

# SysML - a modeling language for Systems Engineering

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Ingeniørhøjskolen i Århus &  
ASE: Aarhus School of Engineering

## Agenda

- Systems Engineering and SysML
  - SE processes
- What is SysML?
- New SysML concepts and diagrams
  1. SysML Requirements
  2. SysML Structure
  3. SysML Behaviour
  4. SysML Parametric
- SysML Tools
- Perspectives for SysML

## Systems Engineering



According to **INCOSE**:

*“Systems Engineering is an **engineering discipline** whose responsibility is creating and executing an **interdisciplinary process** to **ensure** that the **customer and stakeholder’s needs are satisfied** in a high quality, trustworthy, cost efficient and schedule compliant manner **throughout a system’s entire life cycle**”*

**INCOSE**: The International Council on Systems Engineering  
Founded in 1990, 6720 members in dec. 2008

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## Model Based Systems Engineering (MBSE)

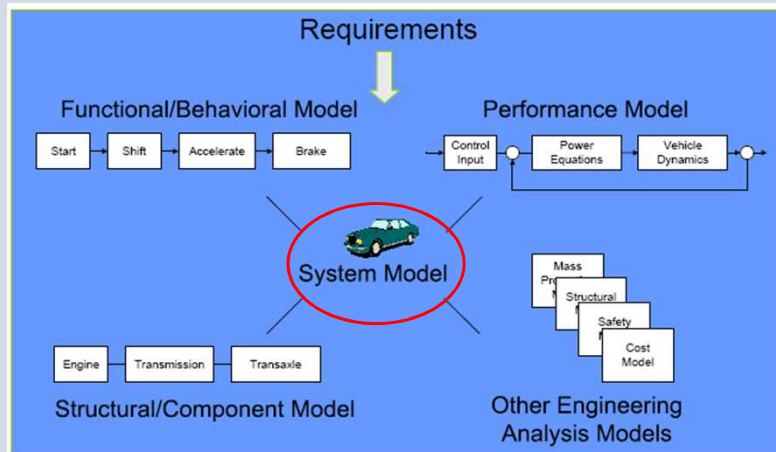


- From **document-based** to **model-based** approach
- A model-based approach requires modeling concepts and tools
- MBSE: producing and controlling a coherent **System Model**
- SysML is created to realize an MBSE approach based on a System model of the wanted system
- **SysML is a modeling language** not a **System Engineering (SE) process**

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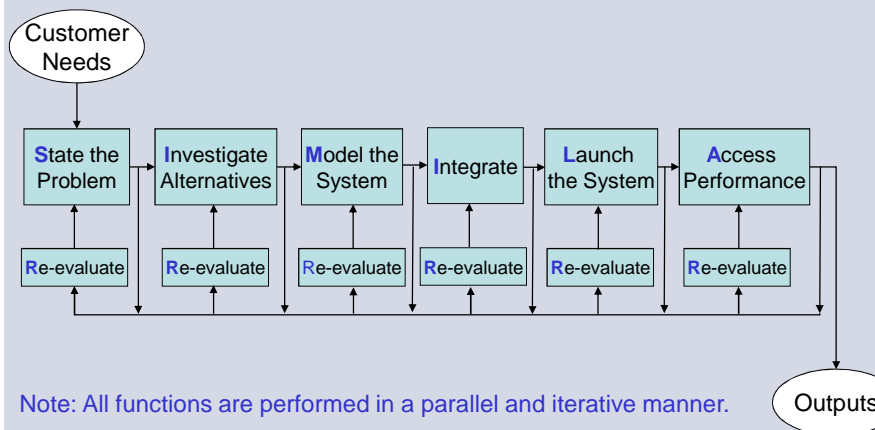
# Systems Modeling



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# The SIMILAR (SE) Process



Note: All functions are performed in a parallel and iterative manner.

Ref. A.T. Bahill and B.Gissing, 1998

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## The Harmony (SE) Process (IBM)

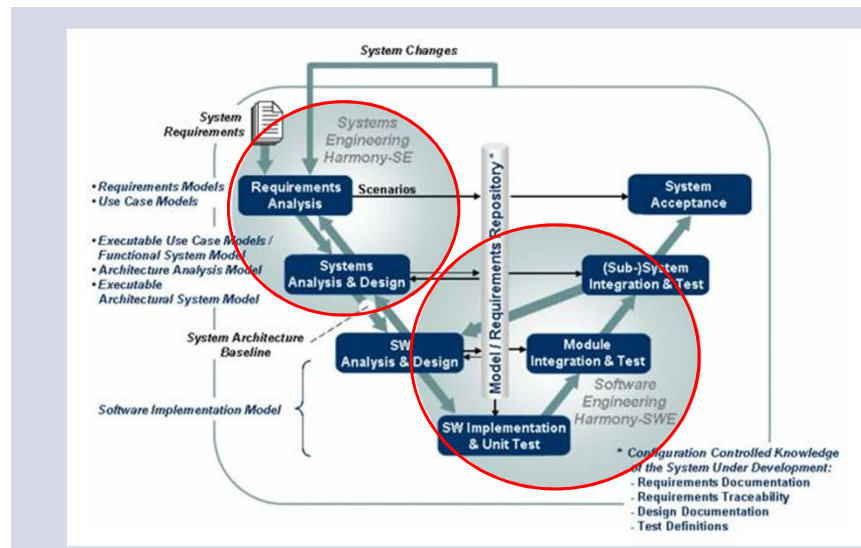


- The Harmony process facilitates a seamless transition from **Systems Engineering** to **Software Engineering**
  - It uses SysML exclusively for system representation and specification
- Harmony process characteristics:
  - a scenario-driven and iterative development process
  - promotes reuse of test scenarios throughout system development

