# SysML

## OODA approach to  Systems Engineering

# Goals

- Appreciating the science of Architecture
- Issues involved with RT System Arch.
- Take a Look at a modeling language
- Peek into the future for the trends in Indus.
- Get a feel for the role that an architect plays in the development process

# SysML

- Abstract view on things
- Modeling Requirement of RT Systems
- OMG’ s MDA
- UML overview
- Finally…. SysML spec.
- Case Study
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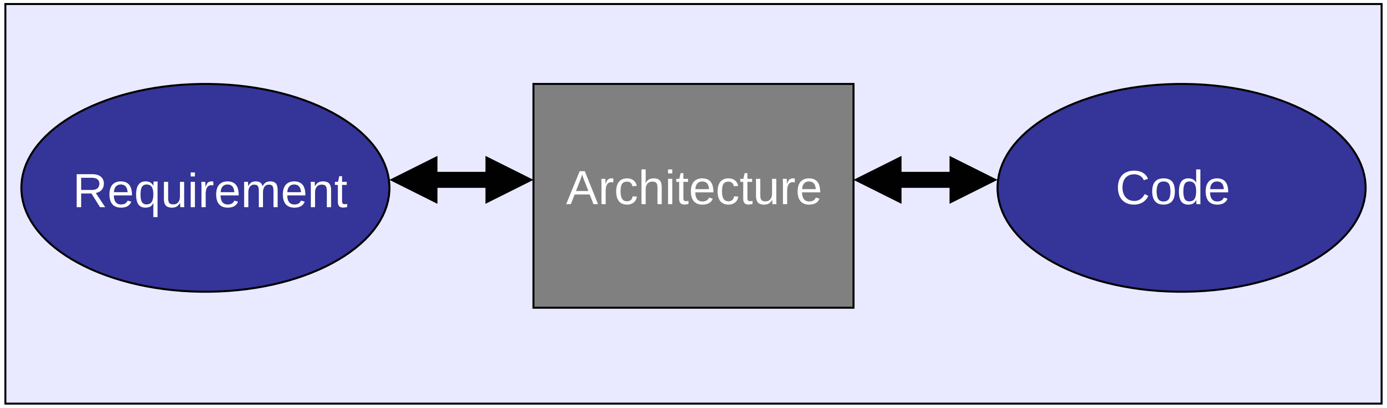
*Some Definition ….*

***Software Architecture** of a program or computing system is the structure/structures of a system which comprises of software components, the externally visible properties of those components and the relationships among them.*



Features that you can attach to a Software Architecture -

- Organization of system as a composition of components
- Identifies global control structures
- Provides protocols for communication
- Provides synchronization & data access
- Is a composition of design elements
- Provides physical distribution
- Adds dimension towards evolution

Hmmm…..but what role does it play ?

- Understanding
- Reuse
- Construction
- Evolution
- Analysis
- Management
- Communication

System Consistency checking, constraints, conformance to quality ,dependency analysis & domain specific analysis

Three important advancements in the technology basis of Architecture –

1) Development of Architecture description languages and tools .
2) Emergence of product line engineering and architecture standards.
3) Codification and dissemination of architecture design expertise.

ADL has tools for parsing, displaying, compiling, analyzing or simulating architectural descriptions.

**Egs.** Acme, **Adage**, Aesop, Darwin, Rapide ,SADL , Unicon, **Meta-H**, Wright

# SysML

- Classes of views identified
  - Code-oriented view
  - Execution oriented view

- Execution-oriented views should have

1) **Components** – multiple interfaces to environment

2) **Connectors** – Interactions among components ; mediate communications and coordinate activities among components

3) **Systems** – Graphs of components and connectors

4) **Properties** – Used to represent anticipated & required extra-functional aspects of architecture designs

5) **Styles** – Vocabulary of design elements

## OO Analysis

- Builds a model of a system that is composed of objects.
- Behavior of the system is achieved through collaboration between these objects
- The state of the system is the combined state of all the objects in it.
- An analysis model will not take into account implementation constraints.

## OO Design

- System is modeled as a collection of cooperating objects

- Relationships between Architecture and OO methods. Three perspectives proposed-
  - OOD as Architectural Style
  - OOD as implementation base
  - OOD as modeling notation

Choose any one of these !!!!

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**Modeling Real time Systems – Joseph Sifakis (VERIMAG+CNRS)**

Requirements related to development of real time Systems

- Cost effectiveness & time to market
- Fast evolving environment with rich dynamics
- Combination of Hard/Soft RT activities which implies –scheduling policies respecting optimality criteria .Soft RT harder to visualize ‘cause of changing timing requirement.
- Behavior which is dynamically adaptive, reconfigurable, reflexive, intelligent etc.
- Dependability covering in particular reliability, security, safety & availability

# Why do we need modeling ….

- Need of unified view of various lifecycle activities and their interdependencies ,motivated model-based approaches, which heavily rely on use of modeling tool & methods to provide support & guidance for development & validation.

# Modeling RT systems

1) **Component Based Modeling** – models built composing components which are model units fully characterized by their interface.

2) **Timed Modeling**

## Summary behind the discussion

- A dynamic model of RT system can be realized by adequately restricting the behavior of its application software with timing information

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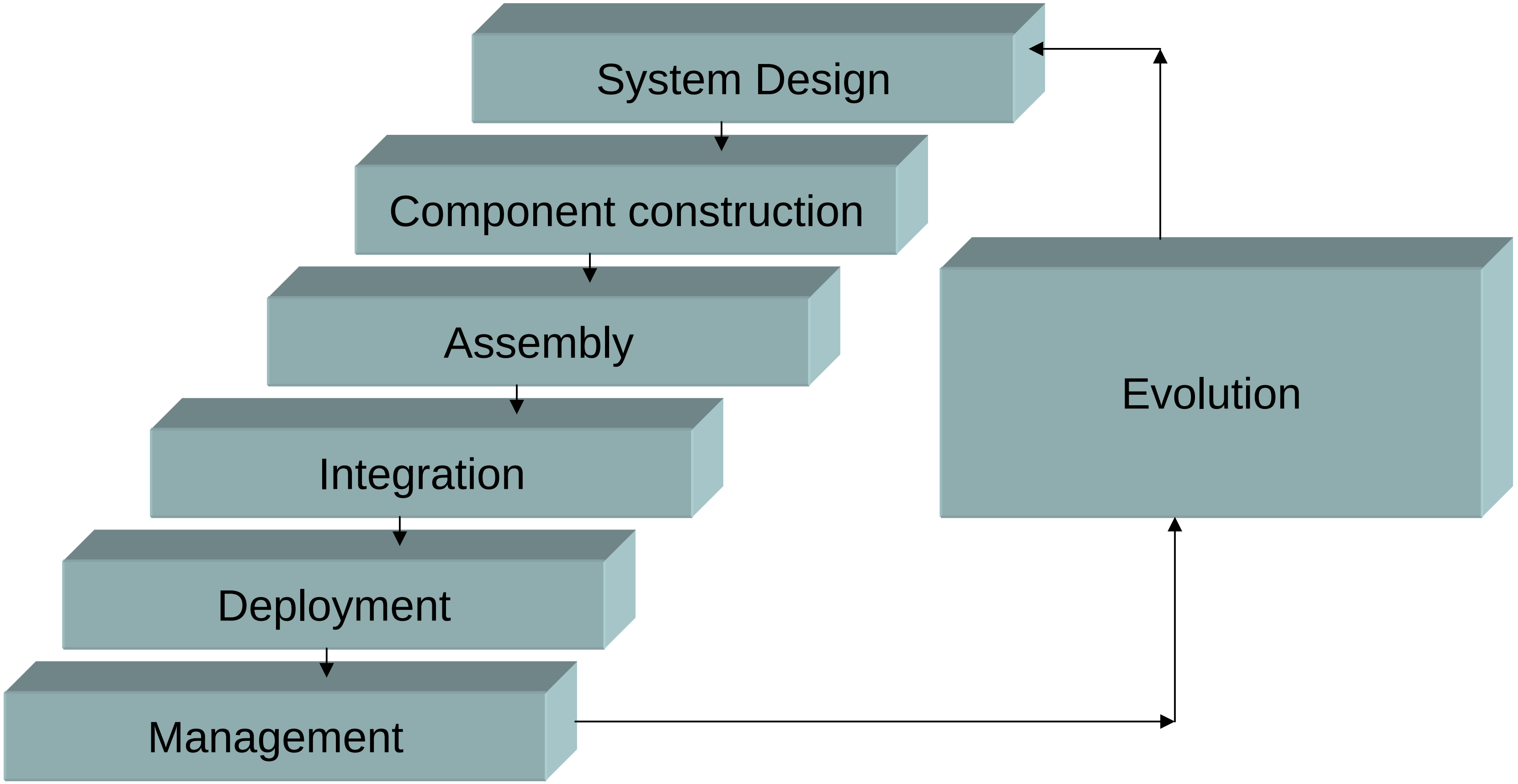
- Model Driven Architecture

Provides an open vendor neutral approach to the challenges of business and technology change. It separates business and application logic from underlying platform technology.

# SysML

During the development process of any system it is necessary to support interoperability with specifications that address integration through entire lifetime of the system :



MDA integrates through –

1) Embracing tech. like CORBA,J2EE,XML,.NET etc.

2) Improving the portability of applications by allowing some model to be realized on multiple platforms through mapping standards.

3) Improving integration based on models of relationships across different domain applications & interfaces allowing interoperability.

# SysML

PIM – Platform Independent Models

- Provides formal specification of the structure and function of the system that abstracts away technical details.

- Describes the computational components and their interactions in a platform-independent manner.

Eg. CORBA

PSM – Platform Specific Models

- Functionality specified in PIM is realized in platform-specific way in the PSM.

- Derived from the PIM via some transformation.

Eg RMI stub, skeleton

All OMG stds. are based on this approach of defining systems in terms of PIM and one or more PSM. Eg. UML

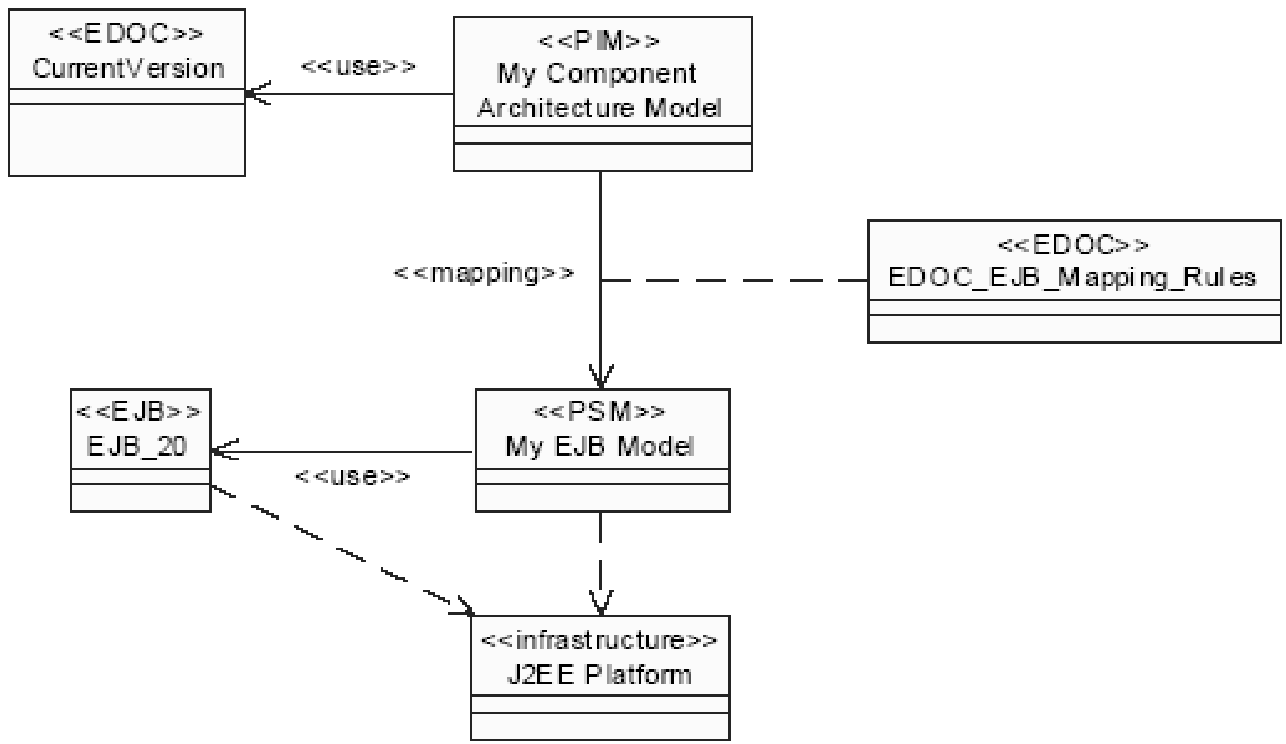
# SysML

PIM has OCL (Object Constraint language)

- It formalizes the vocabulary otherwise left imprecise in interface Specification (JAVA & Microsoft IDL).
- Abstract yet precise model of state of object providing interface and any parameter exchanged.

