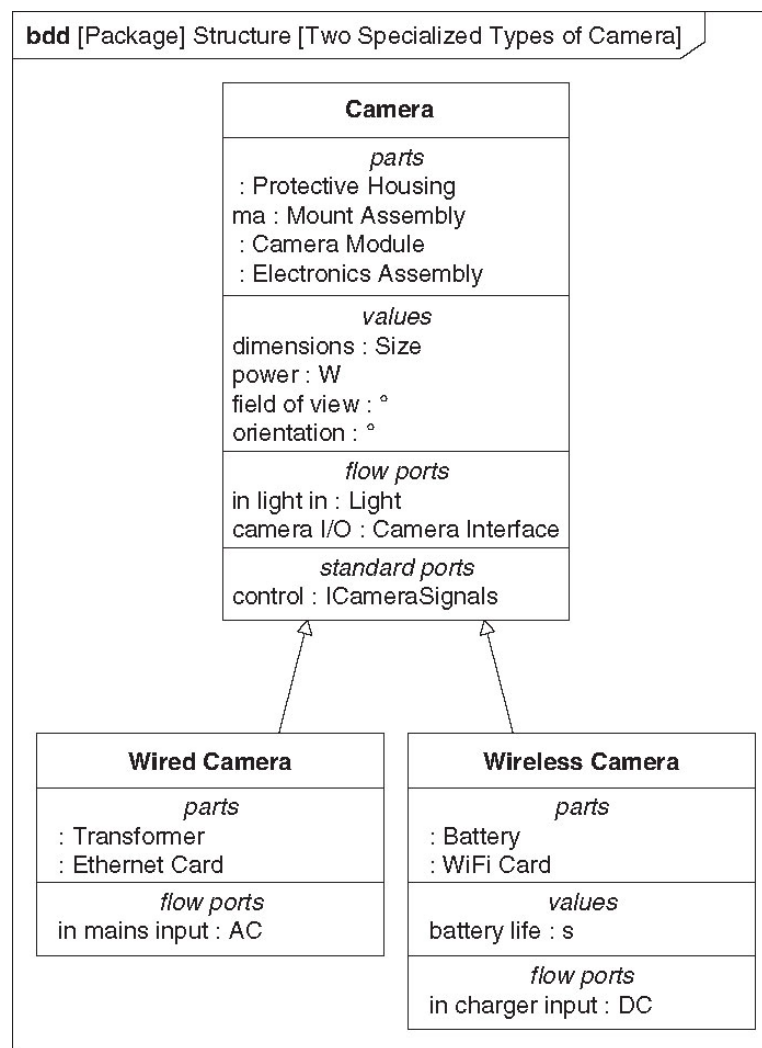


# Modeling Block Behavior



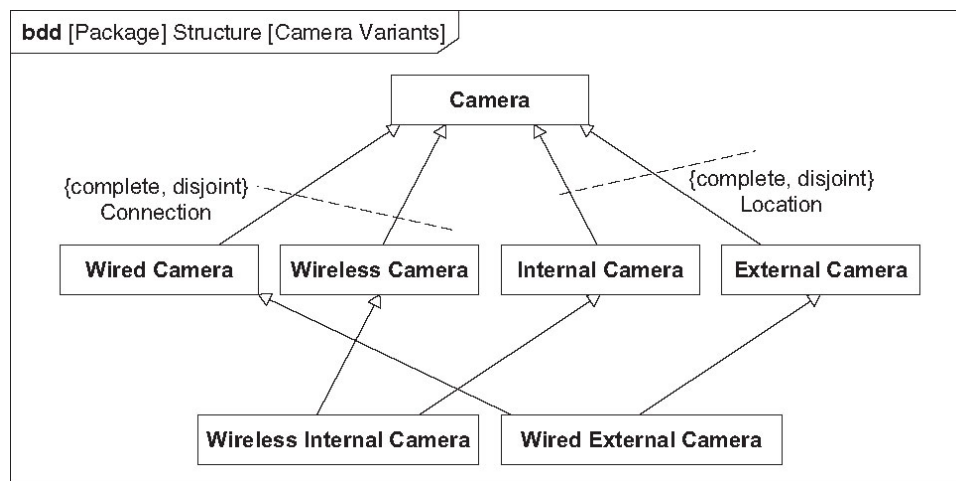
# Modeling Classification Hierarchies

- Block definition diagrams can be used for classification
  - Superclass : general classifier
  - Subclass : specialized classifier
  - Generalization : relationship between superclass and subclass



