Modeling Constraints with Parametrics (Part 1 – SysML Concepts)

Section Objectives

- In this Section, you will learn:
  - How to model Constraints with Parametric Diagrams in SysML

Overview

- This section will discuss:
  - Parametric Modeling Concepts
    - Why Model Parametric Diagrams?
    - Defining Parametric Models
    - Basics of Constraint Modeling
      - Defining Constraints in Constraint Blocks
      - Defining and Using Constraint Blocks
      - Binding Parameters in a Parametric Diagram
      - Constraining Value Properties of a Block
    - Applications of Parametric Diagrams
  - Modeling Constraints for In-Class Project

Acknowledgments

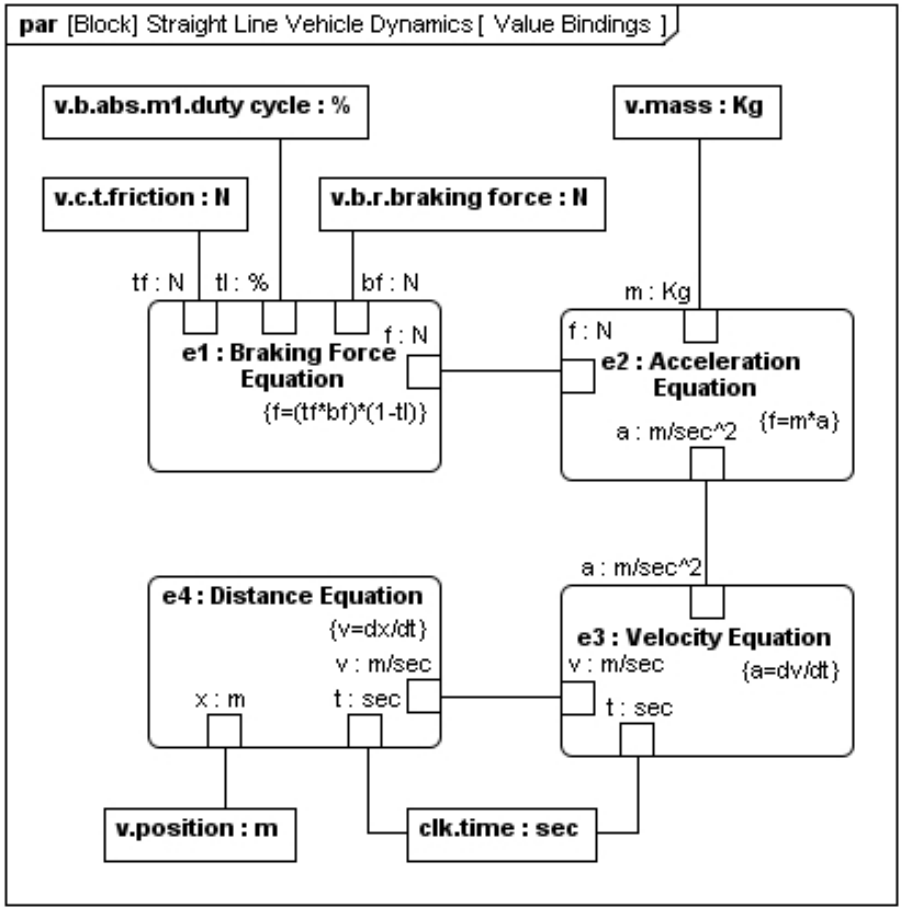
- Portions of this work are from the book, *A Practical Guide to SysML*, by Sanford Friedenthal, Alan Moore, and Rick Steiner, published by Morgan Kaufmann Publishers, Copyright 2009 Elsevier Inc. All rights reserved.
  - This section is based primarily on Chapter 7 of *A Practical Guide to SysML*

Why Model Parametric Diagrams?

- Used to depict constraints on value properties
- Parametric Models capture analysis, such as:
  - Performance
  - Reliability
  - Cost
- Parametric Models support:
  - Sensitivity analysis
  - Trade-off studies
  - Design optimization
  - Design verification
- Provides a link between the system design model and the analysis models
  - Each design may have multiple parametric diagrams each of which captures a particular analysis