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## Harmony Process for Systems Engineering



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## The Harmony process benefits



- The Harmony process models allow systems engineers to **find design errors** early in the development
- **Customer requests** can be more efficiently assessed, incorporated, and given timely feedback
- However, the **greatest benefit** of a model-driven process is **improved communication**
  - between engineering disciplines
  - between technical and non-technical parties
  - using different levels of abstraction
  - avoids information overload

## What is SysML?



- A graphical modeling language created in response to the UML for Systems Engineering RFP developed by the **OMG** and **INCOSE**.
  - a UML Profile that represents a subset of UML 2 with important extensions
- Supports the specification, analysis, design, verification and validation of systems that include **hardware, software, data, personnel, procedures, and facilities**
- Supports model and data interchange via **XMI**

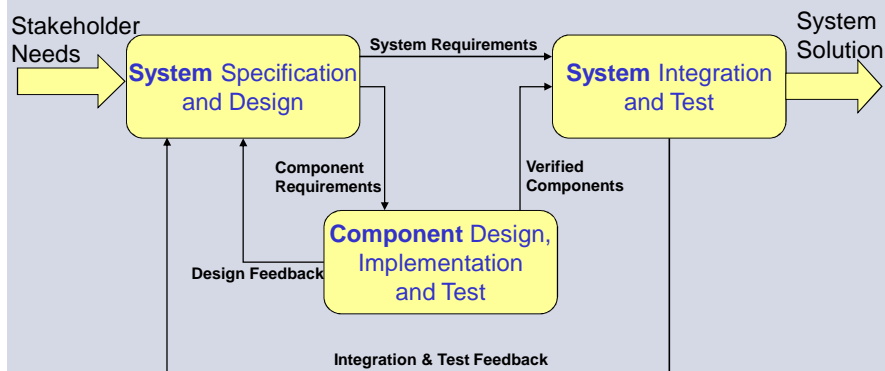
SysML is a Critical Enabler for Model Driven or  
Model Based Systems Engineering

# SysML Specification History and Status

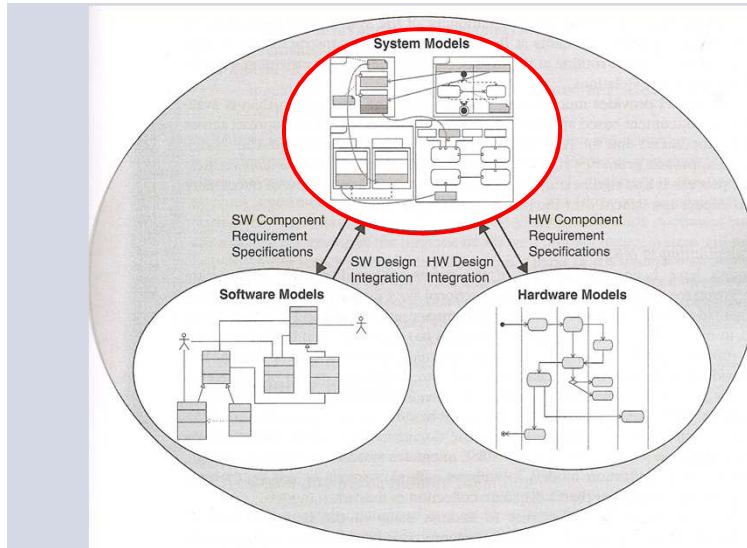


- **Nov. 1997: UML V1.1 launched by OMG**
- **March 2003:** The UML for Systems Engineering RFP (Request for Proposal) was developed jointly by **OMG** and **INCOSE**
  - The SysML specification was developed in response to these requirements by the diverse group of **tool vendors, end users, academia, and government representatives**
- **Sept. 2007:** OMG SysML v.1.0
- **Nov. 2008:** OMG SysML v1.1 (256 pages)
- **June 2010:** OMG sysML v.1.2  
(doc.id: formal/2010-06-01, 260 pages)

# Systems Engineering Technical Processes



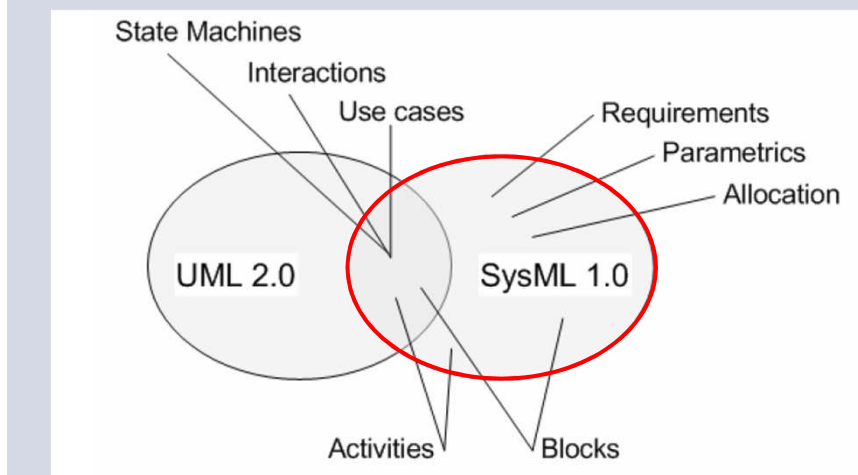
# System Model and HS/SW Components



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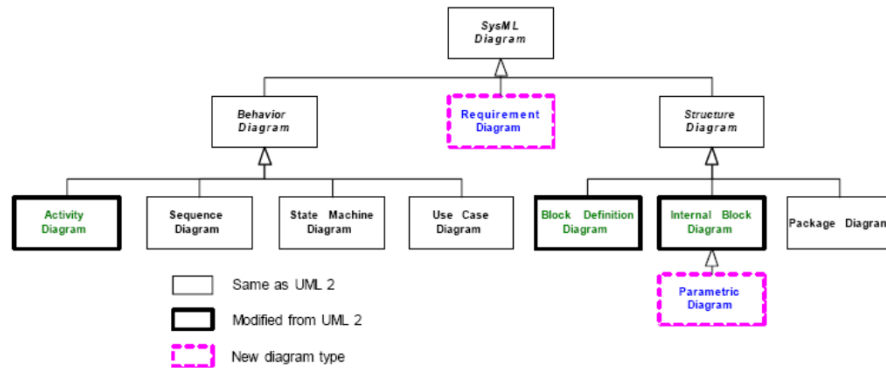
# Comparison of SysML and UML