# Modeling Classification Hierarchies

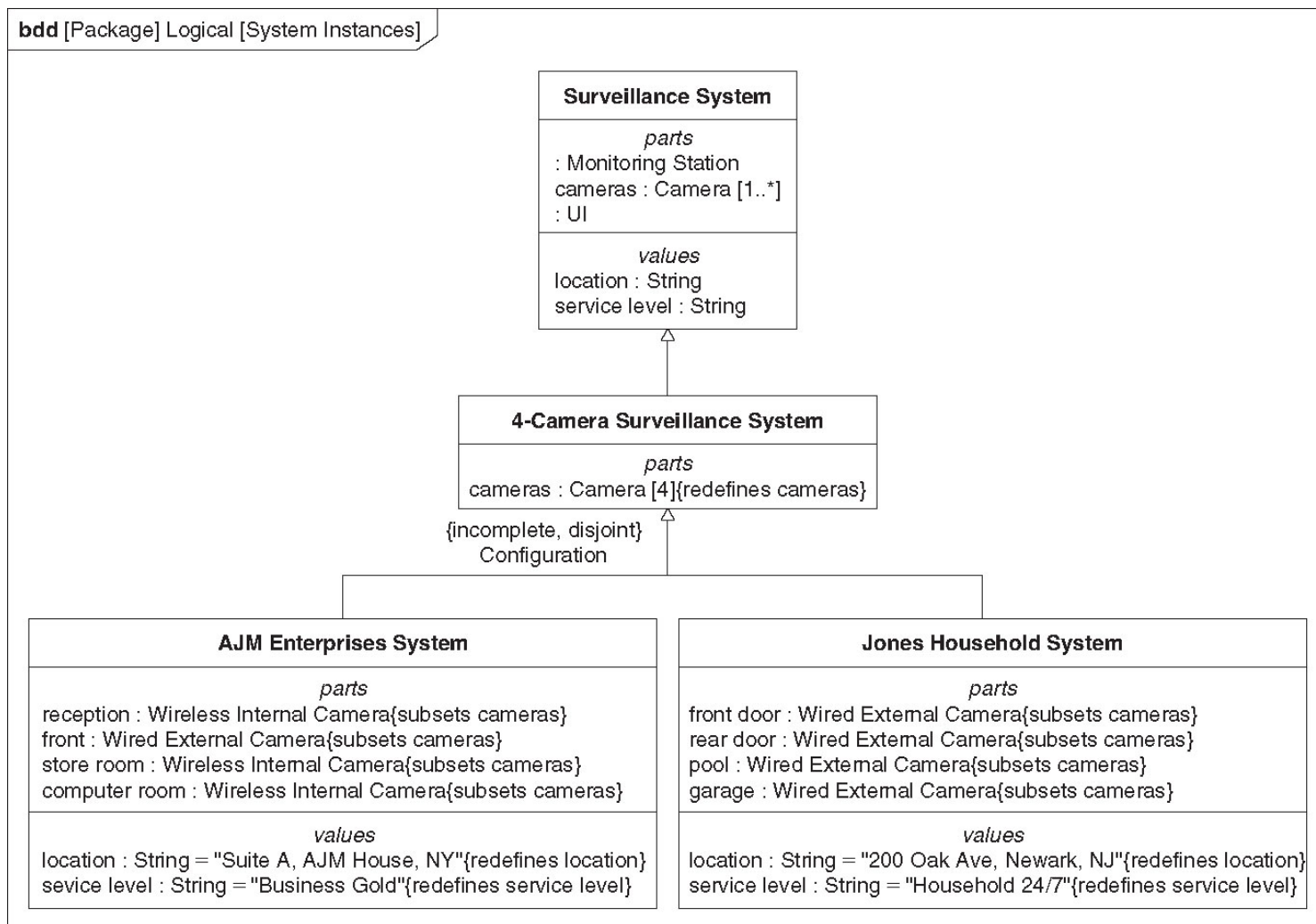
- Using subclasses allow for:
  - Supplying additional detail
  - Redefinition of features
    - Change multiplicity
    - Add or change initial value
    - Add or change probability distribution
    - Change property type to a more restrictive property