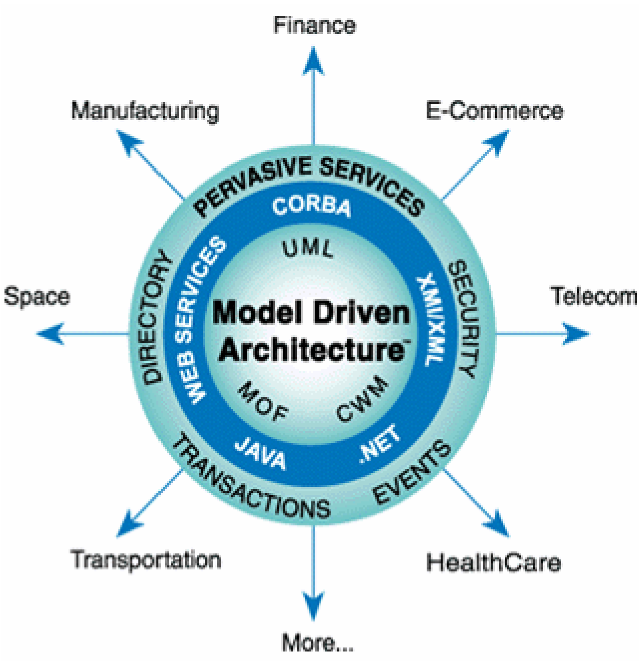
PIM to PSM mappings are maintained to provide the mapping between logical component model to existing commercial component model (eg EJB for J2EE)

# Meta Model Example




**EDOC - Enterprise Distributed Object Computing**

- MDA Spec. Intuitive approach…



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# UML – Unified Modeling Language

The Unified Modeling Language (UML) is a standard language for specifying, visualizing, constructing and documenting the artifacts of software systems, as well as for business modeling and other non-software systems.

The UML represents a collection of best engineering practices that have proven successful in the modeling of large and complex systems.

# UML – Unified Modeling Language

Historical stuff –

- Development of UML began in late 1994 when Grady Booch and Jim Rumbaugh of Rational Software Corporation began their work on unifying the Booch and OMT (Object Modeling Technique) methods.

- In the Fall of 1995, Ivar Jacobson and his Objectory company joined Rational and this unification effort, merging in the OOSE (Object-Oriented Software Engineering) method.

- As the primary authors of the Booch, OMT, and OOSE methods, Grady Booch, Jim Rumbaugh, and Ivar Jacobson were motivated to create a unified modeling language as all were working on common things.

Six diagram types represent static application structure; three represent general types of behavior; and four represent different aspects of interactions:

**Structure Diagrams**

- Class Diagram
- Object Diagram
- Component Diagram
- Composite Structure Diagram
- Package Diagram
- Deployment Diagram.

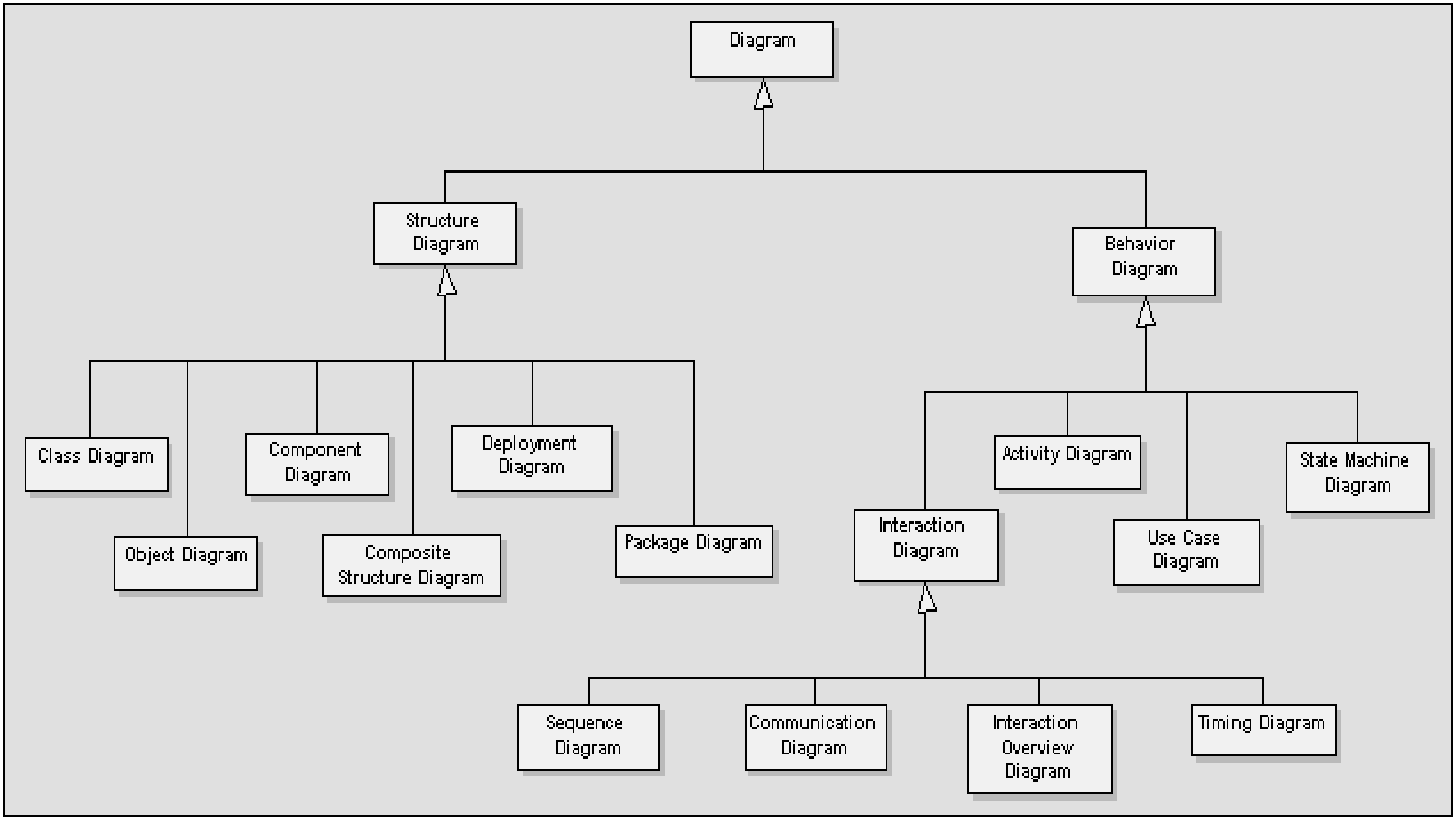
**Behavior Diagrams**

- Use Case Diagram
- Activity Diagram
- State Machine Diagram.

**Interaction Diagrams,**

- Sequence Diagram
- Interaction Overview Diagram
- Communication Diagram
- Timing Diagram

# UML 2 Super Structure Spec.



# Structure Diagrams

## Class Diagram

Class diagram shows the relationships between the various classes in the System .The Classes being identified using the OOD paradigm. It's a static diagram and hence does not show the way in which the interaction happens.

**association** -- an instance of one class must know about the other in order to perform its work. (  )

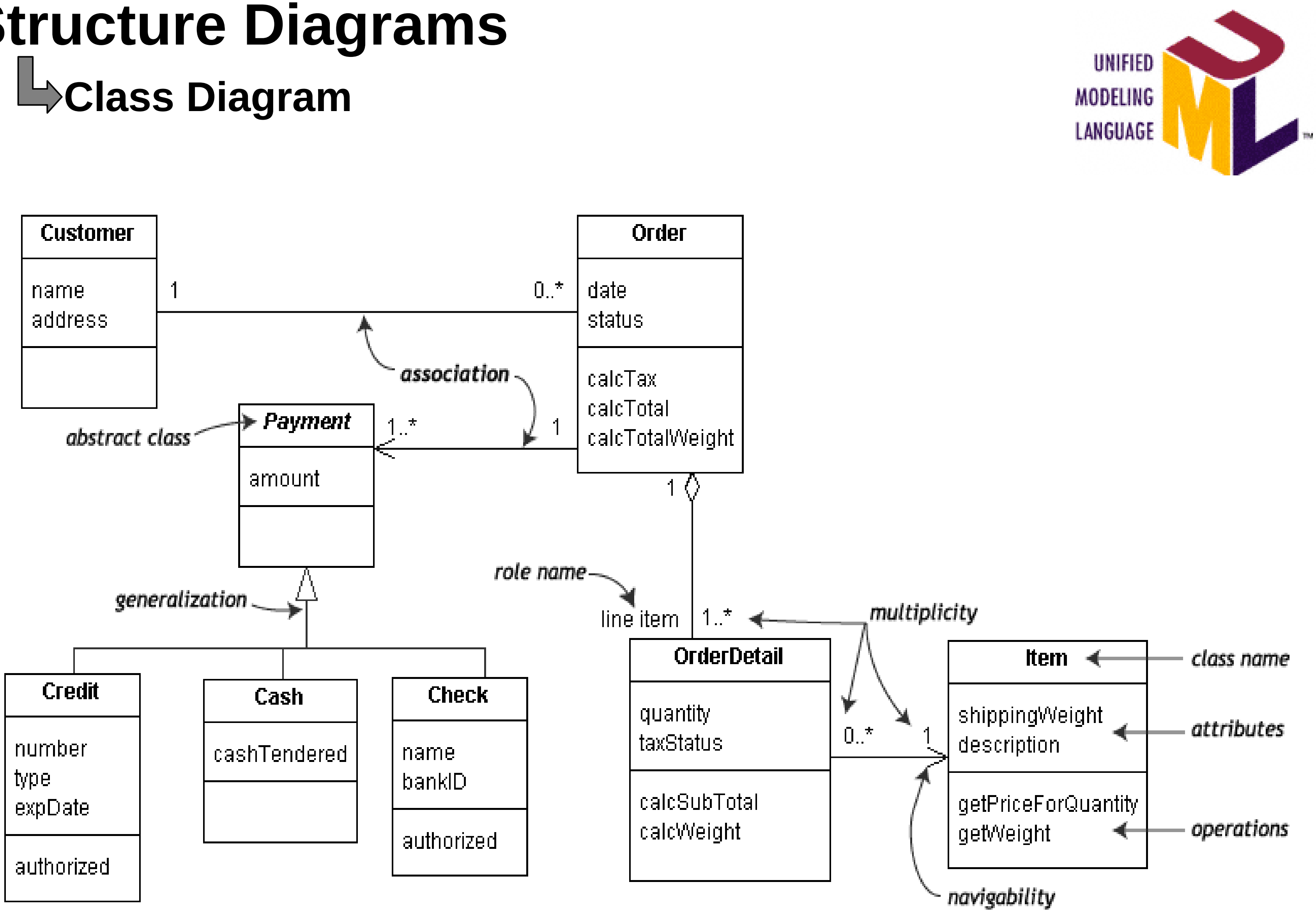
**aggregation** -- an association in which one class belongs to a collection. (  )