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# SysML Diagram Taxonomy



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# Major Extensions compared to UML 2.x

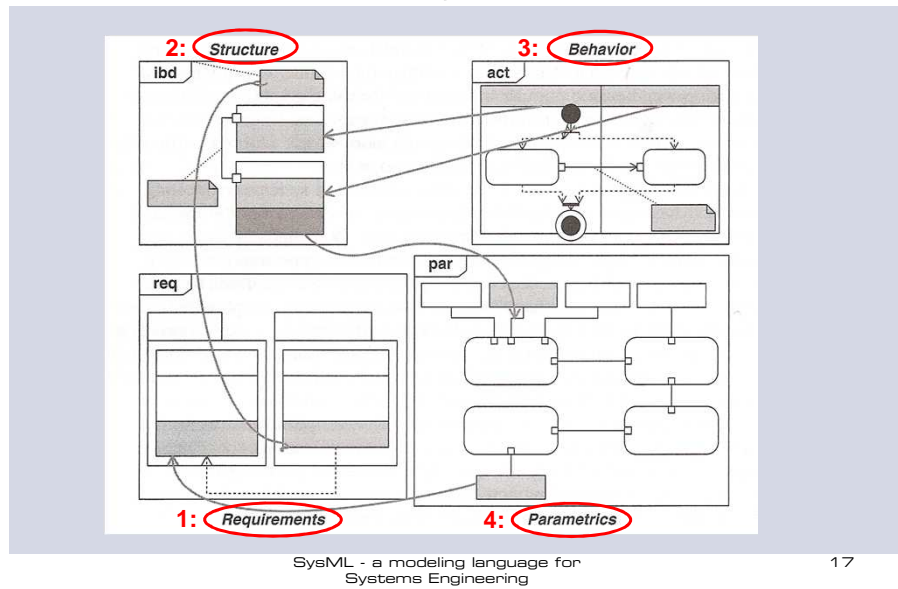


- New Diagram Types
  - Requirement Diagram (req)
  - Parametric Diagram (par)
- Structure Diagrams
  - Block Definition Diagram (bdd)
  - Internal Block Diagrams (ibd)
- Activity Diagrams
  - extensions for **continuous flow** modeling
  - extensions to support control operators

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## The 4 Pillars of SysML



## Project activities using SysML

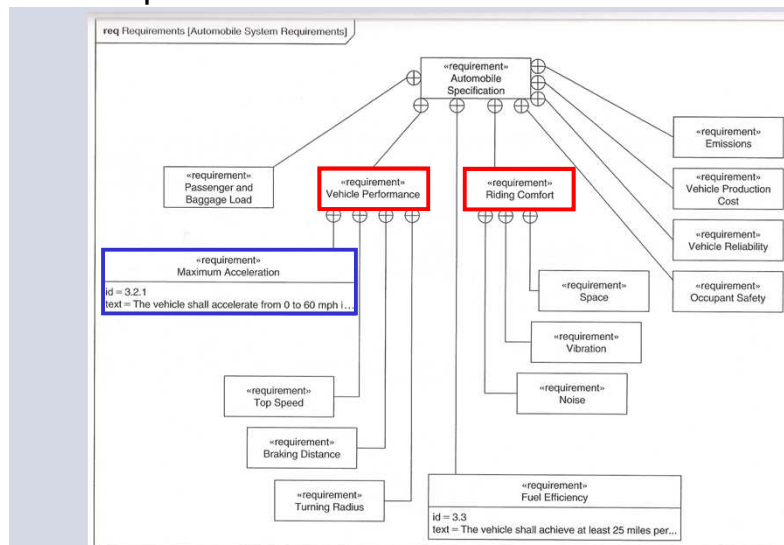


1. Capture and analyze black box system requirements
  - System Context & System Use Cases, Requirement diagrams
2. Develop one or more candidate system architectures
  - Block Definition & Internal Block diagrams
3. Perform engineering trade-off analysis to evaluate and select the optimal architecture
  - Parametric Diagrams
4. Specify component requirements and their traceability to system requirements
  - Requirement diagram
5. Verify the system design by executing system-level test cases

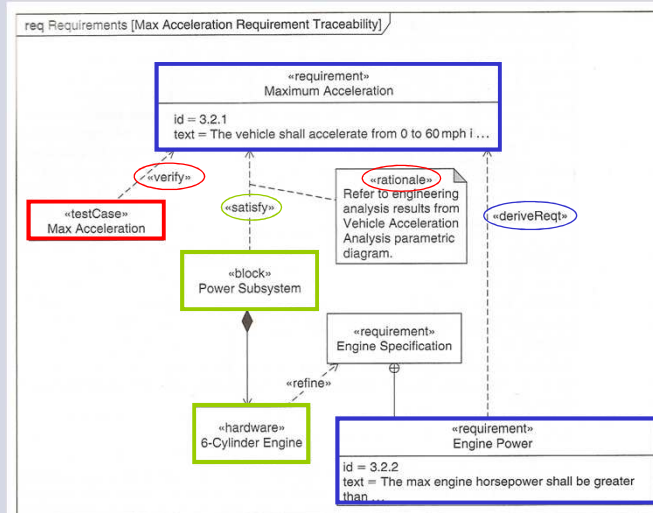
# 1. SysML Requirements

- Requirement Diagram – a NEW diagram type
- Graphical visualization of requirements
  - Functional
  - Non-functional
- Requirements can graphical be related to:
  - Other requirements
  - Design elements
  - Test Cases
- Standard stereotypes:
  - **derive, satisfy, verify, refine, trace and copy**
  - Used for requirement **traceability**