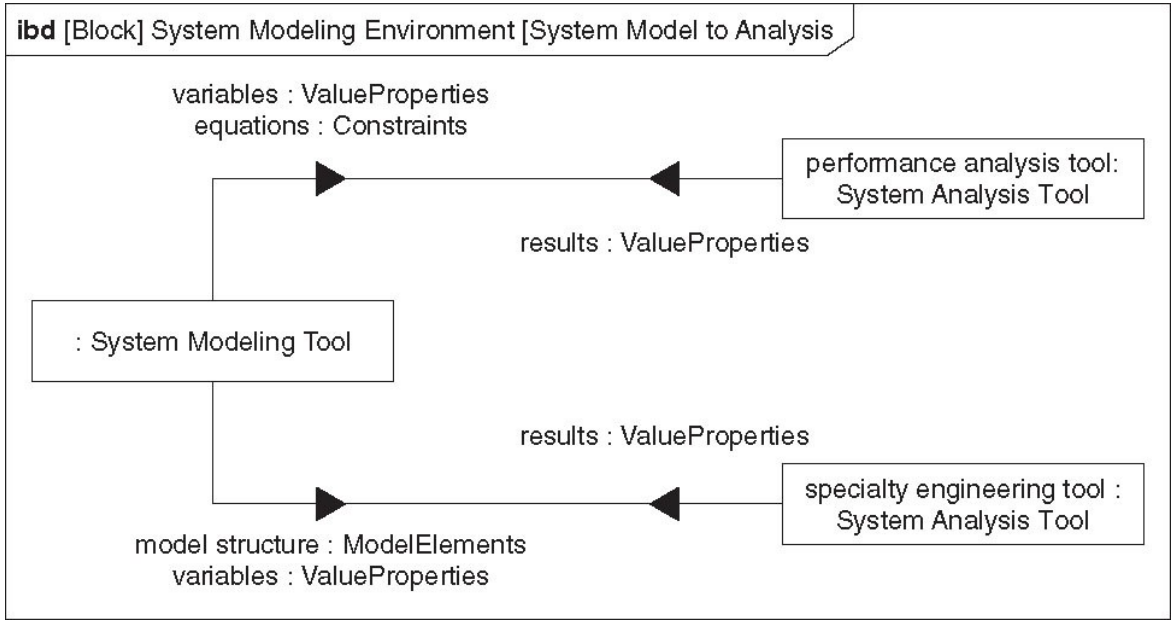
Defining Parametric Models

- Parametric models:
  - Depict a network of equations that constrain the properties of blocks
  - The properties of the system are bound to the parameters of the analysis equations (e.g. vehicle mass is bound to 'm' in F=m x a)
- Example: in the figure, properties of the vehicle are bound to the parameters of the equations used to analyze vehicle stopping distance
- Parametric models thus help identify the properties of the system that are critical to satisfying requirements



Performing the Analysis

- Parametric diagrams capture the analysis
- The paramteric model is then provided to an engineering analysis tool to perform the analysis (e.g. performance, reliability, cost)
- The analysis results are property values that can be incorporated back into the SysML model

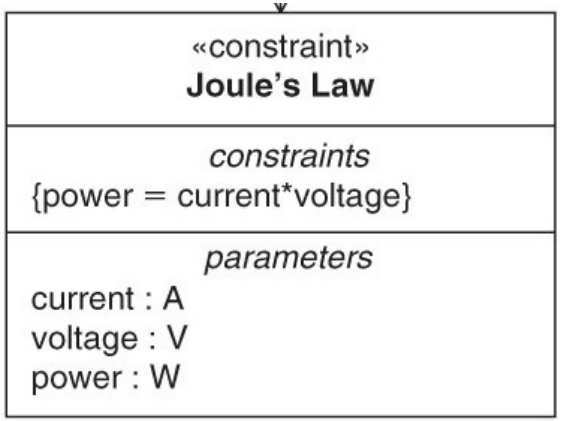


Basics of Constraint Modeling

- Defining Constraints in Constraint Blocks
- Defining and Using Constraint Blocks
- Binding Parameters in a Parametric Diagram
- Constraining Value Properties of a Block

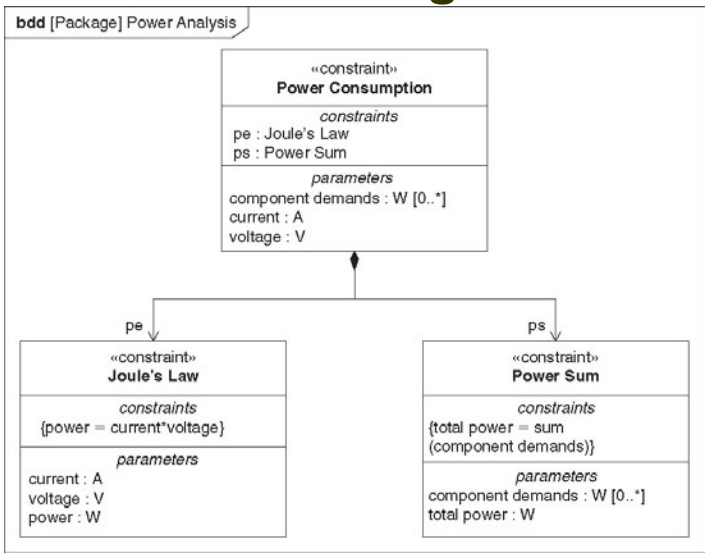
Defining Constraints in Constraint Blocks

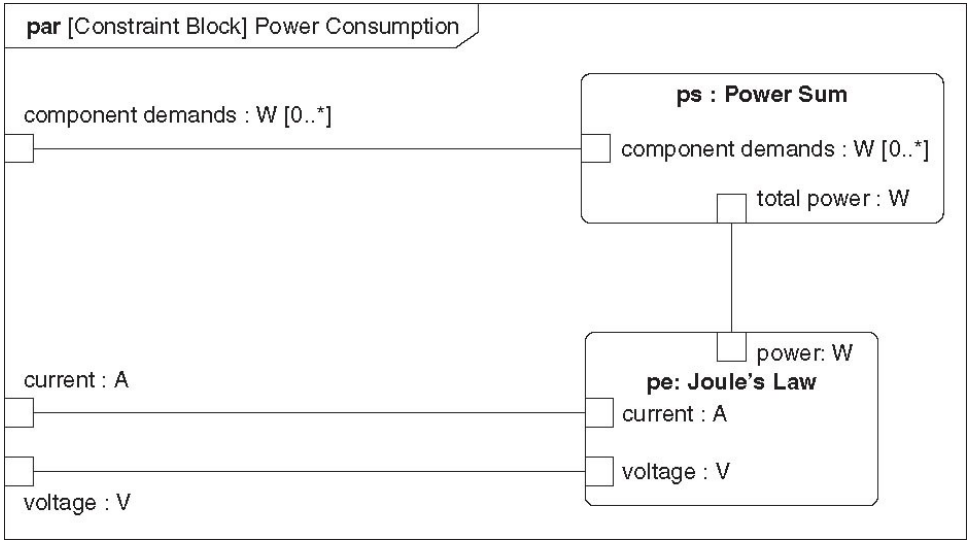
- Constraint Blocks
  - Support the construction of parametric models
  - Define equations so that they may be re-used and inter-connected
  - Define a set of parameters
    - Contained in the ‘parameters’ compartment
  - Define an expression that constrains the parameters
    - Contained in the ‘constraints’ compartment
  - Depicted with the keyword <<constraint>>