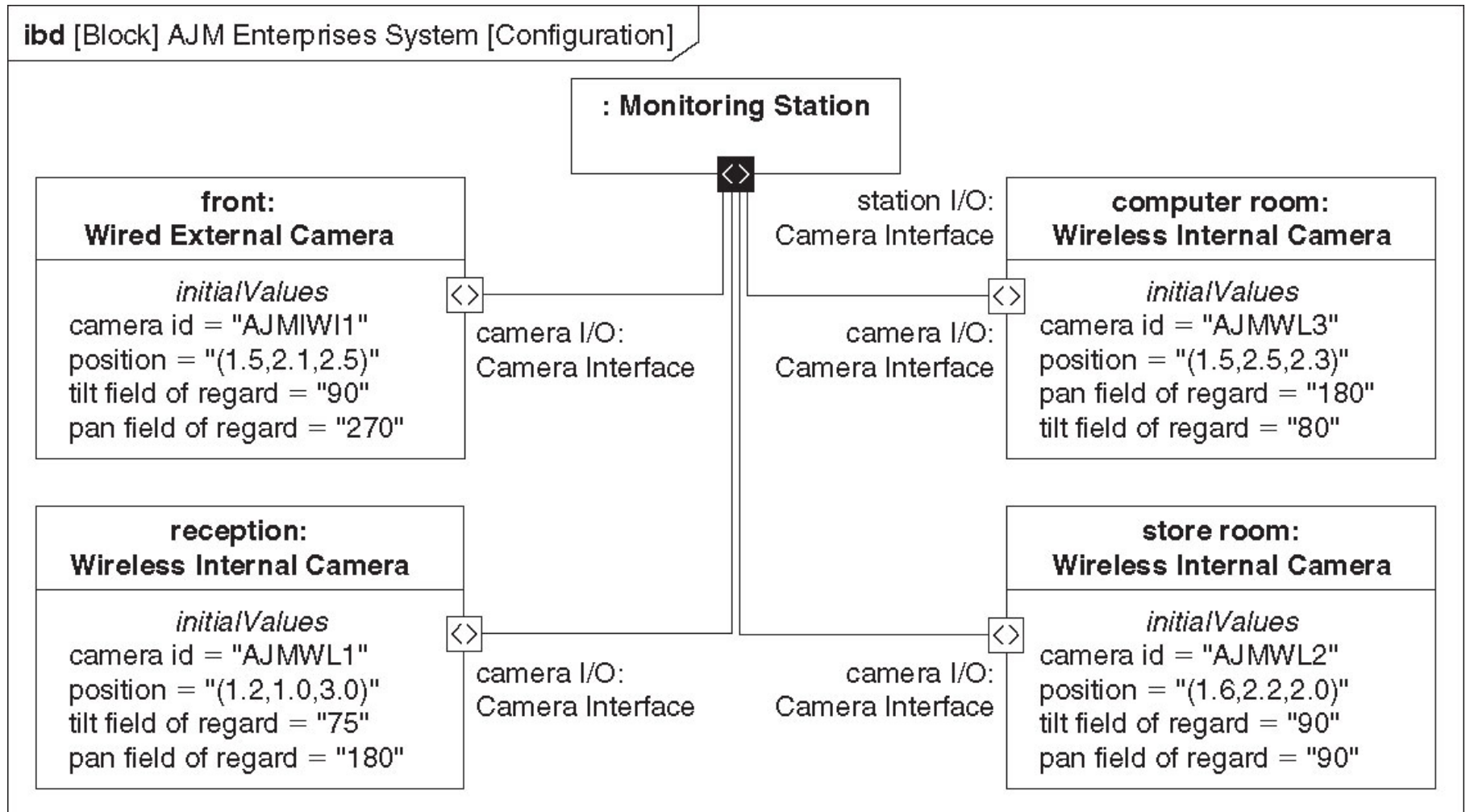
# Generalization

- Similar to class membership
- Provides description of relationship
  - Coverage : complete or incomplete
  - Overlap : can instance be a member of more than one subclass