## Requirements Diagram Example



## Requirements Traceability Example



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## 2. SysML Structure



- UMLs class concept is replaced with the **Block** concept
- A Block connects to other blocks via **Ports**
- Class diagrams are replaced with **Block Definition Diagrams (bdd)**
- Each Block has an **Internal Block Diagram (ibd)** where the internal parts are connected via **ports**
  - a replacement for class composite diagrams
- **Ports** can connect **discrete** as well as **continuous flows of material or information**

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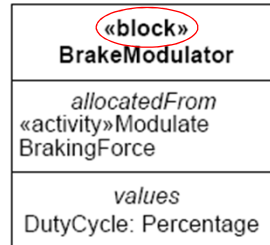
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## Blocks are Basic Structural Elements



- Provides a unifying concept to describe the structure of an element or system

- Hardware
- Software
- Data
- Procedure
- Facility
- Person

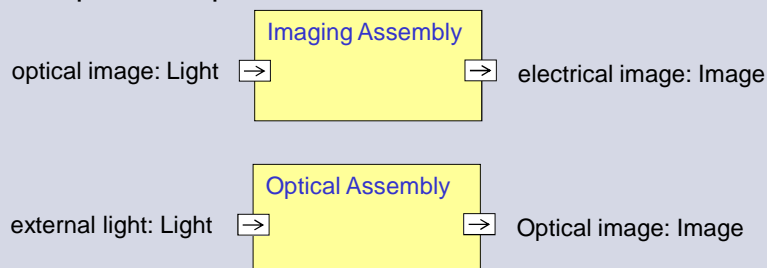


- Multiple compartments can describe the block characteristics
  - Properties (parts, references, values)
  - Operations
  - Constraints
  - Allocations to the block (e.g. activities)
  - Requirements the block satisfies

## Blocks and Atomic Flow Ports



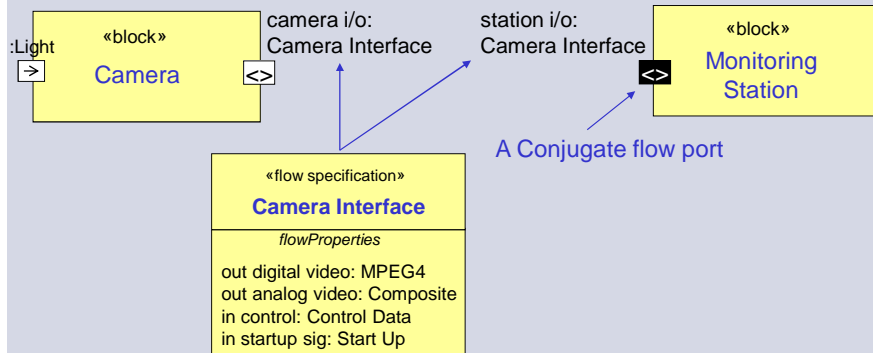
- A **flow port** describes an interaction point for items flowing in or out of a block
- An **atomic flow port** specifies only a single type of input or output



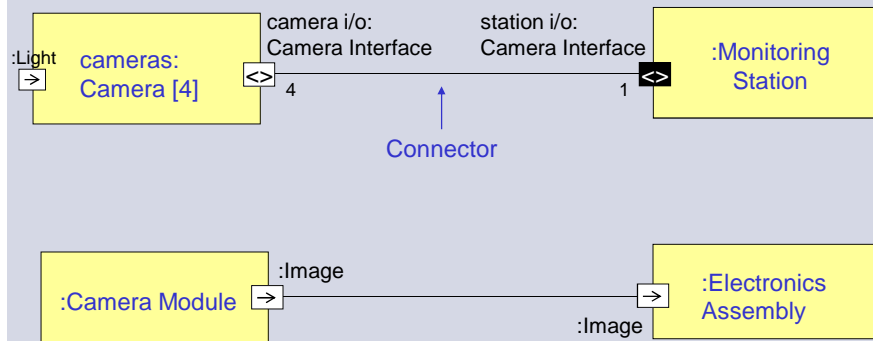
# Blocks and Nonatomic Flow Ports



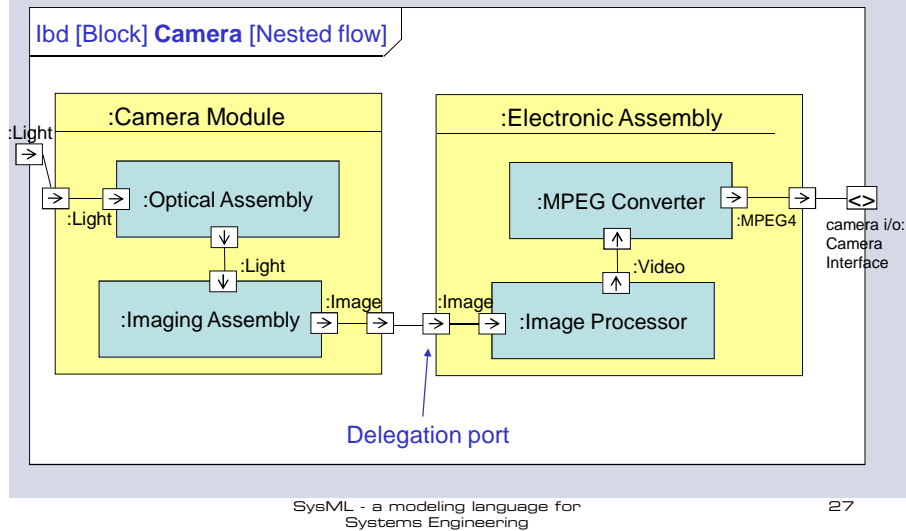
An interaction point with a complex interface is modeled as a **Nonatomic Port**