**composition** -- an association in which one class is composed of other classes.(  )

**generalization** -- an inheritance link indicating one class is a superclass of the other. (  )

# Structure Diagrams

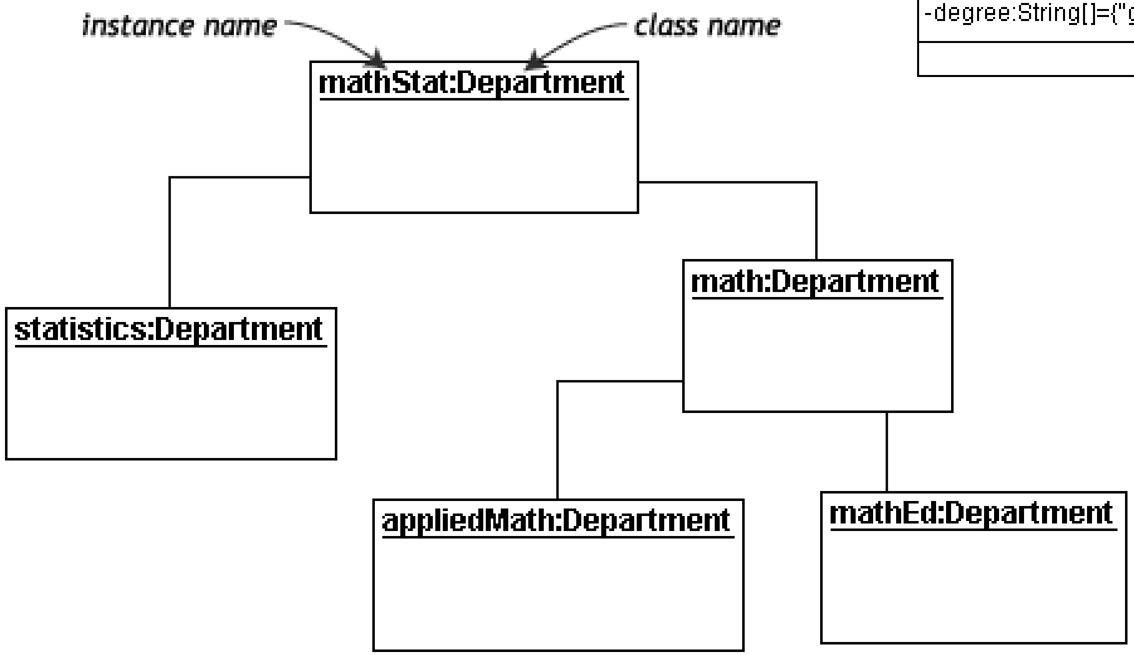
## Class Diagram

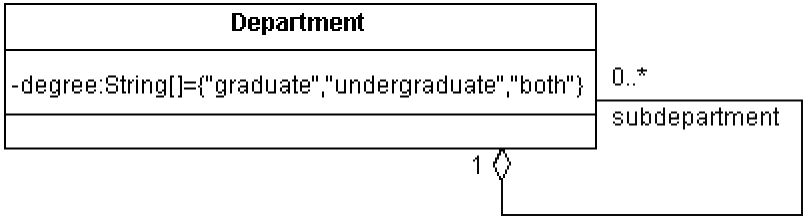


# Structure Diagrams

## Object Diagram

The relationships is shown in terms of the instances created of the objects that we defined .The various objects instantiated are shown as well the relationships between those objects.

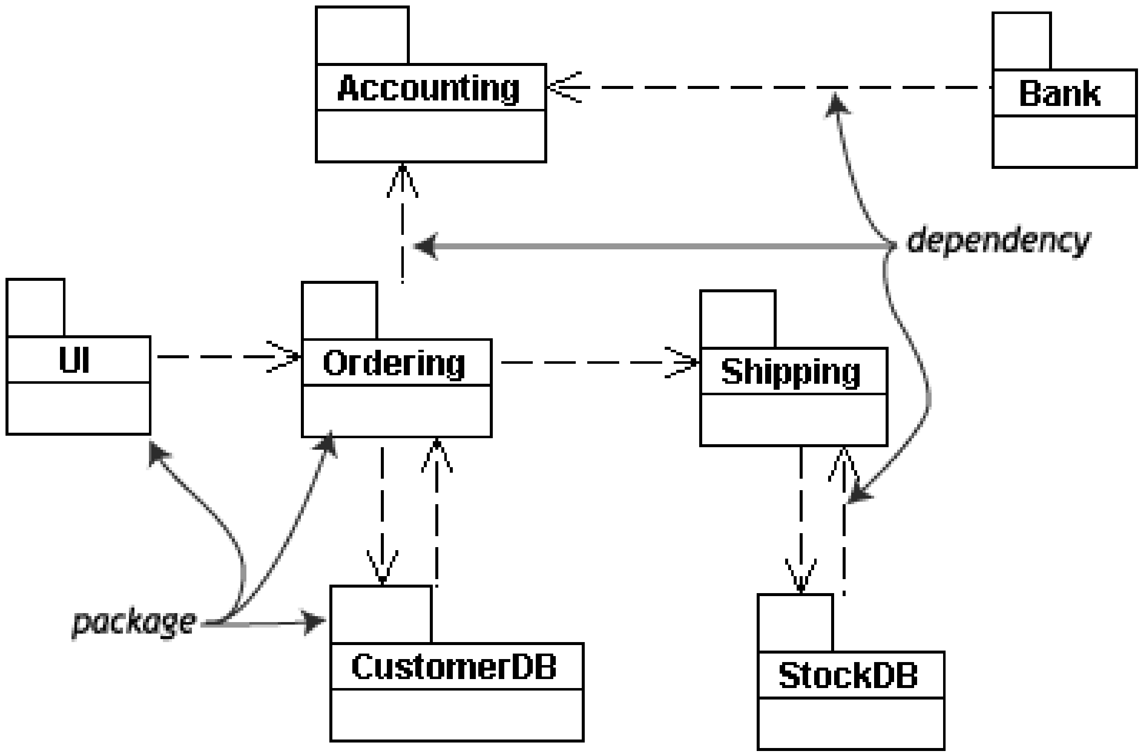


# Structure Diagrams

## Package Diagram

Package diagram shows the hierarchy in which the system will be modeled in the implementation. It gives a high level view for the distribution that can be created within the specified project and specify the package visibility.



# Structure Diagrams

## Composite Structure Diagram

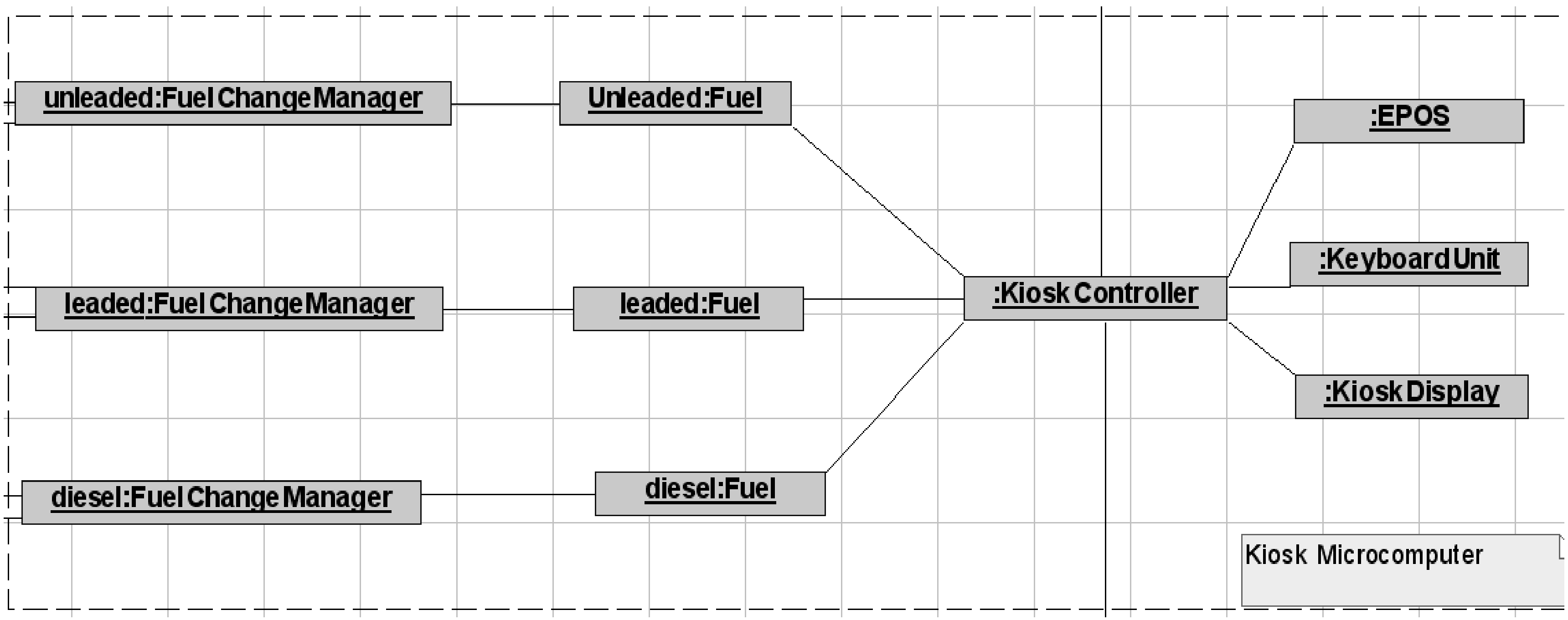
- Composite Structure diagram reflects the internal collaboration of classes, interfaces or components to describe a functionality.

- Composite Structure diagrams are similar to Class diagrams, except that they model a specific usage of the structure.

- Composite Structure diagram is used to express run-time architectures, usage patterns, and the participating elements' relationships, which might not be reflected by static diagrams.

# Structure Diagrams

## Composite Structure Diagram

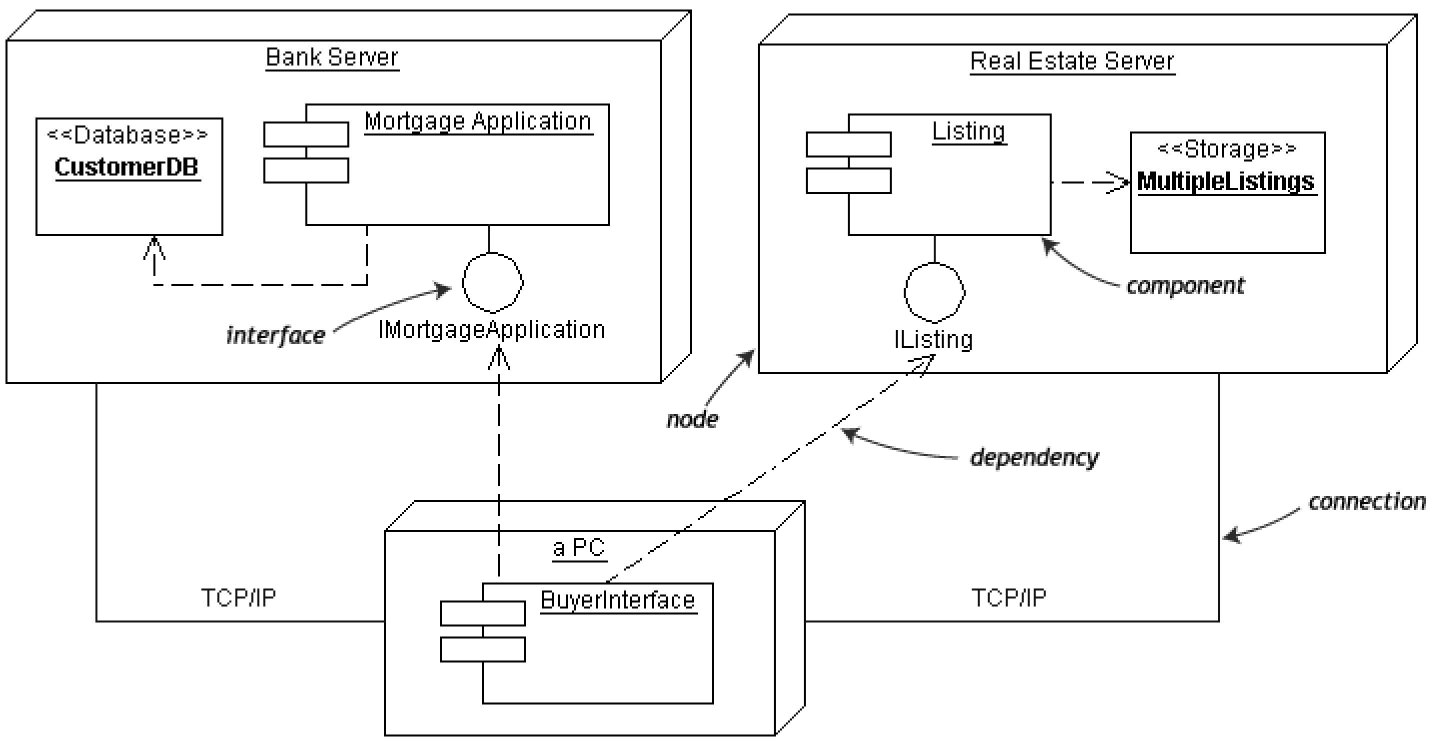


# Structure Diagrams

## Deployment Diagram

Deployment diagram shows how and where the system will be deployed.