# Modeling Configurations



# Modeling Configurations

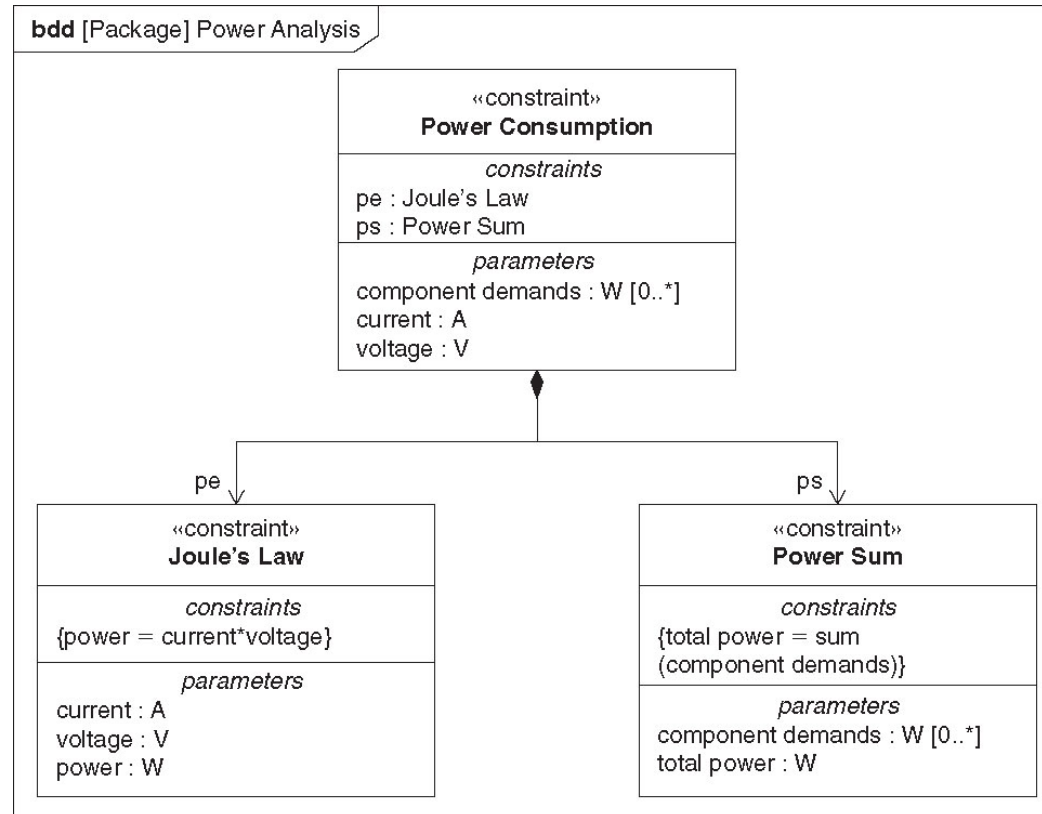


# Parametric Diagram

- New Structure Diagram
- Contains information to create a system of equations to constrain the block properties

<b>par</b> [model element type] model element name [diagram name]

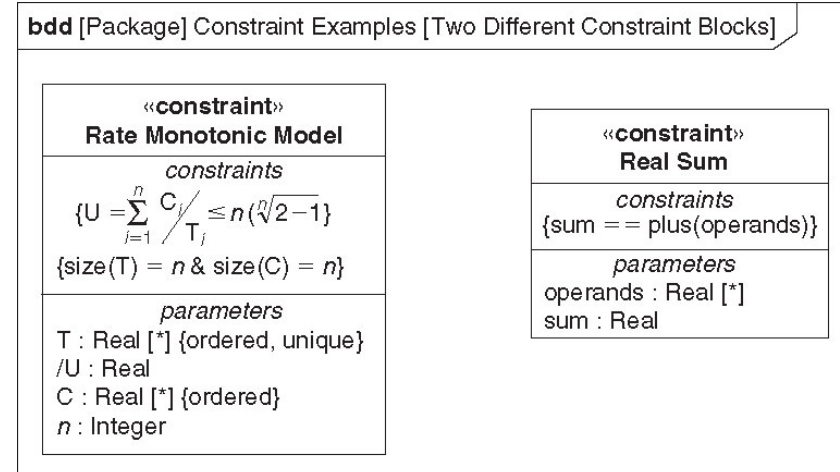
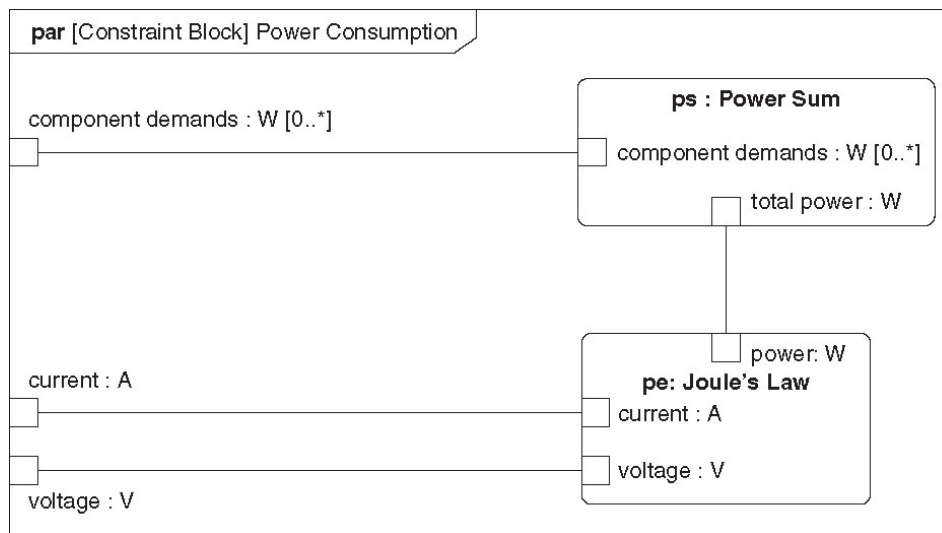
# Parametric Diagrams