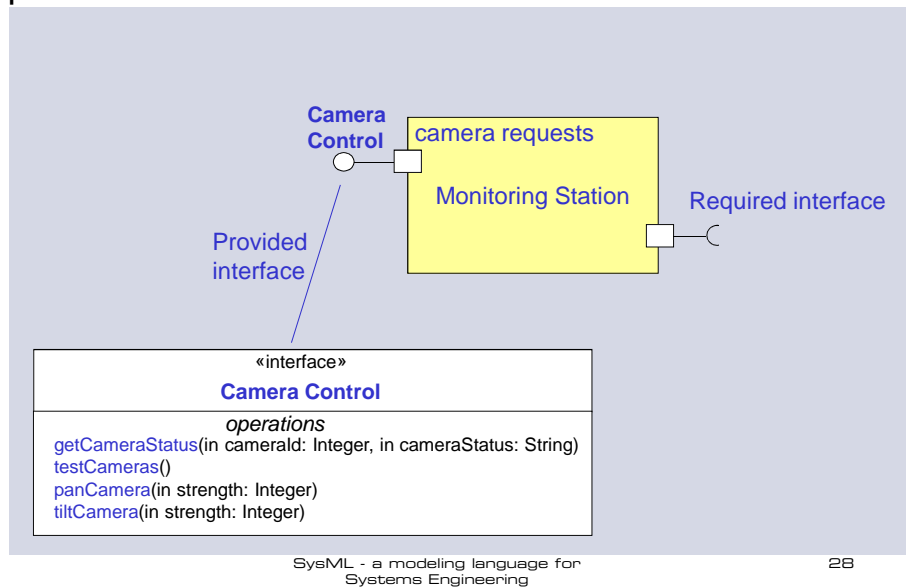
# Connector and Ports



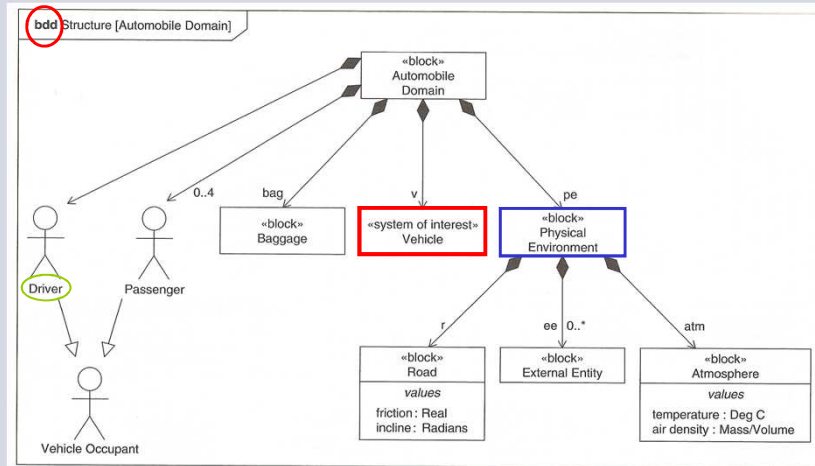
## Delegation Ports



## Standard (service based) ports



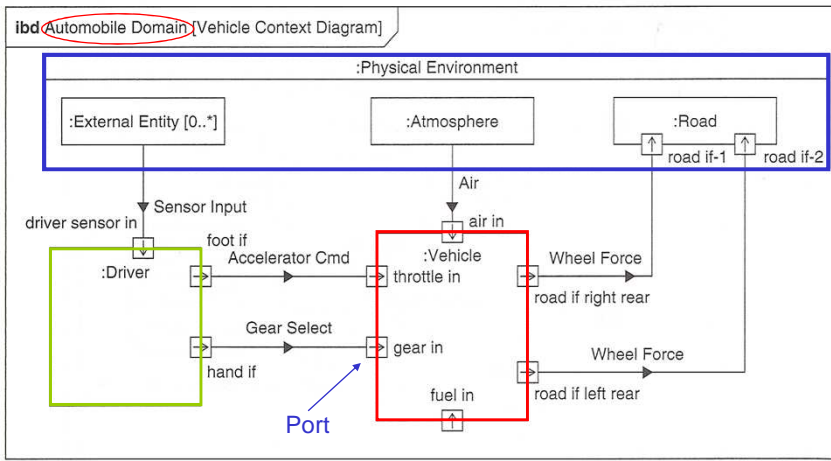
# Block Definition Diagram Example



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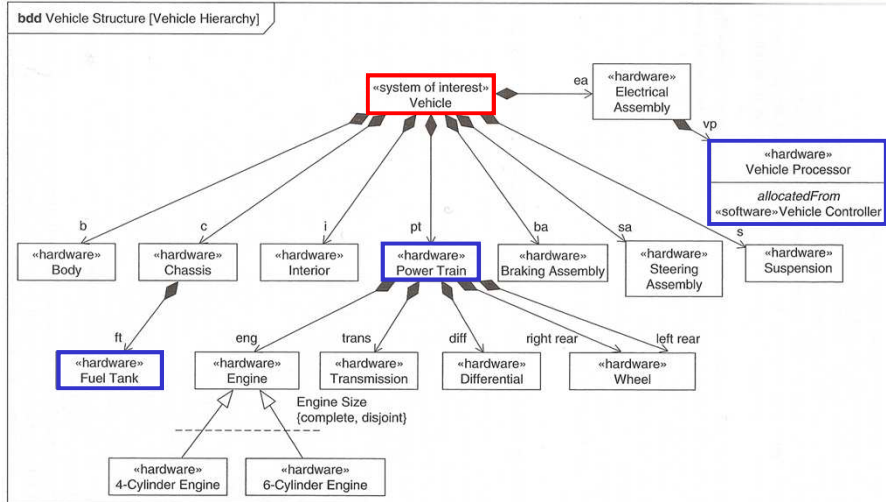
# Internal Block Diagram for an Automobile Domain