Physical machines and processors are reflected as nodes, and the internal construction can be depicted by embedding nodes or artifacts.

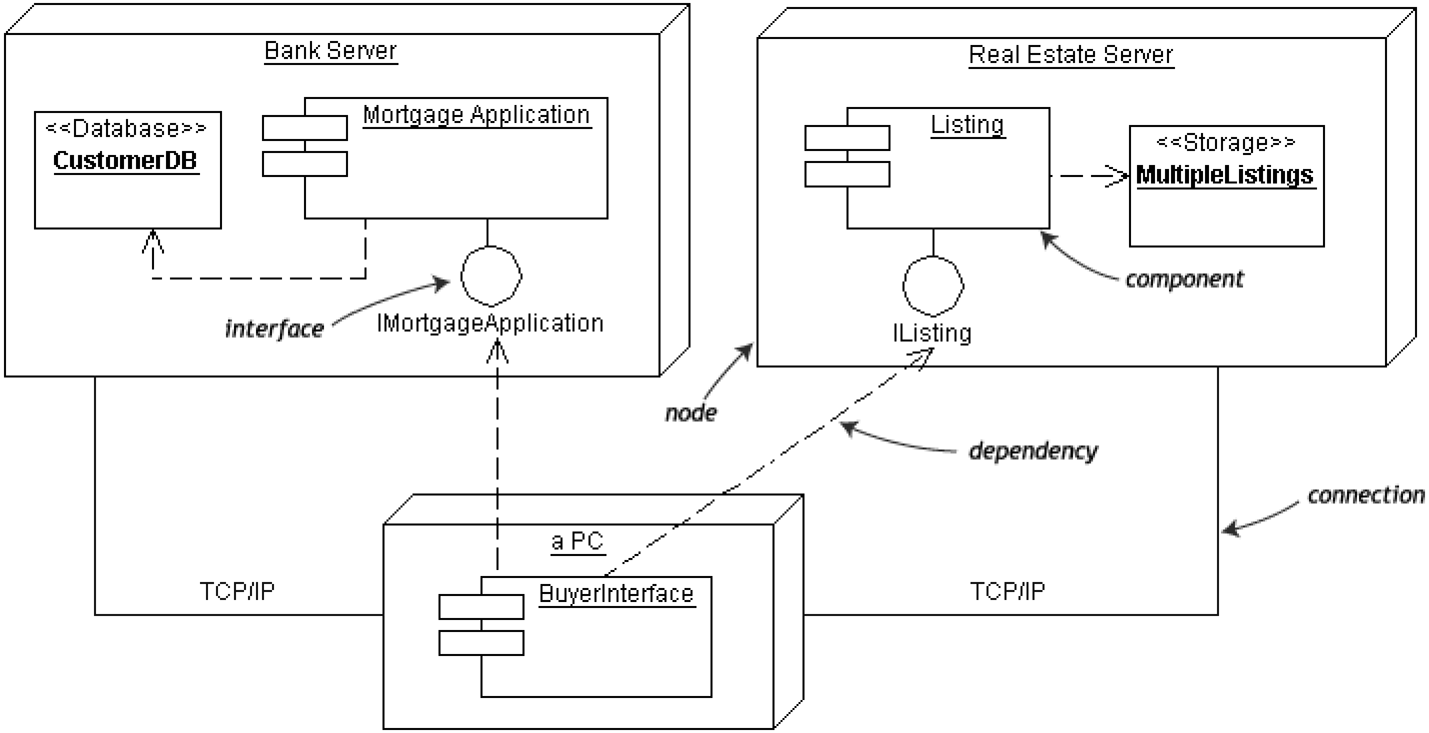


# Structure Diagrams

## Component Diagram

Component diagram illustrates the pieces of software, embedded controllers, etc. that will make up a system.

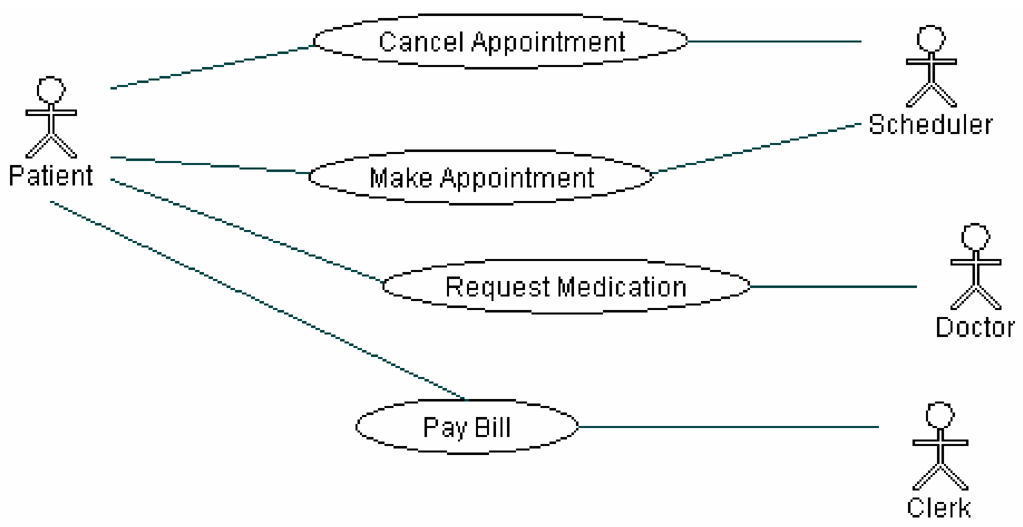
Component diagram has a higher level of abstraction than a Class diagram - usually a component is implemented by one or more classes (or objects) at runtime.



# Behavior Diagrams

## Use-Case Diagram

Use cases diagram basically are a substitute of the requirements being Modeled into the architecture. The external viewpoint as to “what” the System should do rather “how”.



# Behavior Diagrams

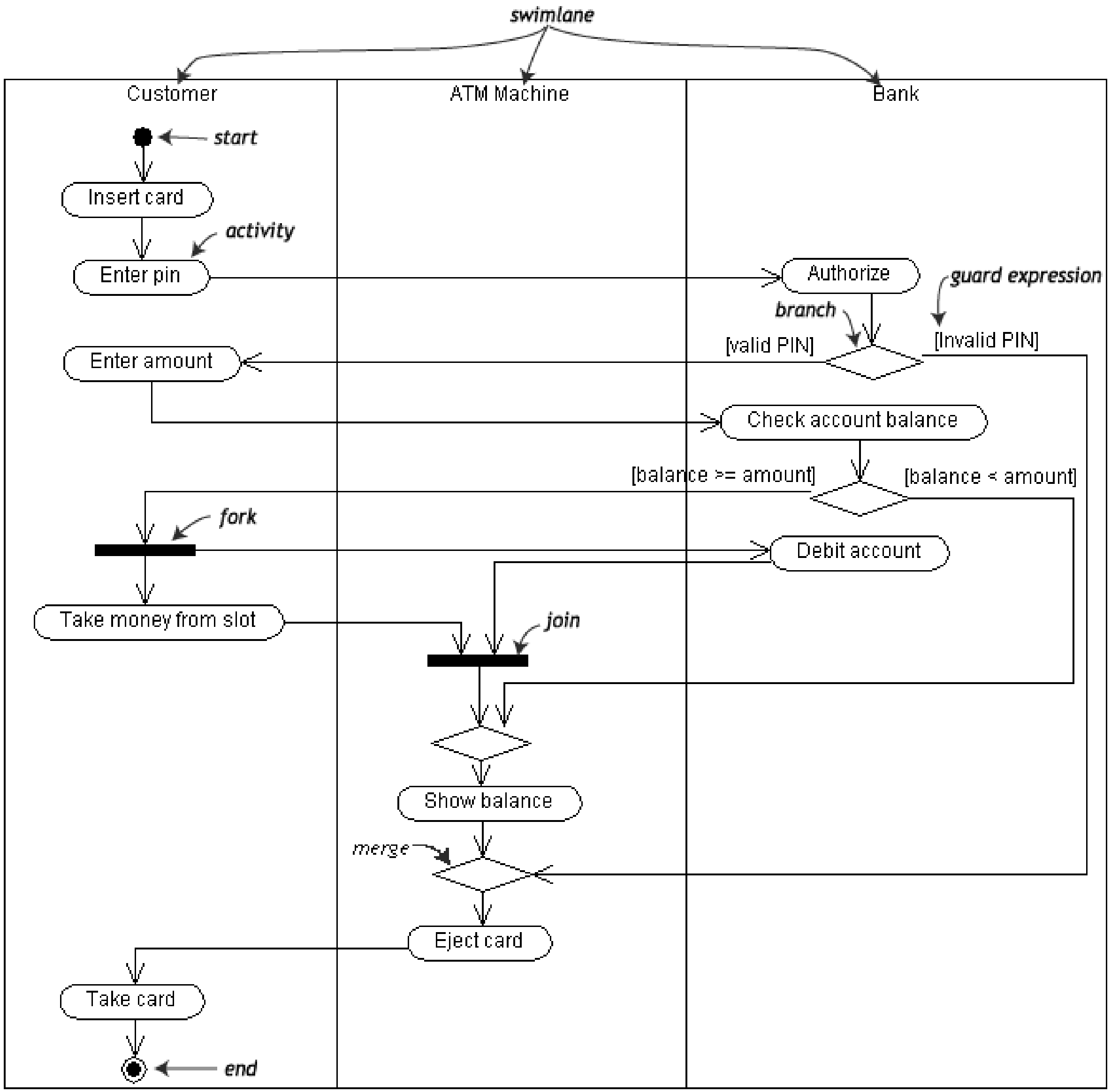
## Activity Diagram

Activity diagrams are used to model the behaviors of a system, and the way in which these behaviors are related in an overall flow of the system.

The logical paths a process follows, based on various conditions, concurrent processing, data access, interruptions and other logical path distinctions, are all used to construct a process, system or procedure.