# Parametric Diagram

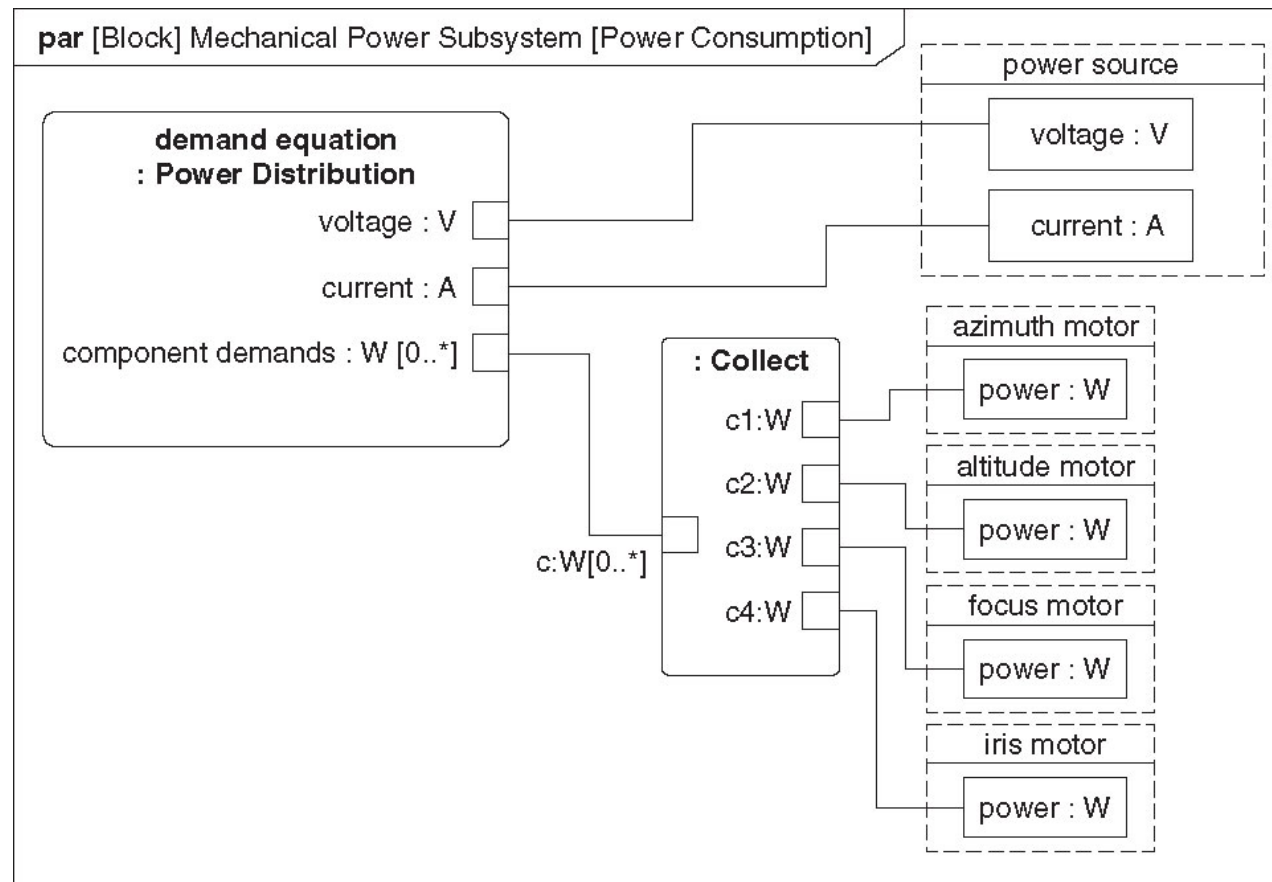
- Can describe interfaces with external software
  - Can be given in constraints compartment or as an attached note
- Constraints can also be given in a separate block