Defining and Using Constraint Blocks

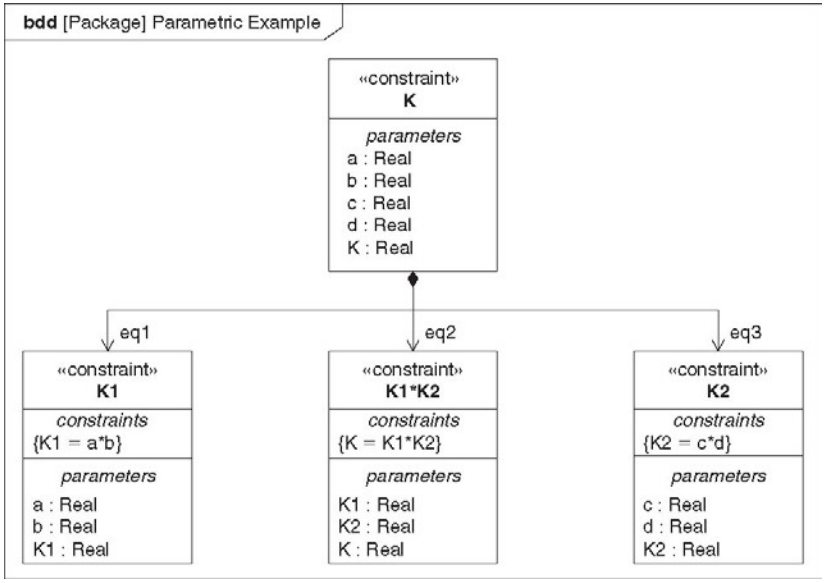
- The **definition** of a Constraint Block is depicted on a BDD
- The **use** of a Constraint Block is called a Constraint Property and is depicted on a Parametric diagram
- The frame of the Parametric diagram represents a Block or a Constraint Block
  - Similar to BDD - IBD relationship
- Parameters are shown as small rectangles flush with the inner surface of the diagram frame or Constraint Property

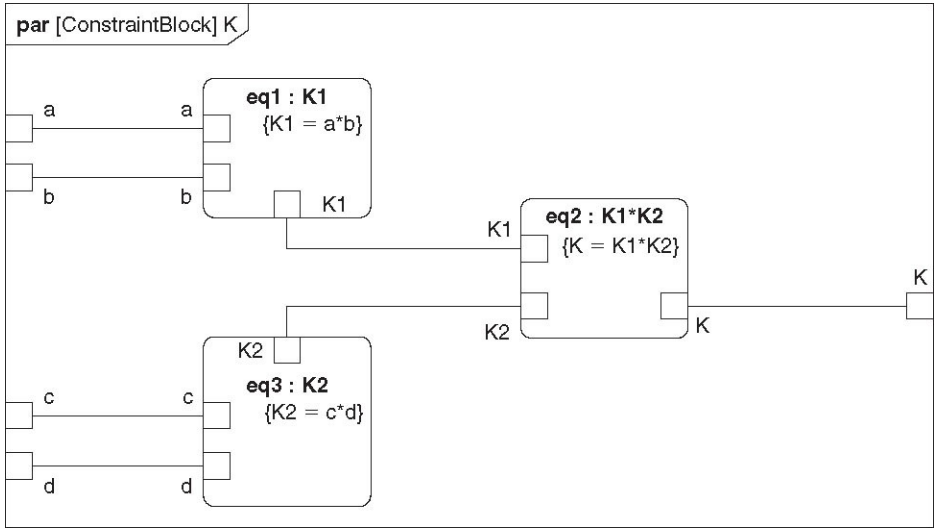




Binding Parameters in a Parametric Diagram

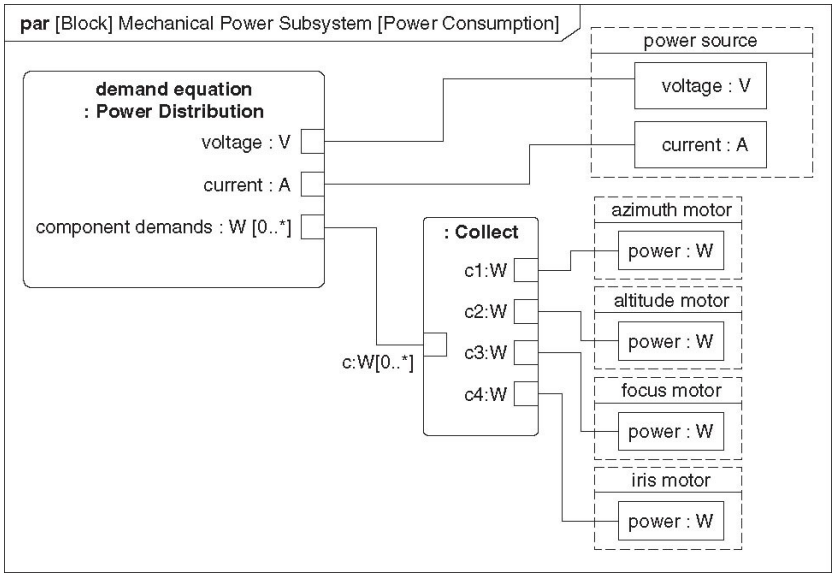
- The interconnection between parameters is shown on a Parametric diagram using binding connectors
- Binding connectors depict an equality relationship between the two connected parameters or between a parameter and a value property