# SysML

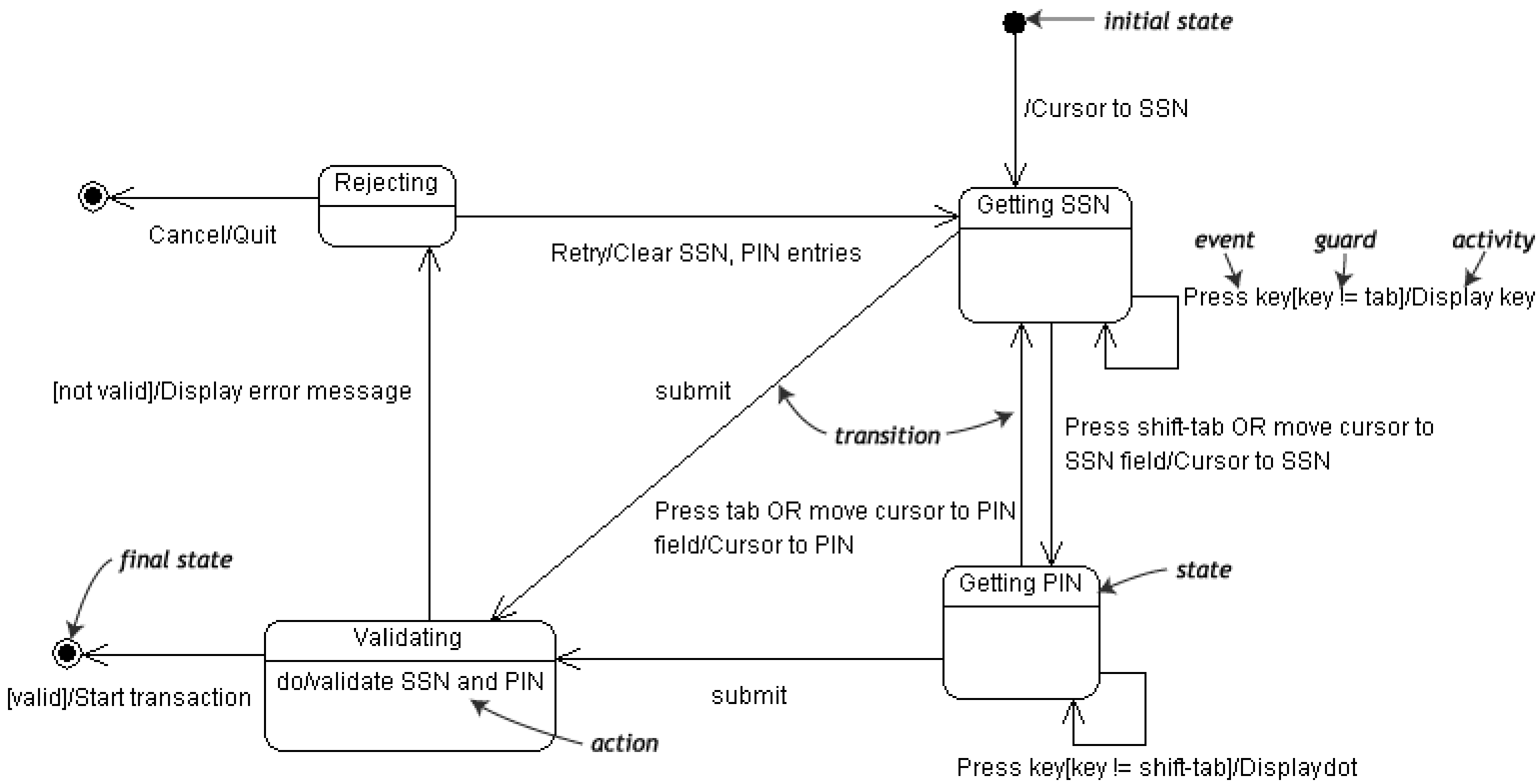
## Activity Diagram



# Behavior Diagrams

## State Machine Diagram

A State Machine diagram illustrates how an element, often a class, can move between states classifying its behavior, according to transition triggers, constraining guards and other aspects of State Machine diagrams that depict and explain movement and behavior.



# Interaction Diagrams

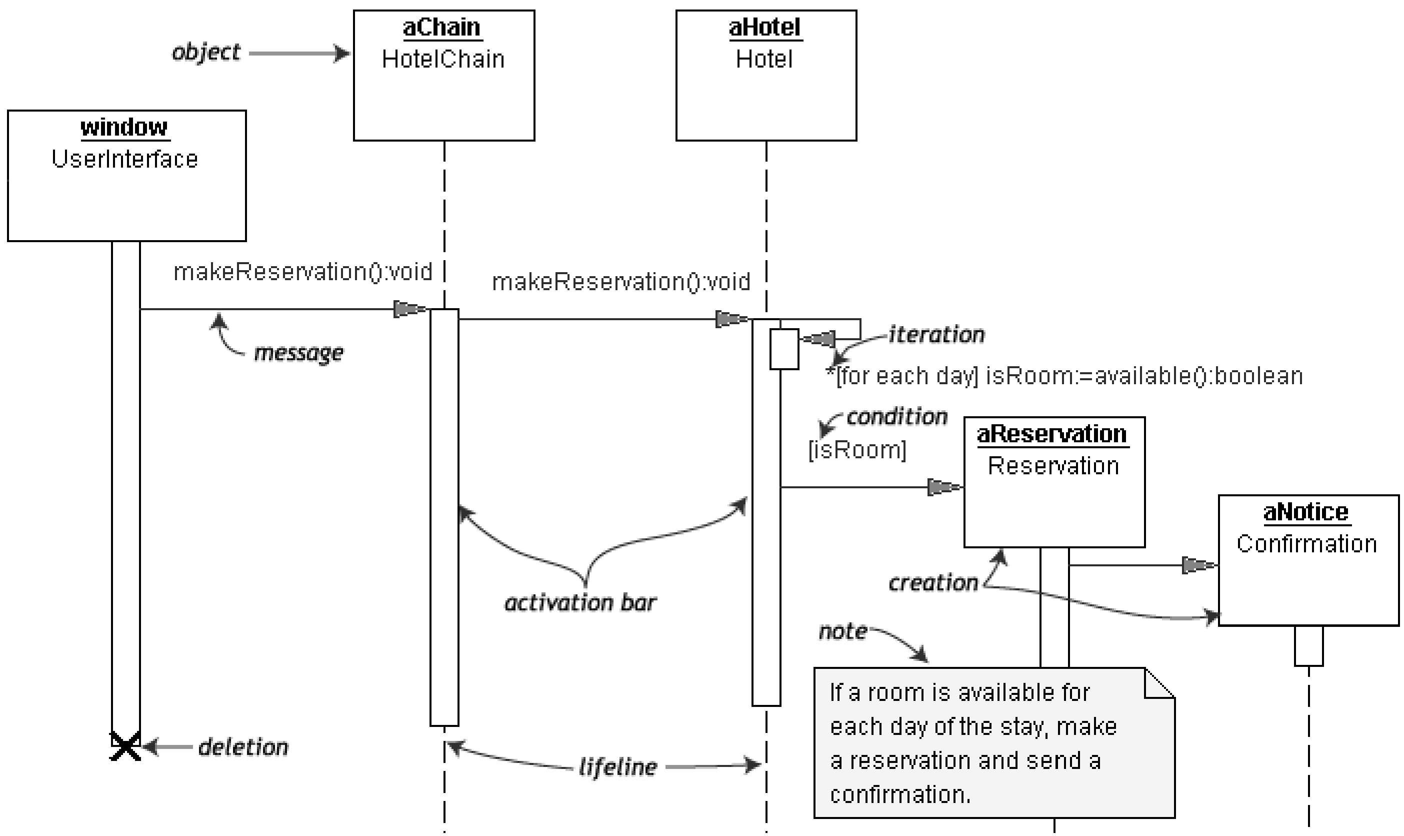
## Sequence Diagram

Sequence diagram is an interaction diagram that details how operations are carried out -- what messages are sent and when.

Sequence diagrams are organized according to time expressed in the sequential order along the vertical plane.

# Interaction Diagrams

## Sequence Diagram



# Interaction Diagrams

## Communication/Collaboration Diagram

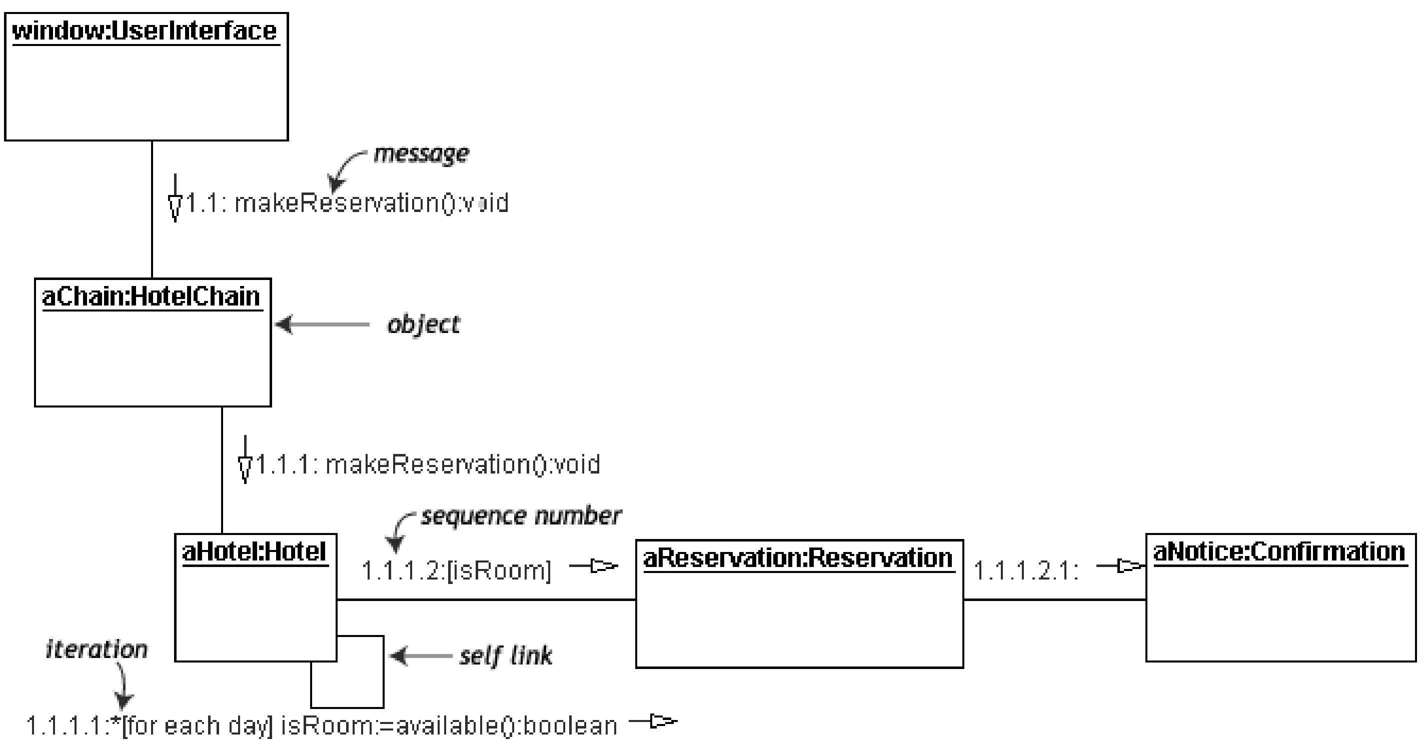
Communication diagram shows the interactions between elements at run-time in much the same manner as a Sequence diagram.

Communication diagrams are used to visualize inter-object relationships, while Sequence diagrams are more effective at visualizing processing over time.

SysML

# Interaction Diagrams

## Communication/Collaboration Diagram

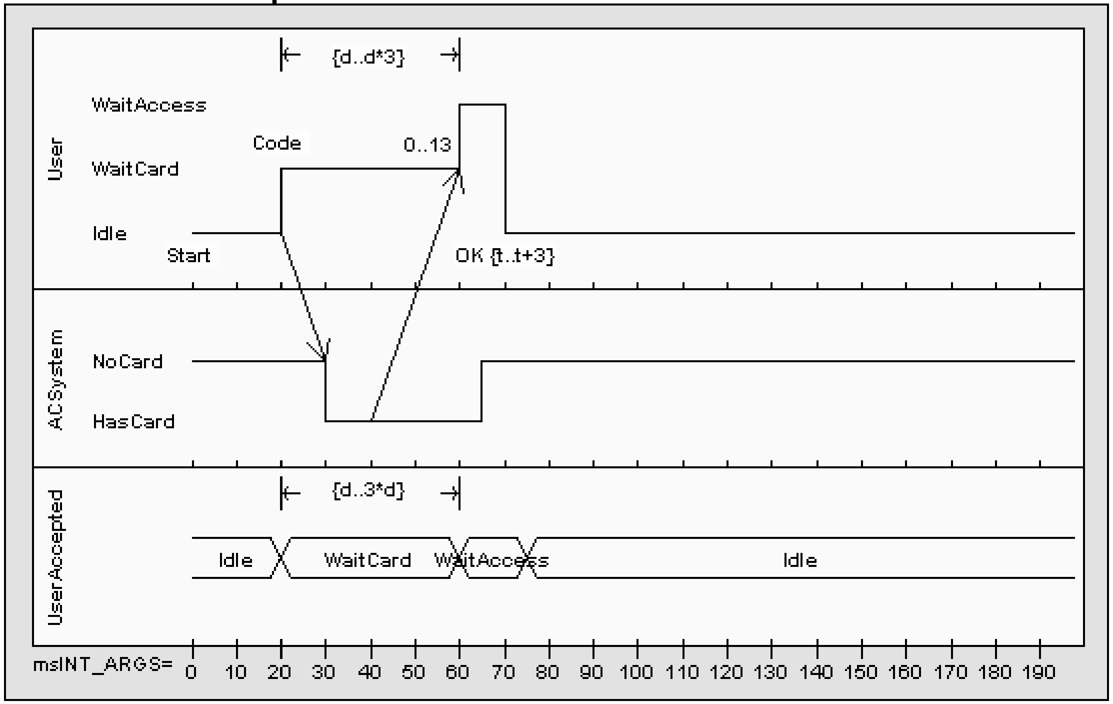


# Interaction Diagrams

## Timing Diagram

Timing diagram defines the behavior of different objects within a time-scale.