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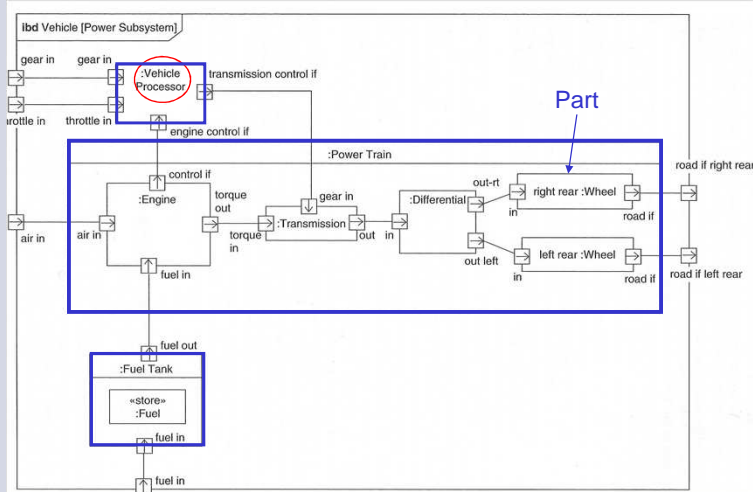
# Block Definition Diagram Example



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# Internal Block Diagram Example

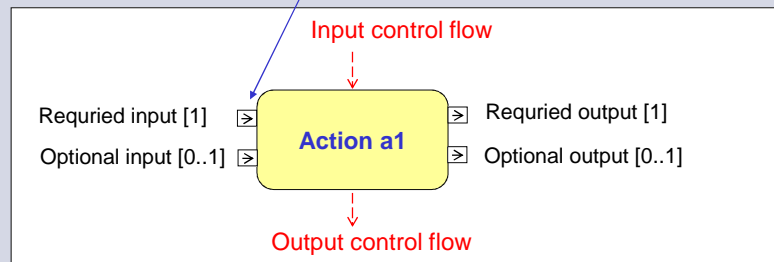


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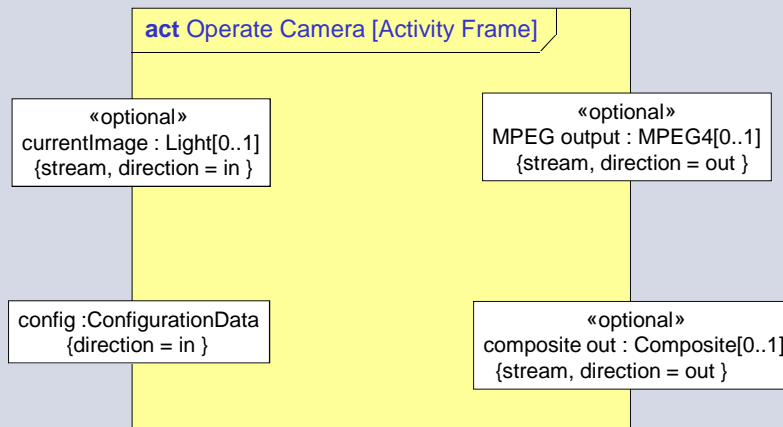
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### 3. SysML - Behavior

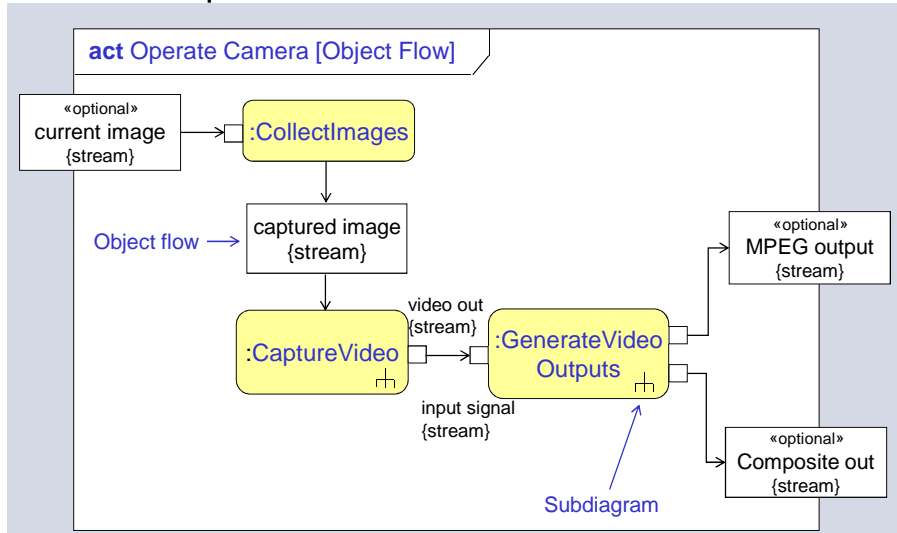
- Activity diagrams are enhanced with new concepts
- Flows can be **continuous** and model **information** as well as **material flow**
- Control flows are introduced
- Activities can have pins