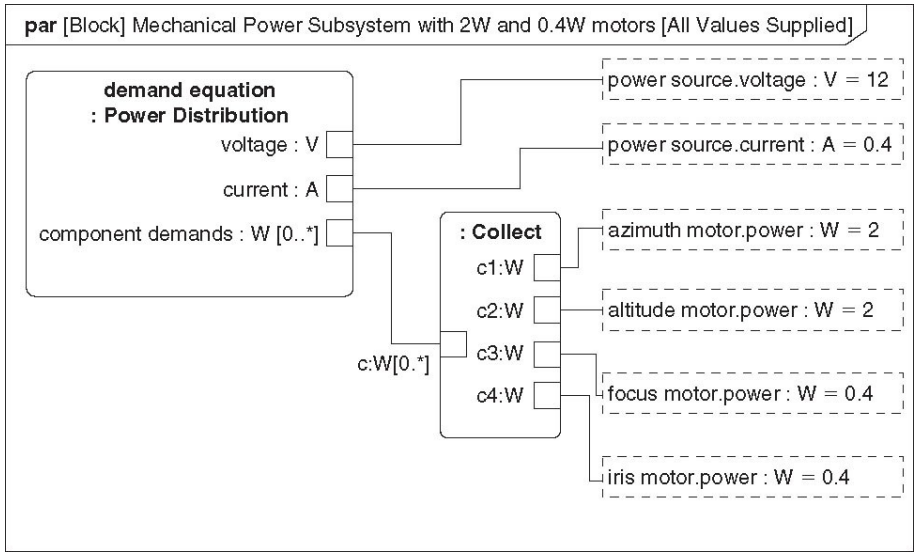




Parametric Diagrams Constrain Value Properties of a Block

- Value Properties are depicted as rectangles on a Parametric Diagram
- Nested Value Properties can be depicted in two ways
  - Nested within its containing part symbol
  - Dot notation, where each level of nesting is separated by a dot



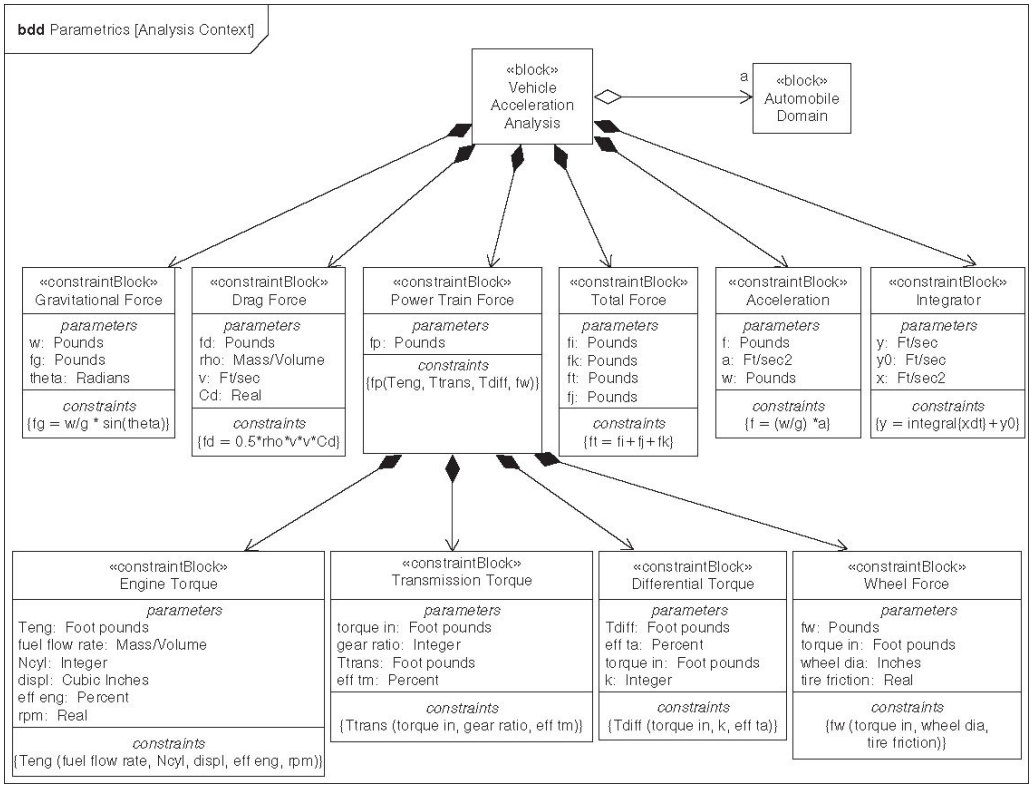


Applications of Parametric Models

- Modeling Sensitivity Analysis
- Modeling Trade Studies
- Modeling Design Optimization