Provides a visual representation of objects changing state and interacting over time. Used for defining hardware-driven or embedded software components.



# Interaction Diagrams

## Interaction Overview Diagram

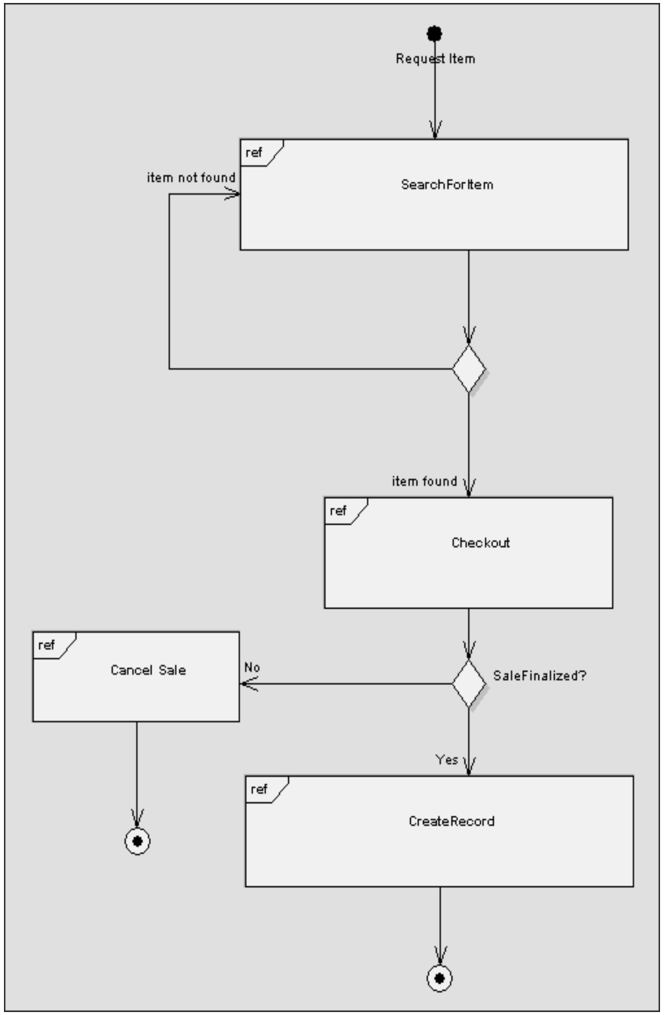
Interaction Overview diagrams visualize the cooperation between other interaction diagrams to illustrate a control flow serving an encompassing purpose.

Interaction Overview diagrams are a variant of activity diagrams, most of the diagram notation is similar, as is the process in constructing the diagram.

Interaction elements display an inline Interaction diagram, which can be a Sequence diagram, Communication diagram, Timing diagram, or Interaction Overview diagrams.

# Interaction Diagrams

## Interaction Overview Diagram



# RTUML- RT flavor to UML

UML was customized under one of the RFP to “define the standard paradigms for modeling of time- ,schedule - and performance-related aspects of RT systems”.

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# SysML

SysML was identified as the key modeling language that could integrate the disparate tools sets that SE's use for a single project across various domains .

The idea behind it was that it would do the same trick for the Systems Engineering field as UML did for the loads of modeling languages in Software.

Short Comings….hold till the end.

# SysML

Design principles -

1. **Parsimony** – Surgical reduction and augmentation of UML

2. **Reuse** – Reuse of UML 2.0

3. **Modularity** – Principle of strong cohesion and loose coupling

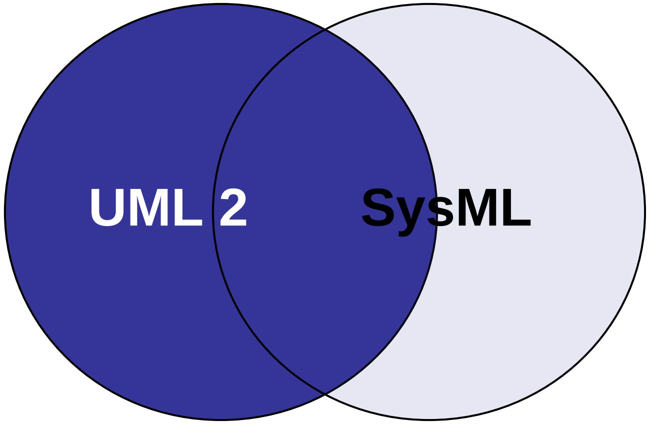
4. **Layering** – SysML packages as extensions layer to UML meta model.

5 **Partitioning** – Configure concept ional areas within some layer.

6 **Extensibility** – It offers the same extension mechanism as UML (meta classes, stereotypes, model libraries).

7 **Interoperability** – SysML is aligned with the semantics of ISO AP-232,same as XMI in UML.

Relationship shared by the SysML and UML Standards.



## Architecture

SysML reuses and extends packages from UML, extension Mechanisms like stereotypes, meta classes and model libraries.

Structure still remains the same for the Constructs .

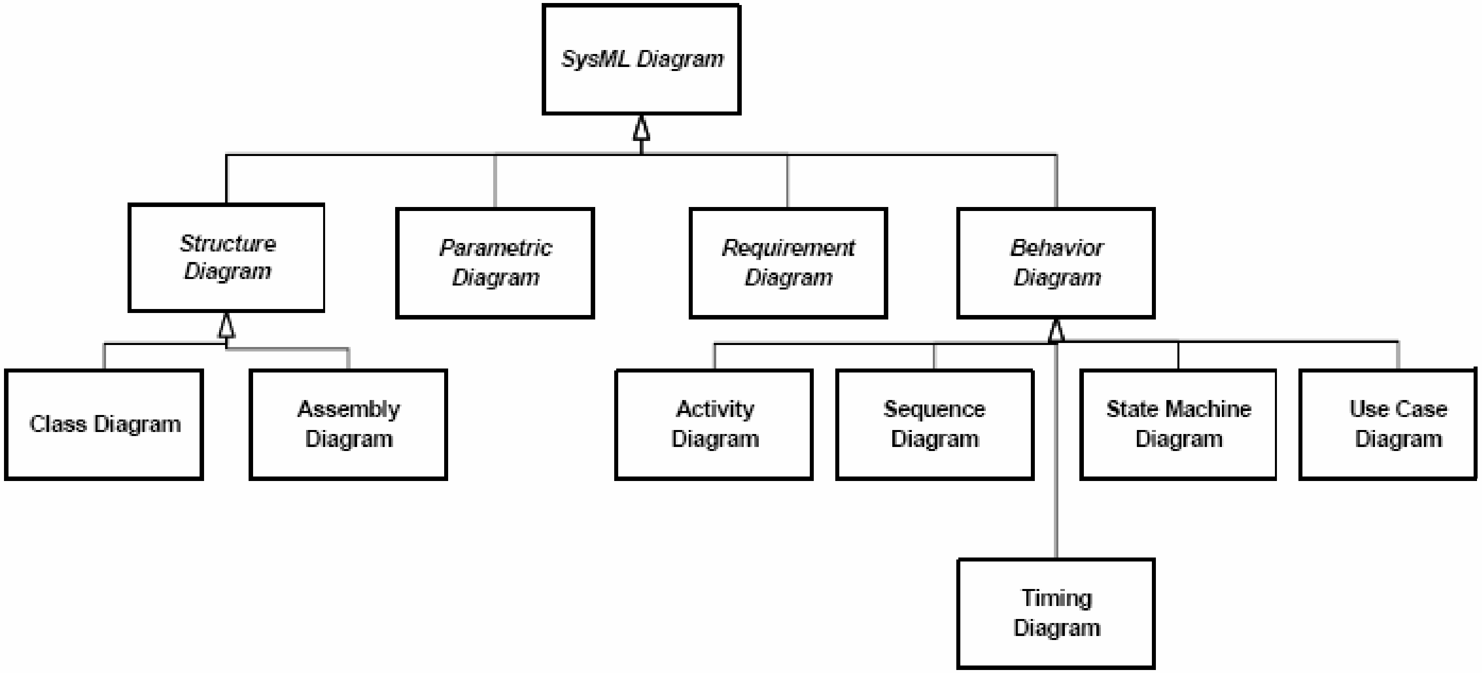
It uses combination of profiling and meta modeling techniques that use precise language to specify constraints and semantics.

Meta Model of SysML defines the packages for –

- Structural Constructs
- Behavioral Constructs
- Auxiliary Constructs

+ State machines , Interactions Diagram, Use cases remain the same
+ New extensions to packages of activity, classes and auxiliary diags.
+ New constructs in the form of Requirements, Allocation and Parametric Diagrams