### Activity Diagram with Parameter Nodes



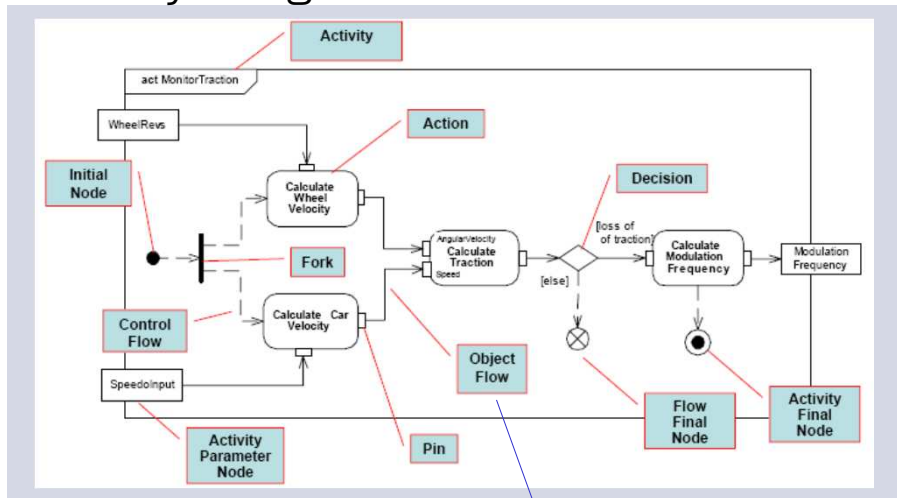
# Activity Diagram - decomposed



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# Activity Diagram Notation

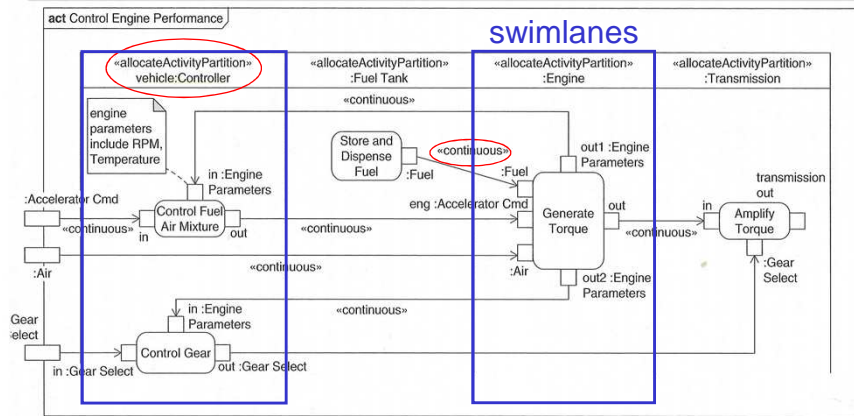


Flows can be discrete, streaming or control

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# Activity Diagram Example



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## 4. SysML Parametric

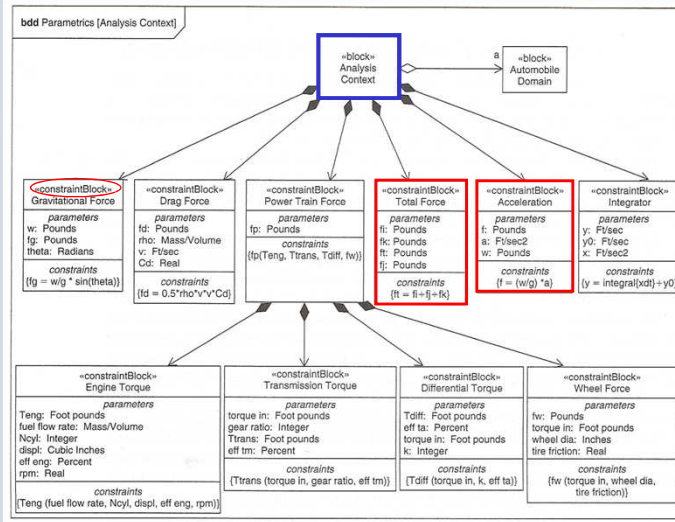


- Parametric Diagram – a NEW diagram type
- Used to express constraints (equations) between value properties
  - Provides support for engineering analysis (e.g., performance, reliability)
- Constraint block captures equations shown on a bdd
  - Expression language can be **formal** (e.g., MathML, OCL) or **informal**
  - Computational engine is defined by applicable analysis tool and not by SysML
- Parametric diagram represents the usage of the constraints in an analysis context
  - Binding of constraint usage to value properties of blocks (e.g., vehicle mass bound to  $F = m \times a$ )
- Parametric enable integration of engineering analysis with design models

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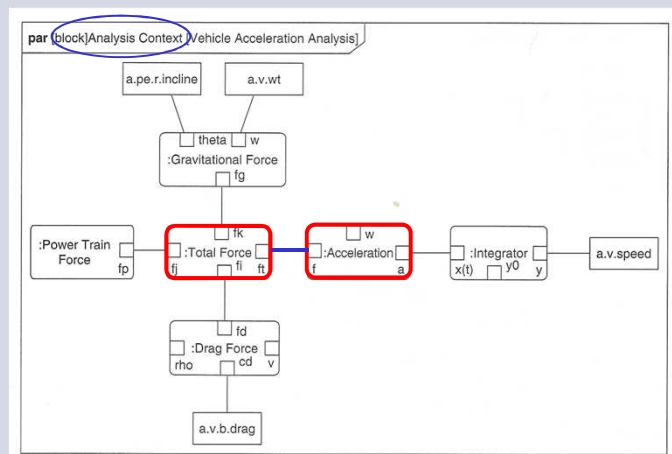
# BDD Parametric Constraint Blocks