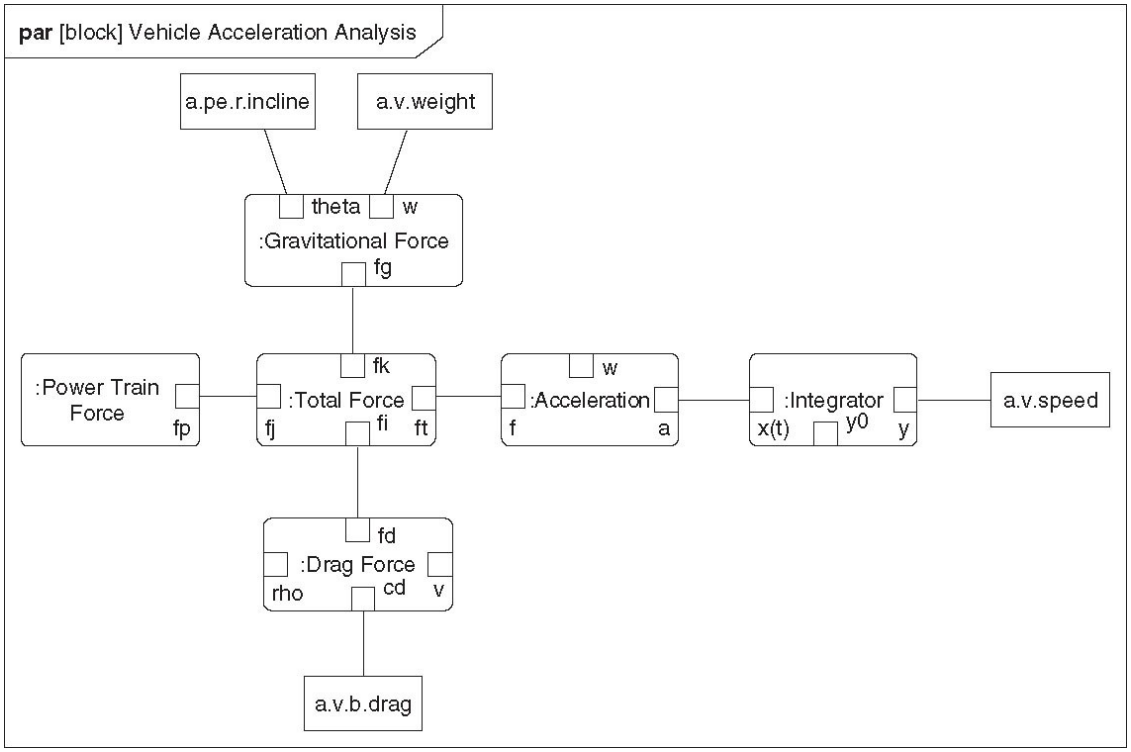
Modeling Sensitivity Analysis

- SysML Block Definition and Parametric diagrams can be used to model a Sensitivity Analysis
- Block Definition Diagram defines the Analysis Context
  - Defines the constraint blocks used in an analysis
    - Constraint blocks define the generic equations to be used
  - References (i.e. identifies) the subject of the analysis



Modeling Sensitivity Analysis (cont'd)

- Parametric Diagram
  - Depicts how the equations are used to perform the analysis
  - Depicts how the Parameters of the equations are bound to each other, to the properties of the system or environment that is being analyzed
- Sensitivity analysis is used to determine which property values have an impact on a requirement

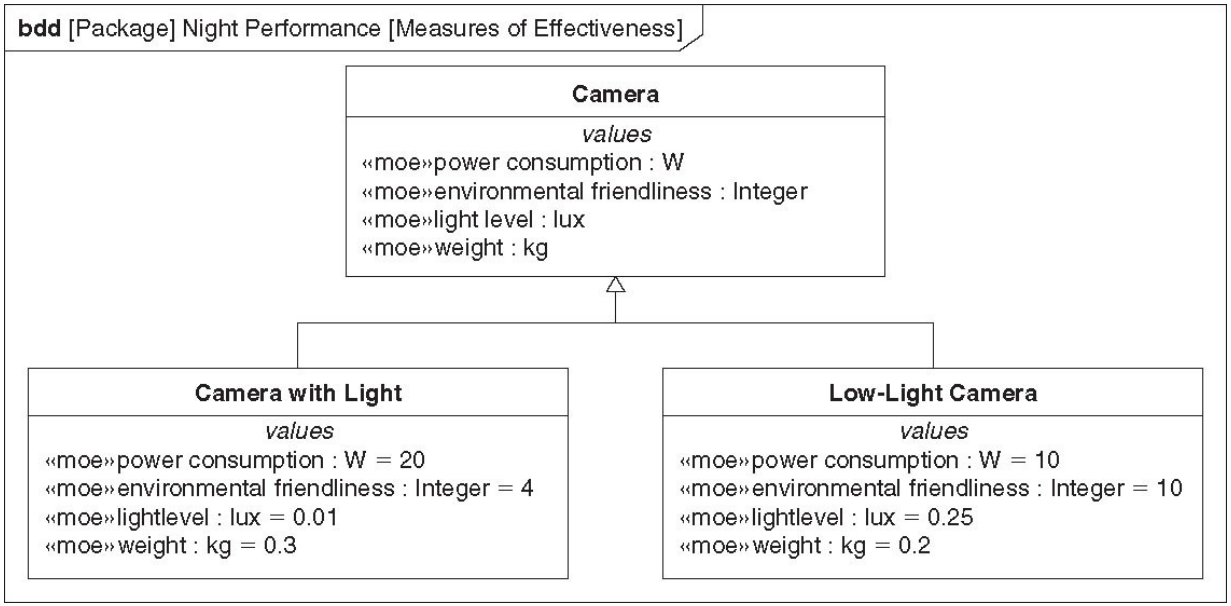


Modeling Trade Studies

- SysML Block and Parametric diagrams can be used to model a Trade Study and its results
- Trade Studies are used to compare alternative solutions
- MOE's are used to define a property to be evaluated in a trade study
- Objective Functions are used to evaluate the MOE's
  - Objective Functions are a kind of Constraint Block
  - Parameters of an Objective Function are related to MOE's using Parametric diagrams