- Package hierarchy in SysML



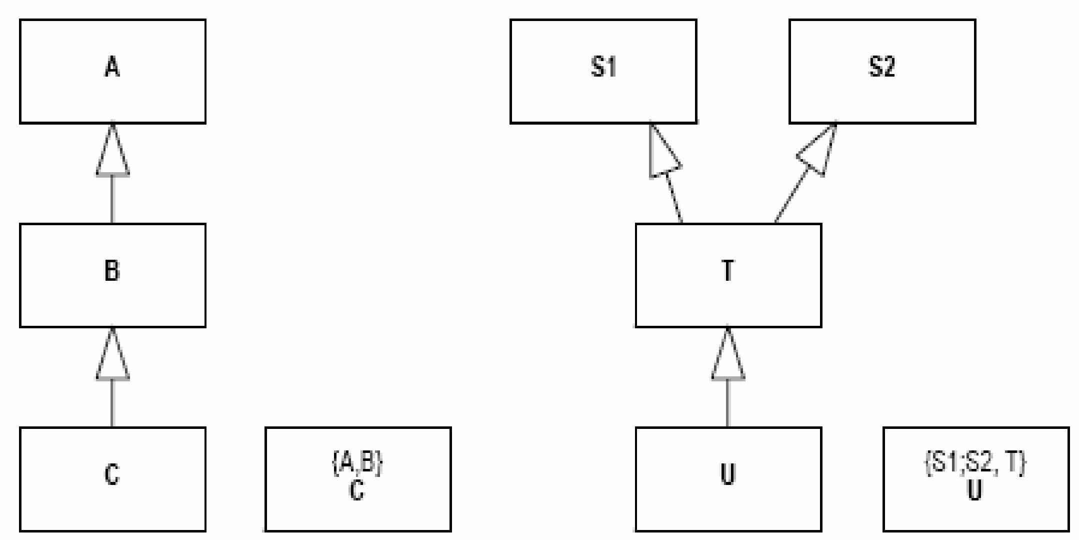
# Structural Constructs

## Class Diagram

Addition to UML specification

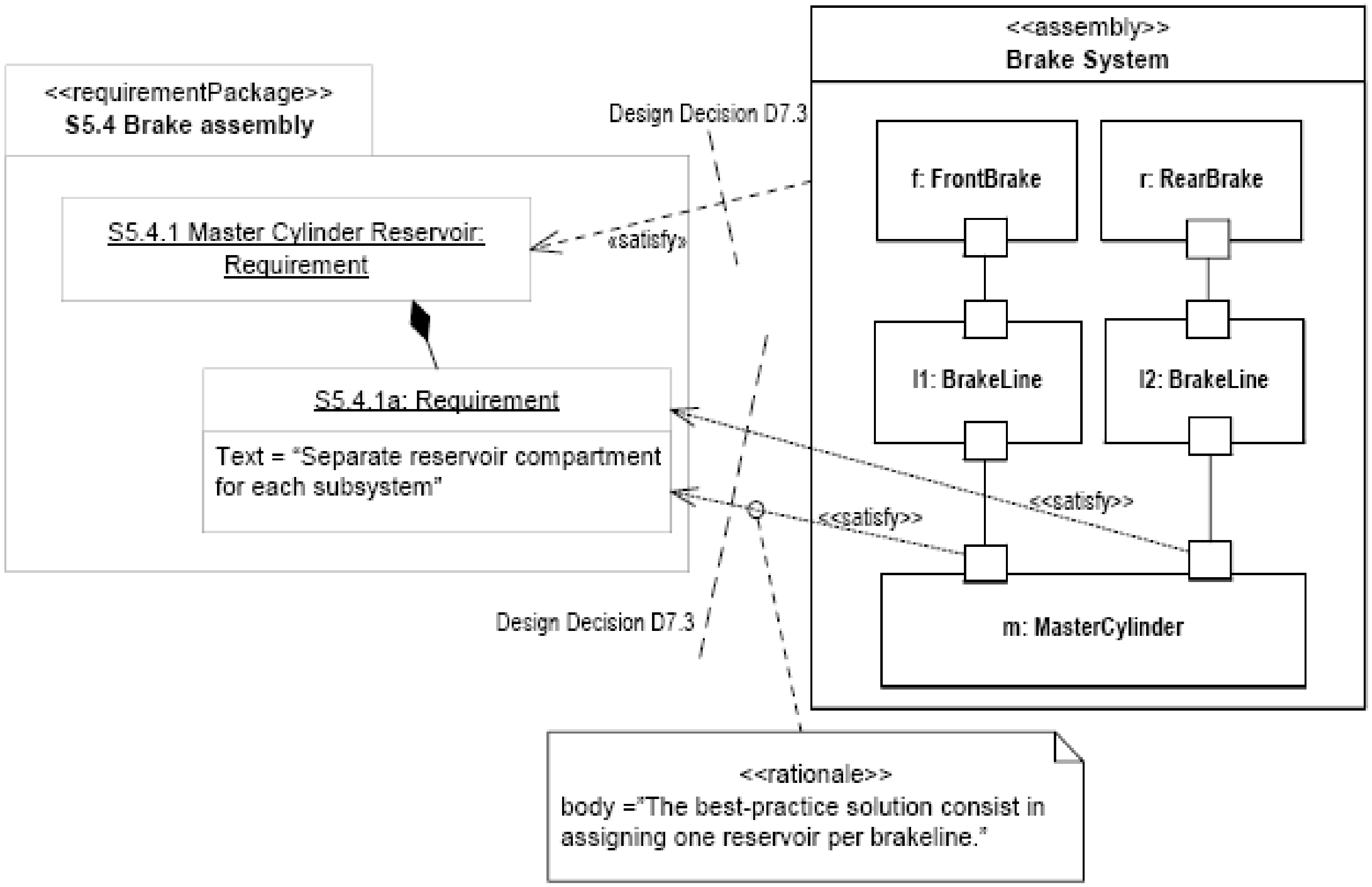
-Dependency Set added to group dependency relationships

-Root notation added to depict multi level hierarchy



# Structural Constructs

## Class Diagram



# Structural Constructs

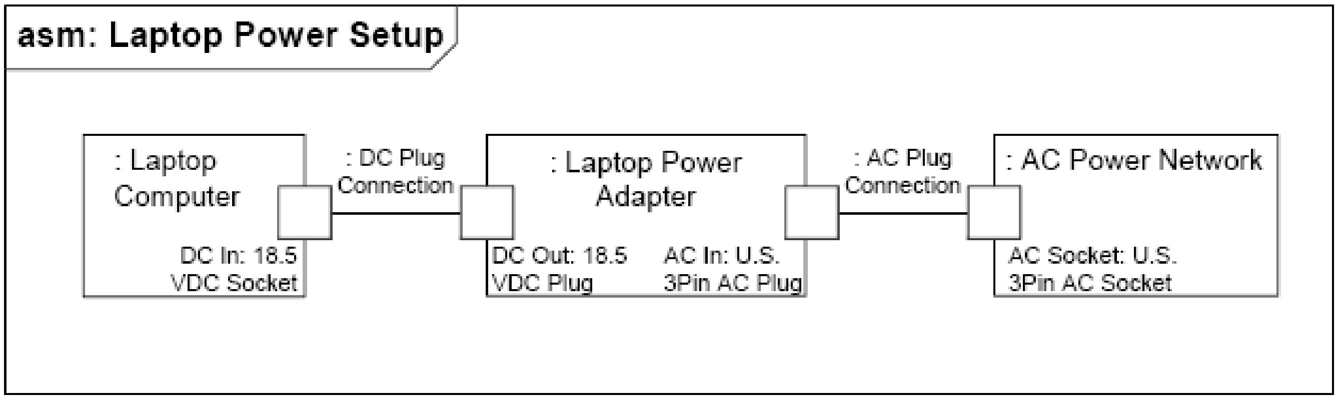
## Assembly Diagram

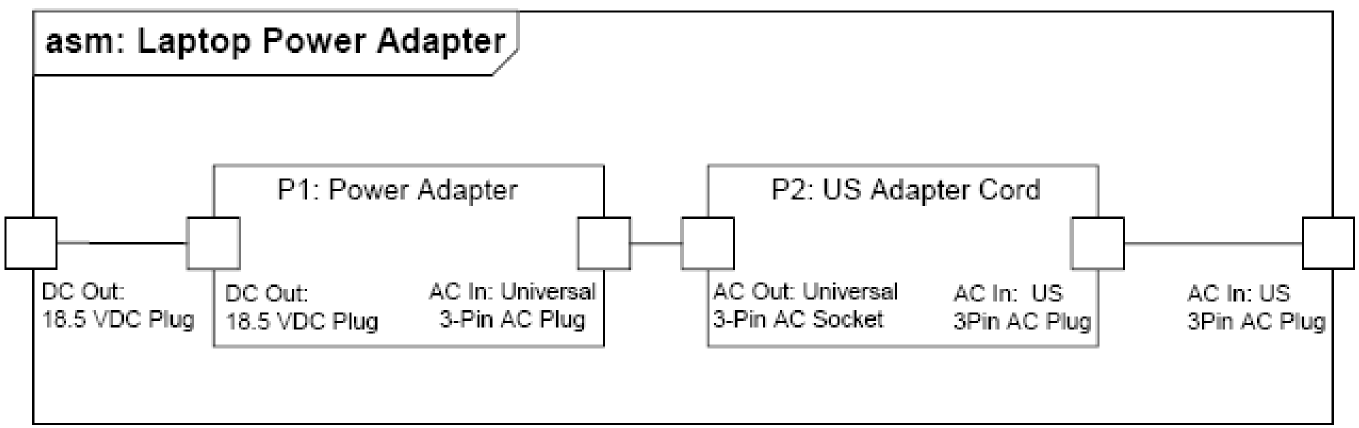
Capability to model systems as tree of modular components. Can be used throughout the development process multiple times.

Views and allocations specifically for multiple representation in SysML.

# Structural Constructs

## Assembly Diagram



# Structural Constructs

## Parametric Diagram

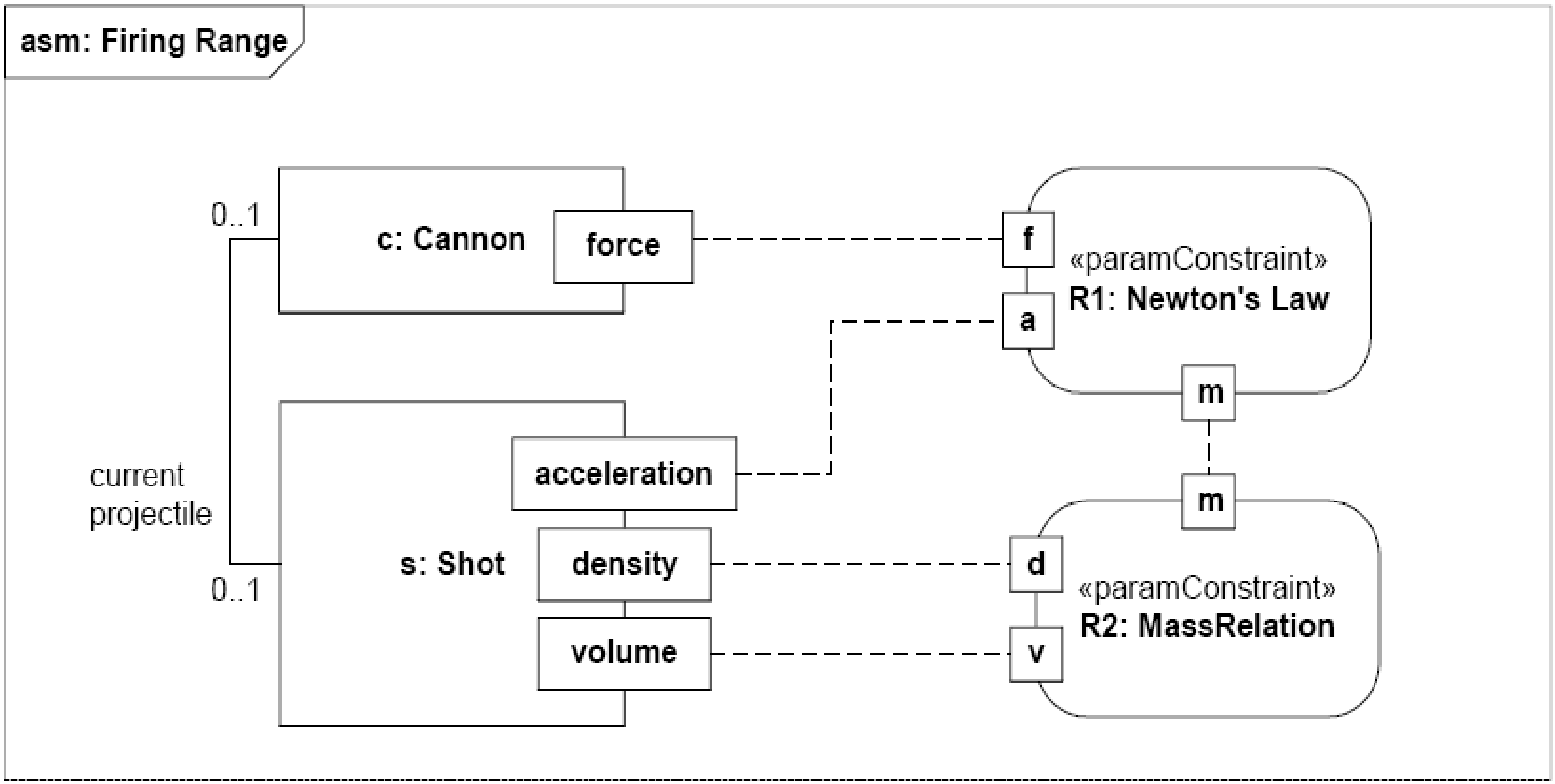
Parametric models are analysis models that define a set of system properties & parametric relationships among them.

Used essentially with Assembly level diagram

Time can be modeled as a additional property & other properties may depend on it.