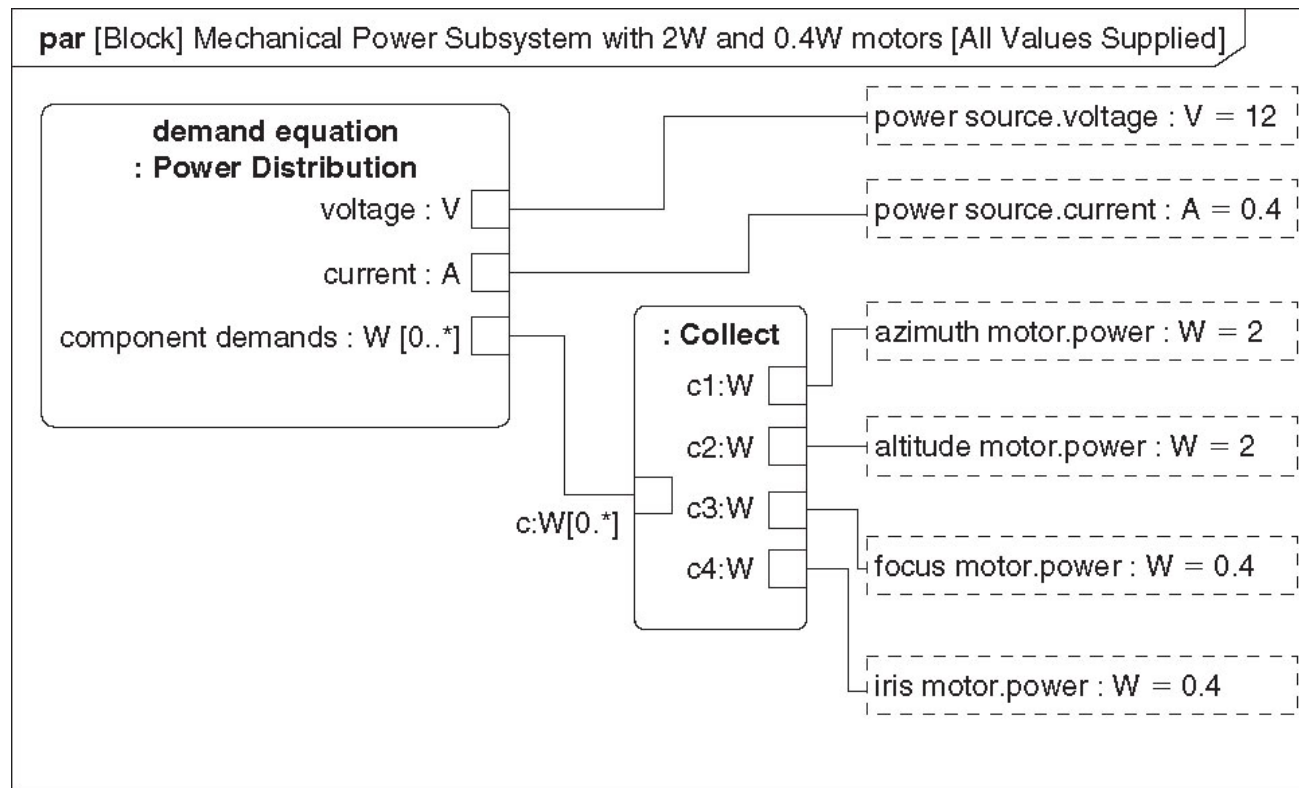
# A note on external solvers

If an external solver is to be used,  
initial values will typically need to  
be specified