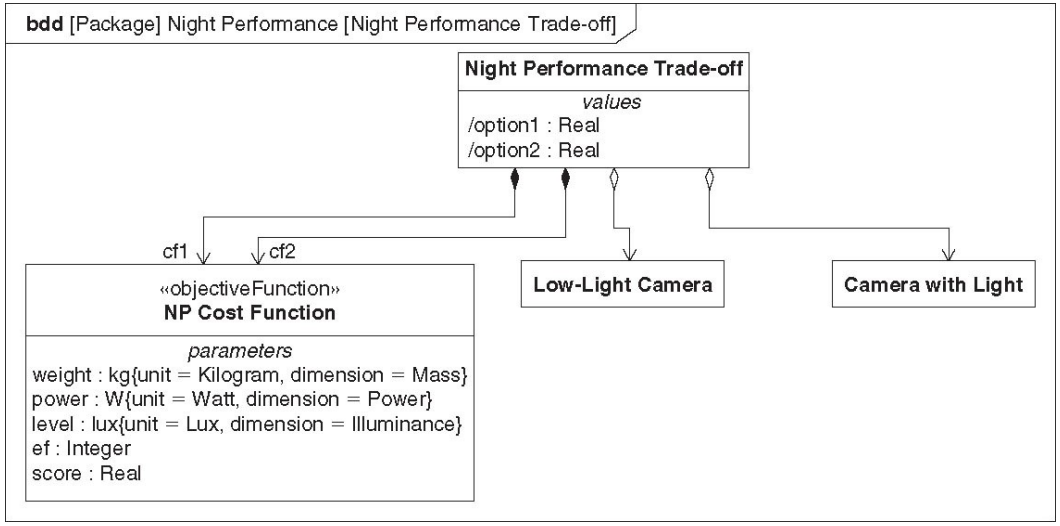
Modeling Trade Studies (cont'd)

- The set of possible solutions for the Trade Study can be depicted as specialized blocks to a general block
- The general block defines all of the MOE's
- The specialized blocks provide different values for the MOE's



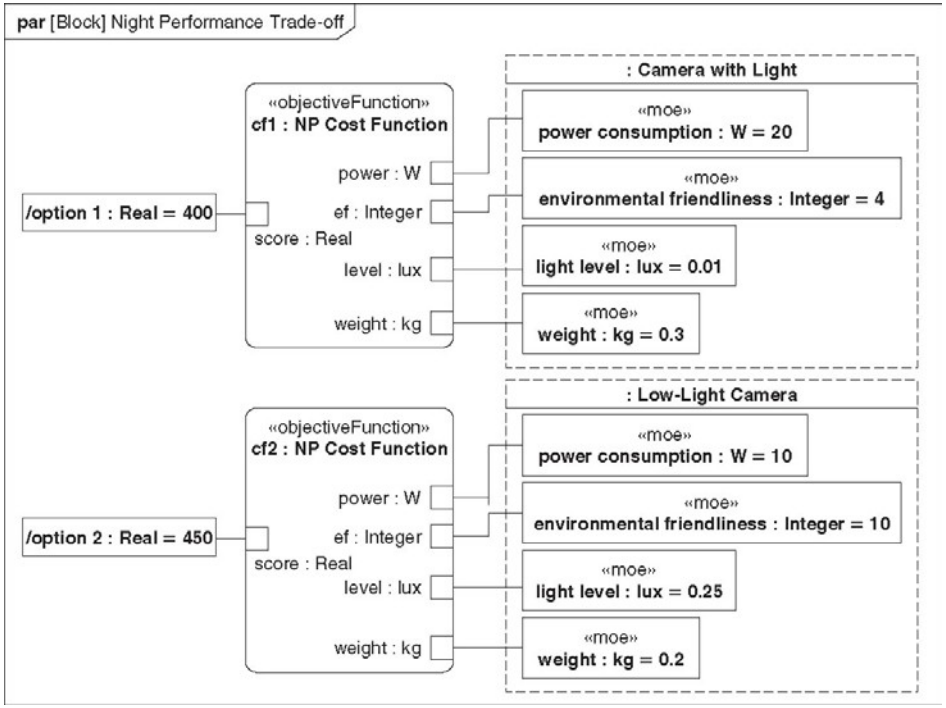
Modeling Trade Studies (cont'd)

- A Block is used to depict the Trade Study
- Trade Study Block:
  - References:
    - Blocks that represent the different alternatives
  - Comprised of:
    - Objective Function, that is used to evaluate the alternatives
    - Value Properties, to capture the score for each alternative