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# Parametric Diagram - Example



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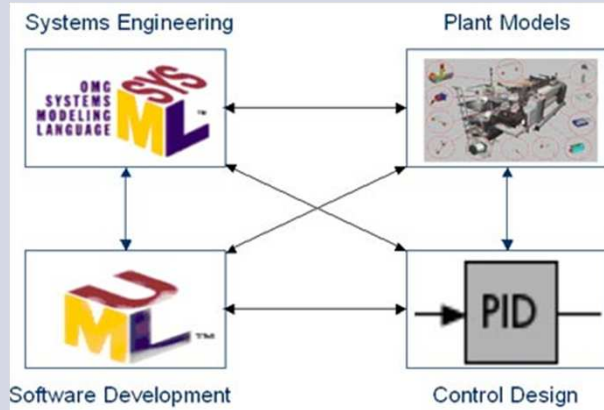
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# Combining Model-Driven (MDD) and Model Based Design (MBD) in Industrial Machine Control



**MDD: Model Driven Development in Rhapsody (IBM)**

**MBD: Model Based Design in Simulink (Mathworks)**



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# MDD versus MBD Feature Comparison



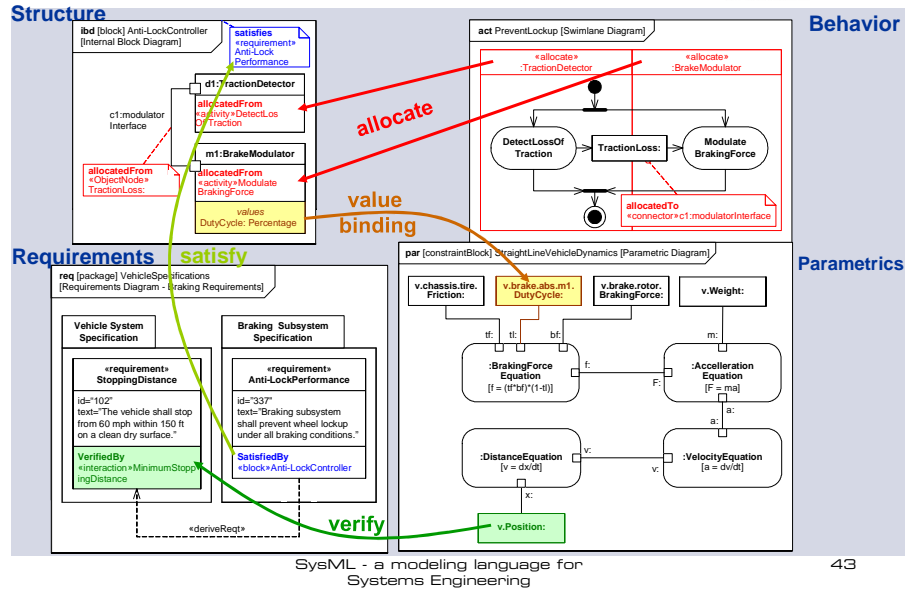
Tool Environment Capabilities	Rhapsody	Simulink
Systems and Software Development Environment	X	
Mathematical Block Diagram Environment		X
UML 2.1, SysML 2.0 Based Code Generation	X	
Dynamic Controls and Signal Processing Engineering		X
Logical Algorithm Development		X
Requirements Traceability & Documentation	X	
Define Physical, Functional & Software Architecture	X	
Mathematical Algorithm Development		X
SysML/UML Analysis, Simulation & Test	X	
Physical Plant Behavior Modeling		X

Table 1. MDD versus MBD feature comparison

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# Cross Connecting Model Elements



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# SysML tools



- [ARTiSAN Software Tools](#) (multiuser and free single user version)
- [IBM Rational® Rhapsody® Developer](#) is a UML/SysML-based, model-driven development environment for real-time and embedded systems and software
- [EmbeddedPlus Engineering](#) (third party tool for IBM Rational)
- [Magic Draw – SysML Plugin](#)
- [Papyrus for SysML](#) (open source eclipse modeling tool)
- [InterCAX](#) (ParaMagic: SysML Parametrics for MagicDraw)
- [Software Stencils](#) - Microsoft Visio SysML and UML templates
- [Spax Systems Enterprise Architects](#) (supports SysML)

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## Perspectives for SysML



- Enable a common modeling language and model across engineering disciplines
- Enable traceability between disciplines
- Enable different kinds of system analysis
- Enable integration of discrete and continuous based modeling tools
- Critical enabler for Model Based System Engineering with tool support

## Summary



- SysML a common modeling language for different disciplines e.g. Hardware, Software and Mechanics
- New and important concepts for cross disciplinary analysis of system properties (e.g. parametric)
- Blocks and ports as general modeling elements
- Important enhancement to activity diagrams
- Lot of support for traceability between models and model elements
- Must be supported by an appropriate Systems Engineering (SE) process

## References

- OMGs SysML homepage: [www.omgsysml.org](http://www.omgsysml.org)
- INCOSE organization: [www.incose.org](http://www.incose.org)
  - "Re-evaluating systems engineering concepts using systems thinking", A.T. Bahill and B. Gissing, IEEE Transaction on Systems, Man and Cybernetics, Part C, 28 (4), 516-527, 1988.
- IBM Rational Harmony:
  - <http://www-01.ibm.com/software/rational/services/harmony/>
- **Books:**
  - "A Practical Guide to SysML – The System Modeling Language", Sanford Friedenthal, Allan Moore, Rick Steiner, Elsevier, 2008.
  - "Systems Engineering with SysML/UML – Modeling, Analysis, Design", Tim Weilkiens, Elsevier, 2007.