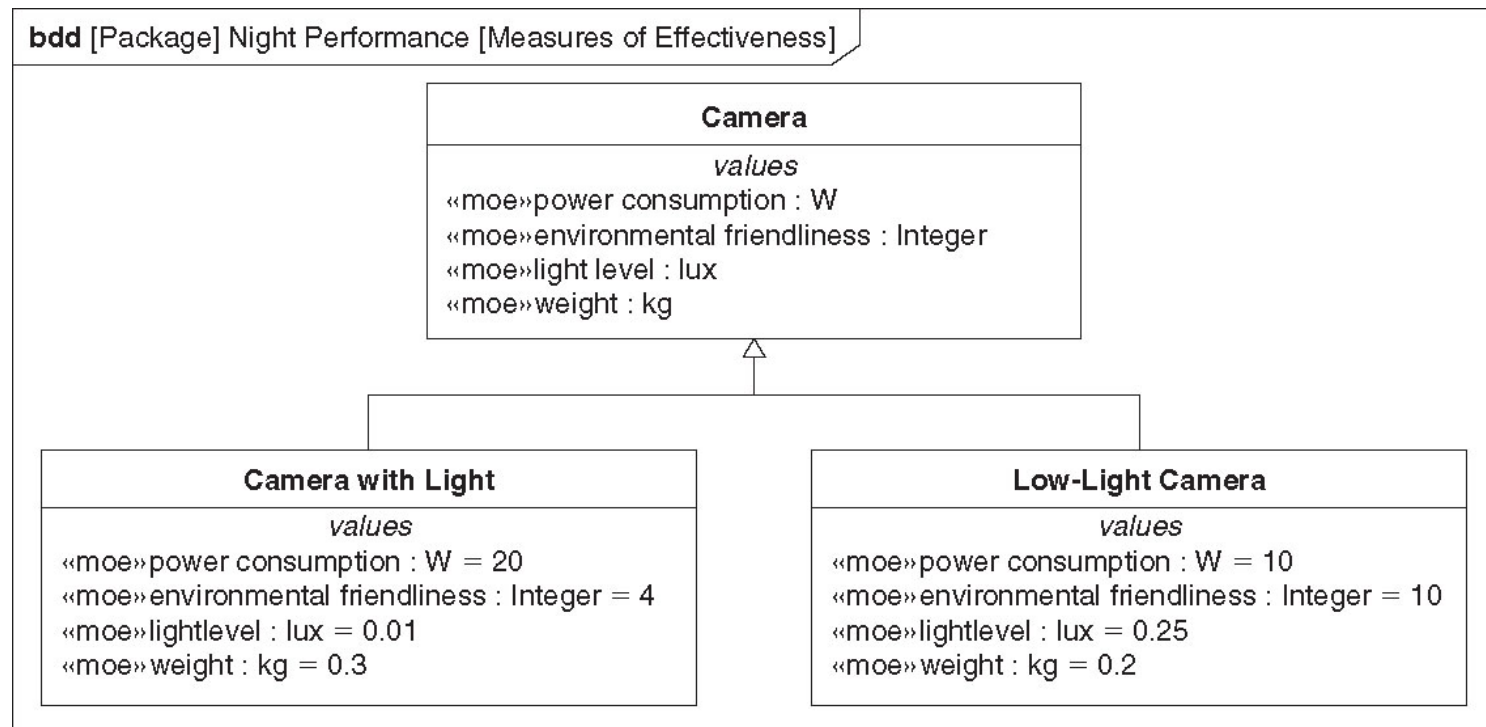
# Parametric Diagram ...