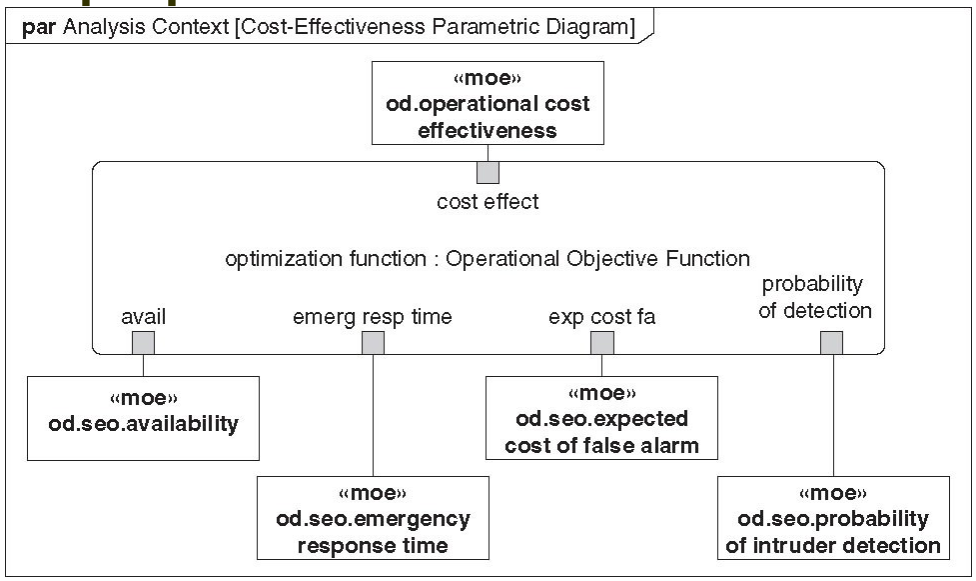
Modeling Trade Studies (cont'd)

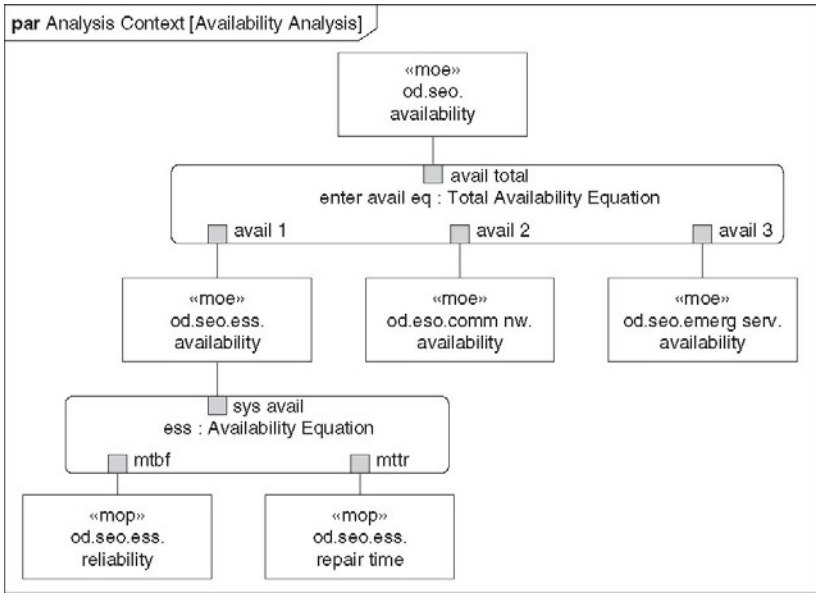
- Parametric diagrams are then used to relate the MOE's to the parameters of the Objective Function
- The Objective Function (score) specifies the overall value of each alternative



Modeling Design Optimization

- A Top-level Parametric Diagram can be used to model how an optimization function defines an overall operational effectiveness in terms of various MOEs
- Lower-level Parametric Diagrams can be established for analyzing each MOE
- This provides a flowdown from the top-level MOE to critical system properties

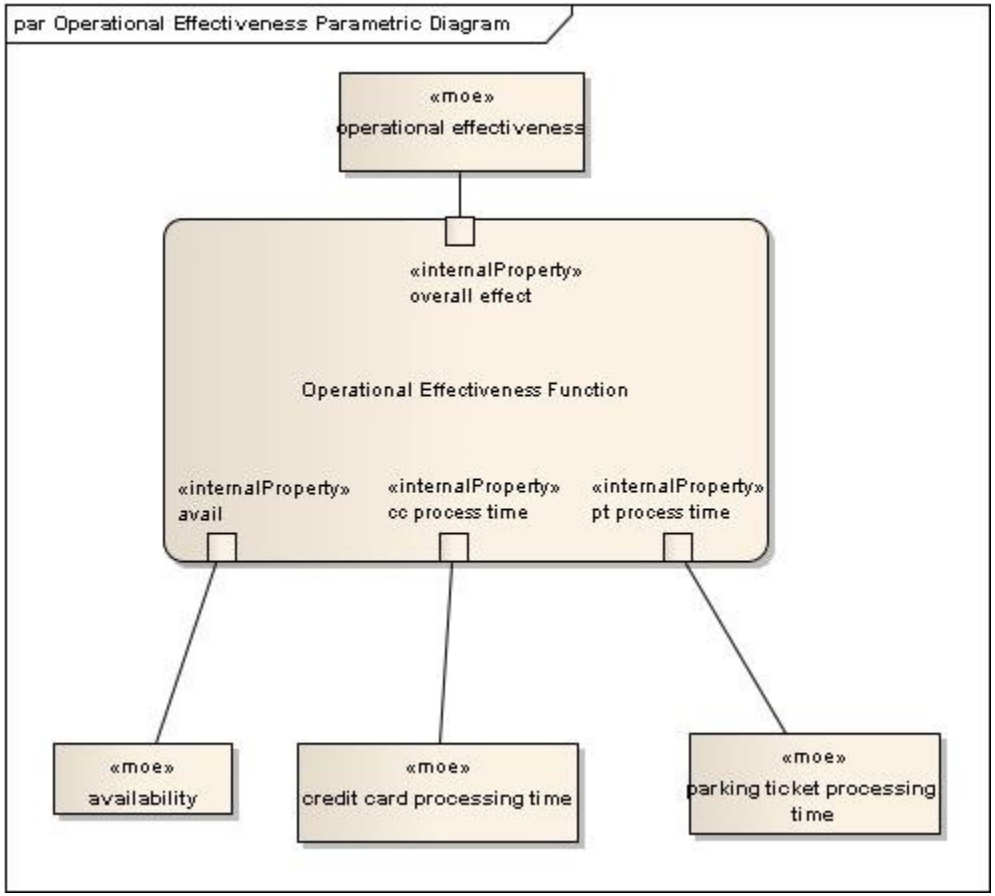




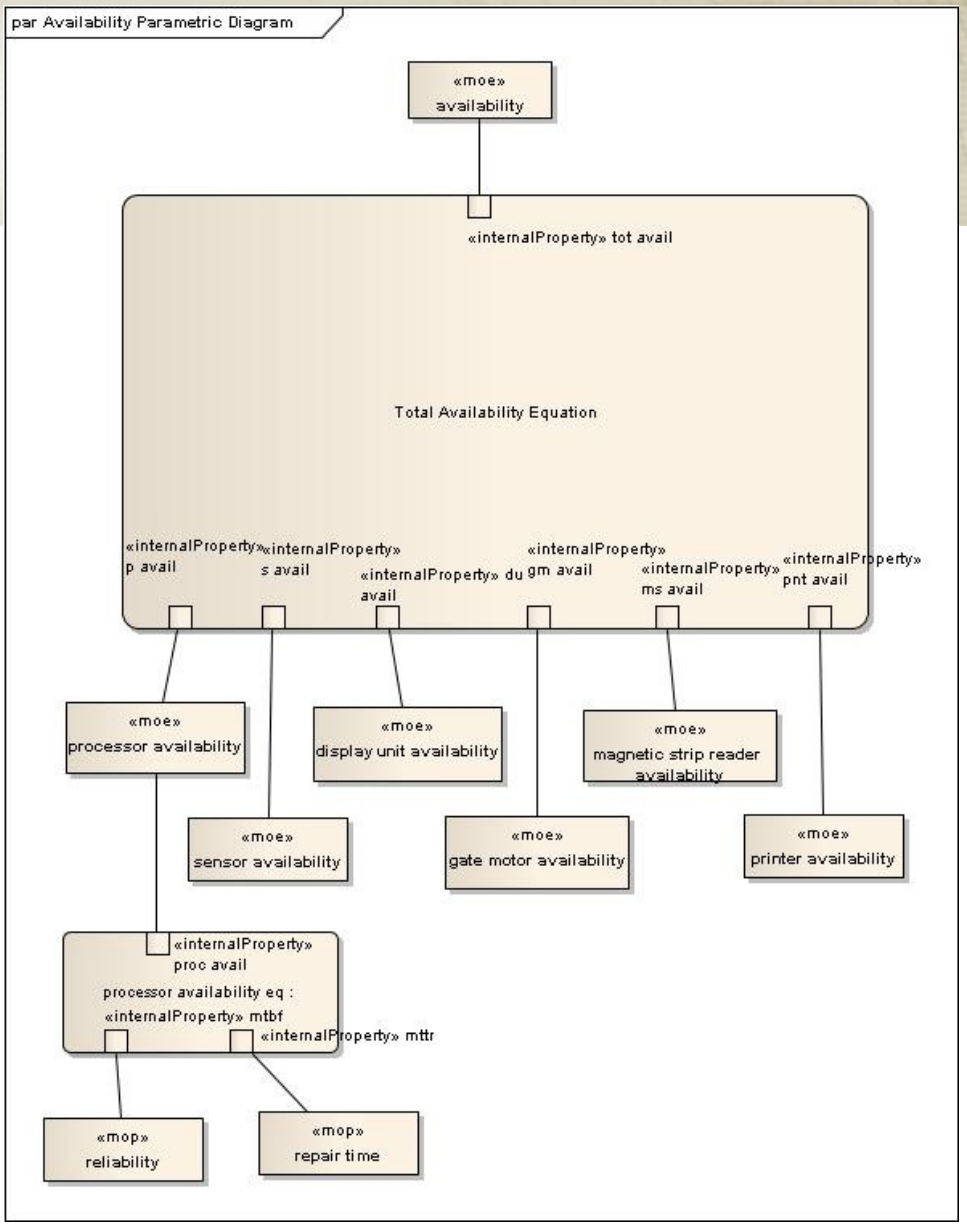
Modeling Parametrics for In-Class Project

- Create a Parametric Diagram for the Parking Garage Gate Project

Top-Level Parametric Diagram for Gate System



Availability Analysis



Summary

- Parametric diagrams
  - Capture the analysis as a network of equations
  - Help ensure consistency between the system design model and multiple engineering analysis models
  - Help to manage technical performance measures
- Constraint Blocks
  - Define parameters and constraint expressions
  - Represented on a Block Definition Diagram
- Constraint Property
  - Usage of constraint blocks
  - Represented on a Parametric Diagram