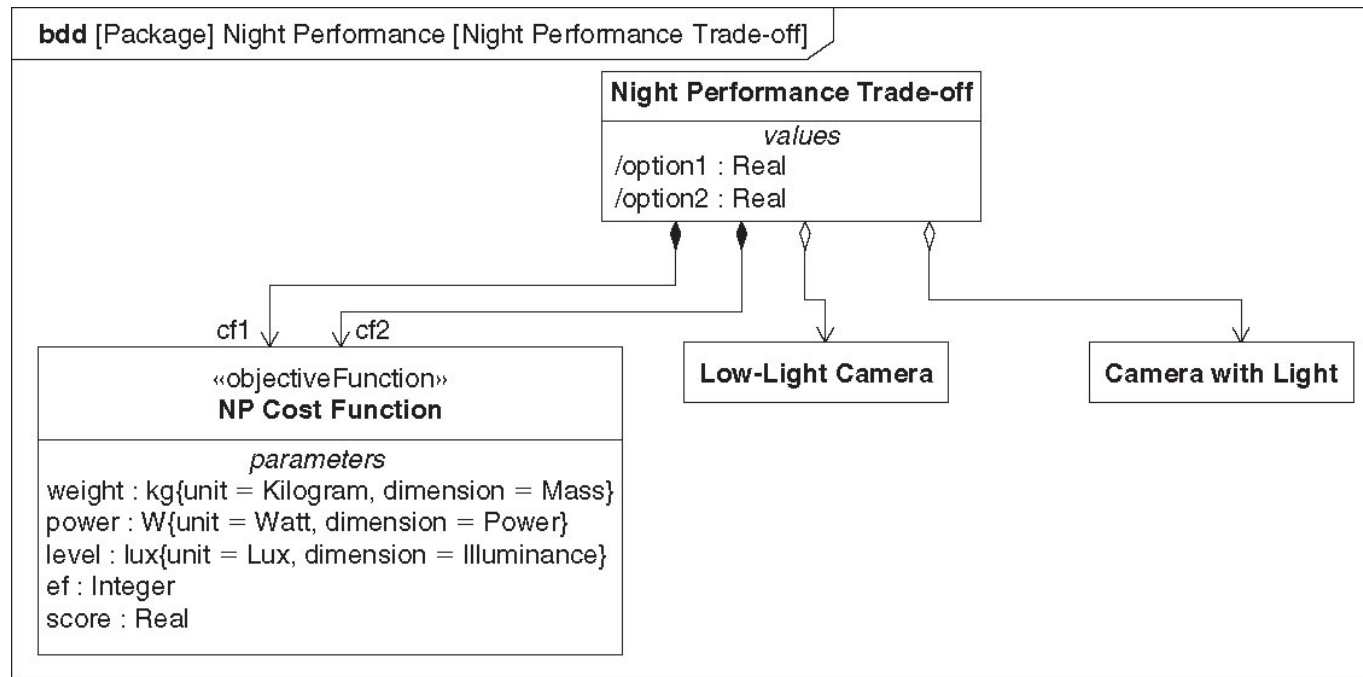
# ... with initial values



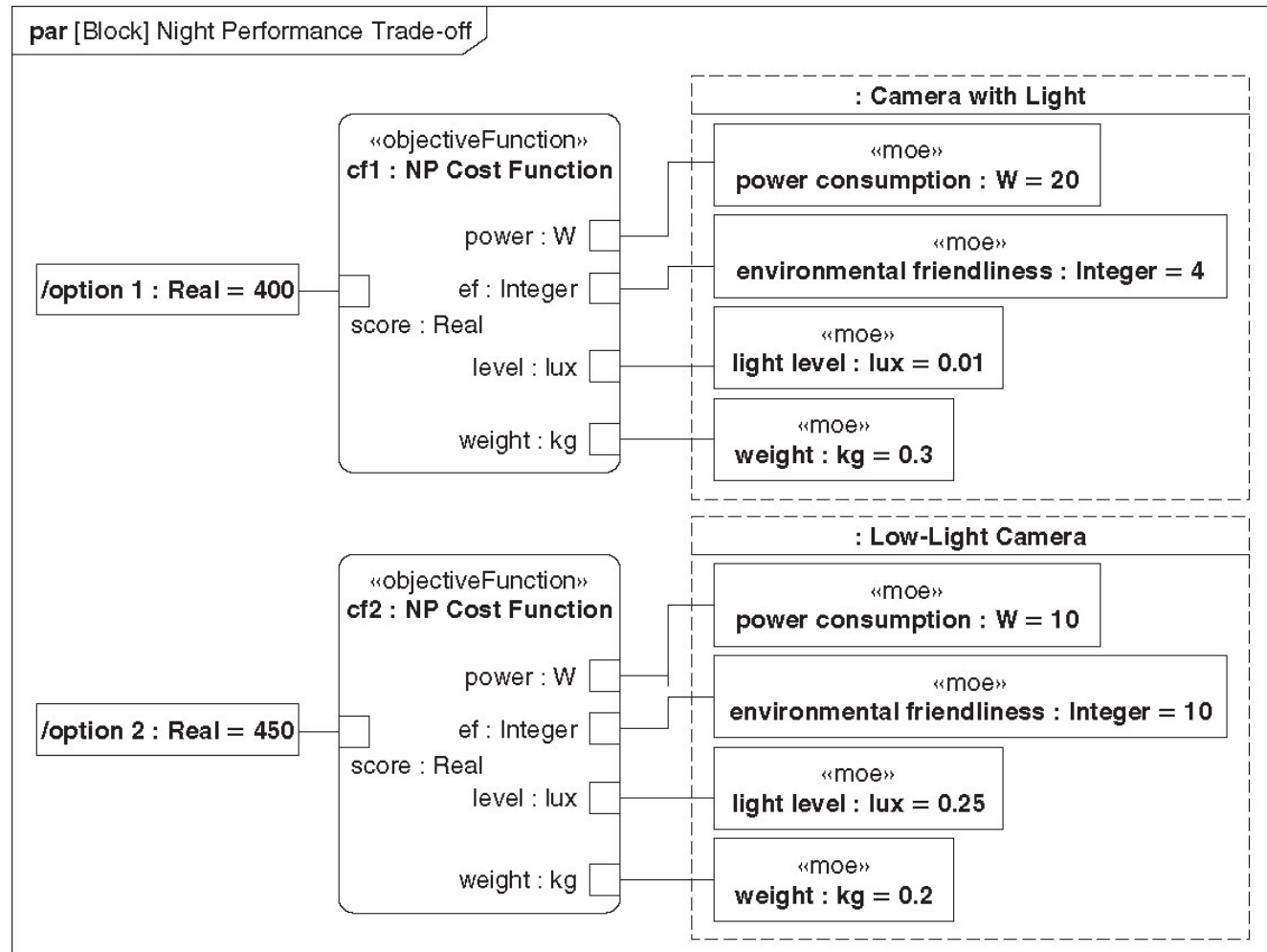
# Parametric Diagrams for Trade Studies



# Parametric Diagrams for Trade Studies



# Parametric Diagrams for Trade Studies



# Next Time

- More on SysML Behaviors
- Assembling models



# *Program Completed*

Missouri University of Science &  
Technology