# Structural Constructs

## Parametric Diagram



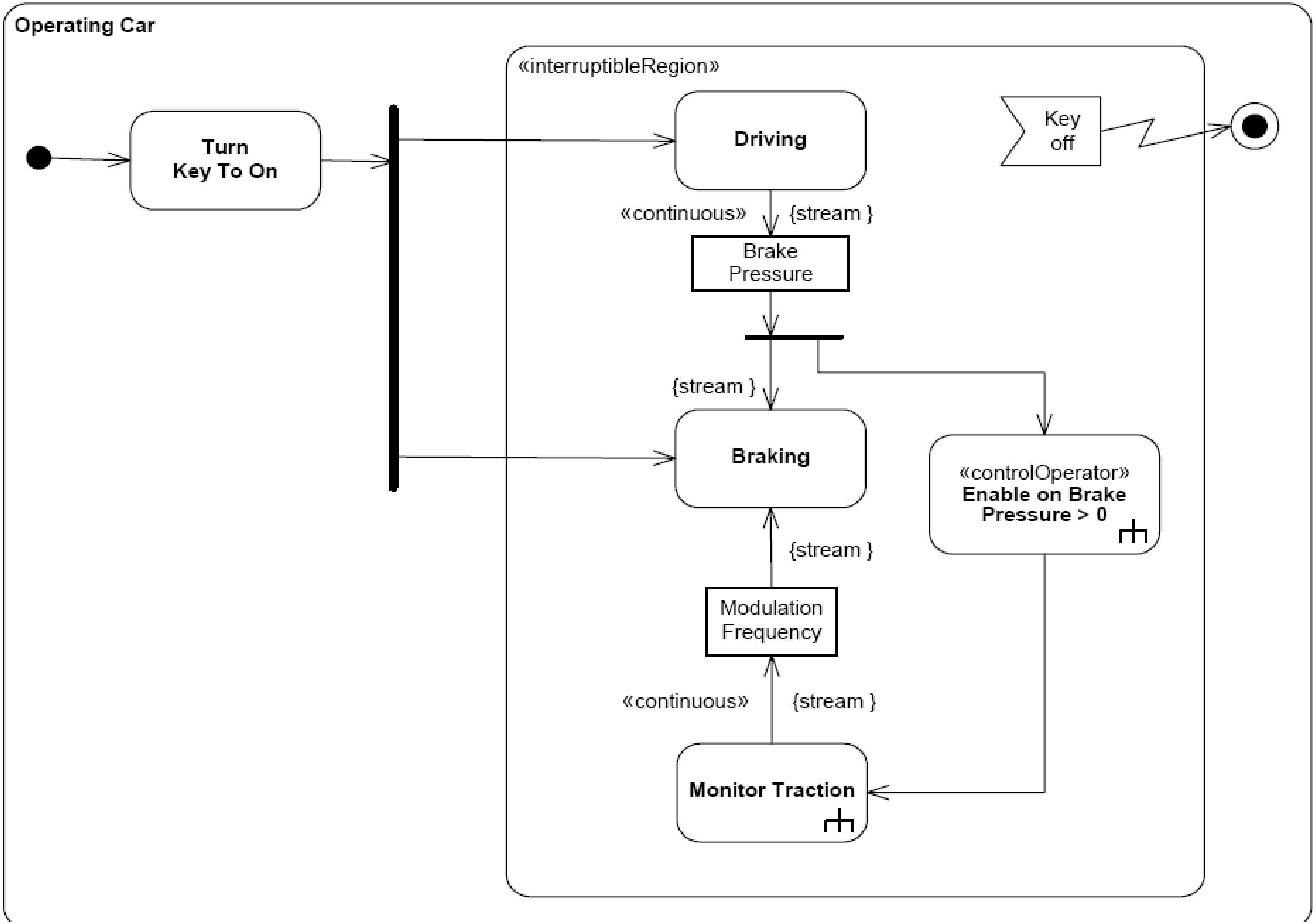
# Behavioral Constructs

## Activity Diagram

Extensions to UML2

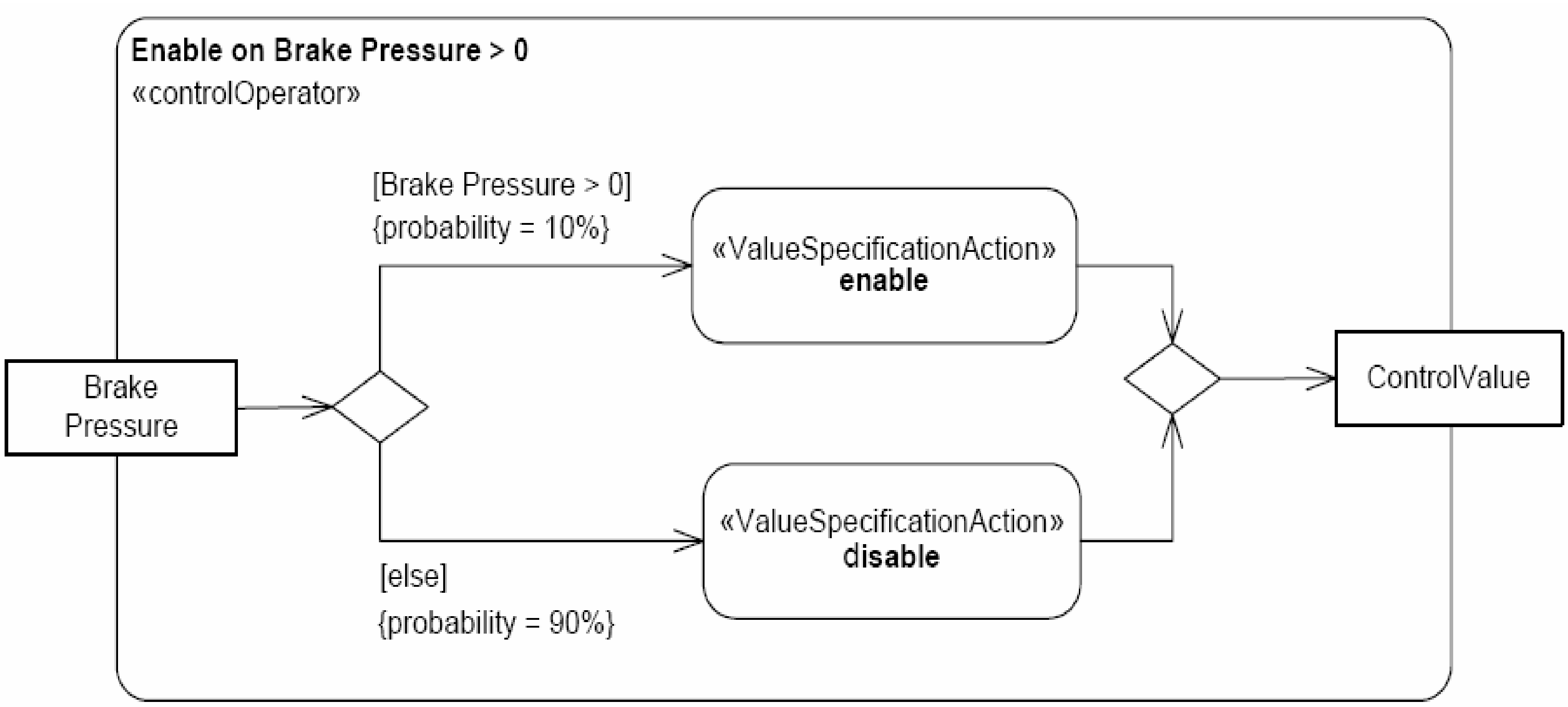
1. **Control as Data** –
   - Control can disable the actions that are executing.
   - Transform its inputs to produce an output to control other actions.
2. **Continuous systems** –
   - Any sort of distributed flow of information & physical items through system.
   - “Nobuffer” and “Overwrite” features added.
3. **Probability –**
   - Edges which have probabilities associated for the likelihood of values traveling on an edge.

# Activity Diagram



# Behavioral Constructs

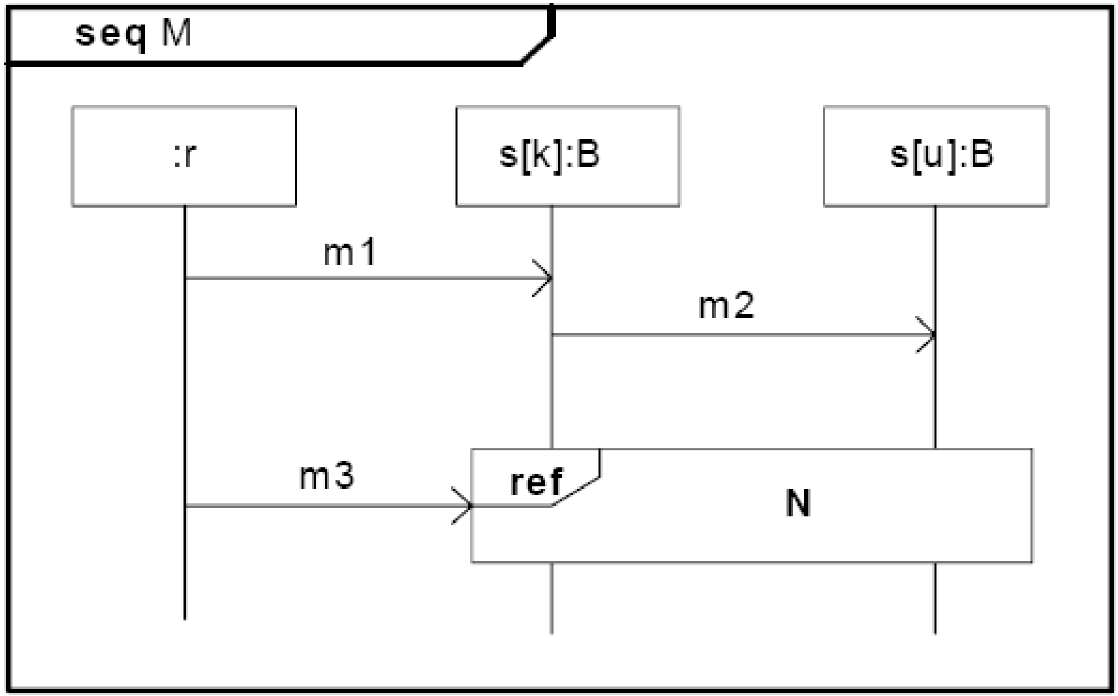
## Activity Diagram



# Behavioral Constructs

## Interaction Diagram

In SysML we only have the Timing Diagrams and Sequence diagrams Defined. The support for Interaction Overview diagram has been removed.



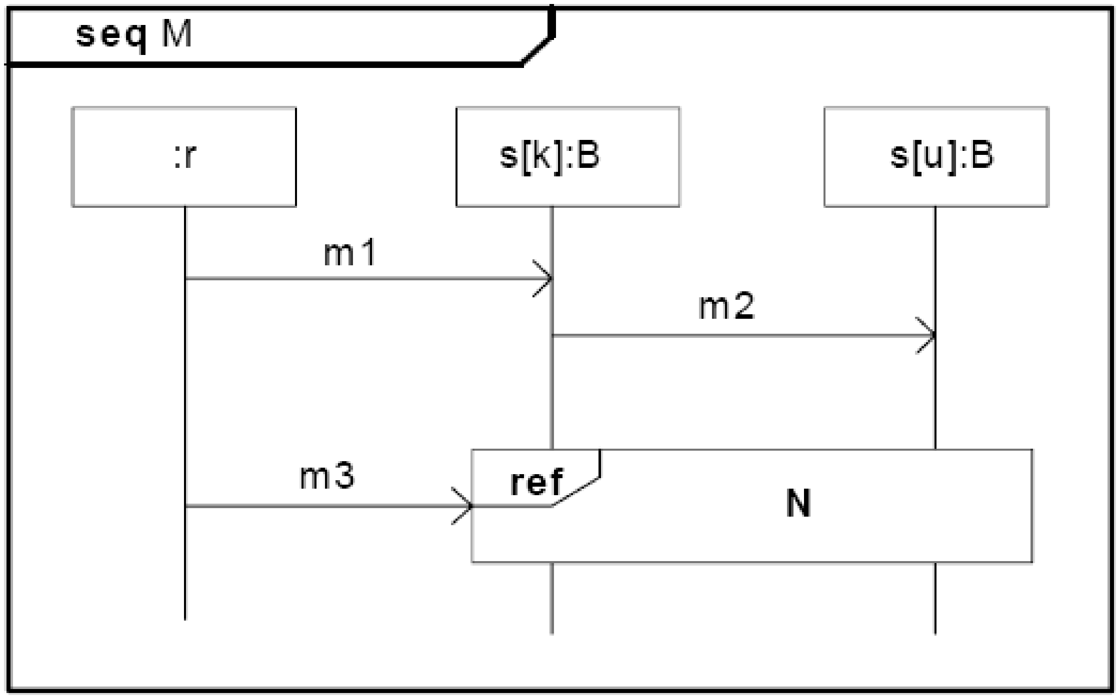
# Behavioral Constructs

## Timing Diagram

Same as UML standard .No additions have been made to the Timing Diagram.

# Behavioral Constructs

## Sequence Diagram

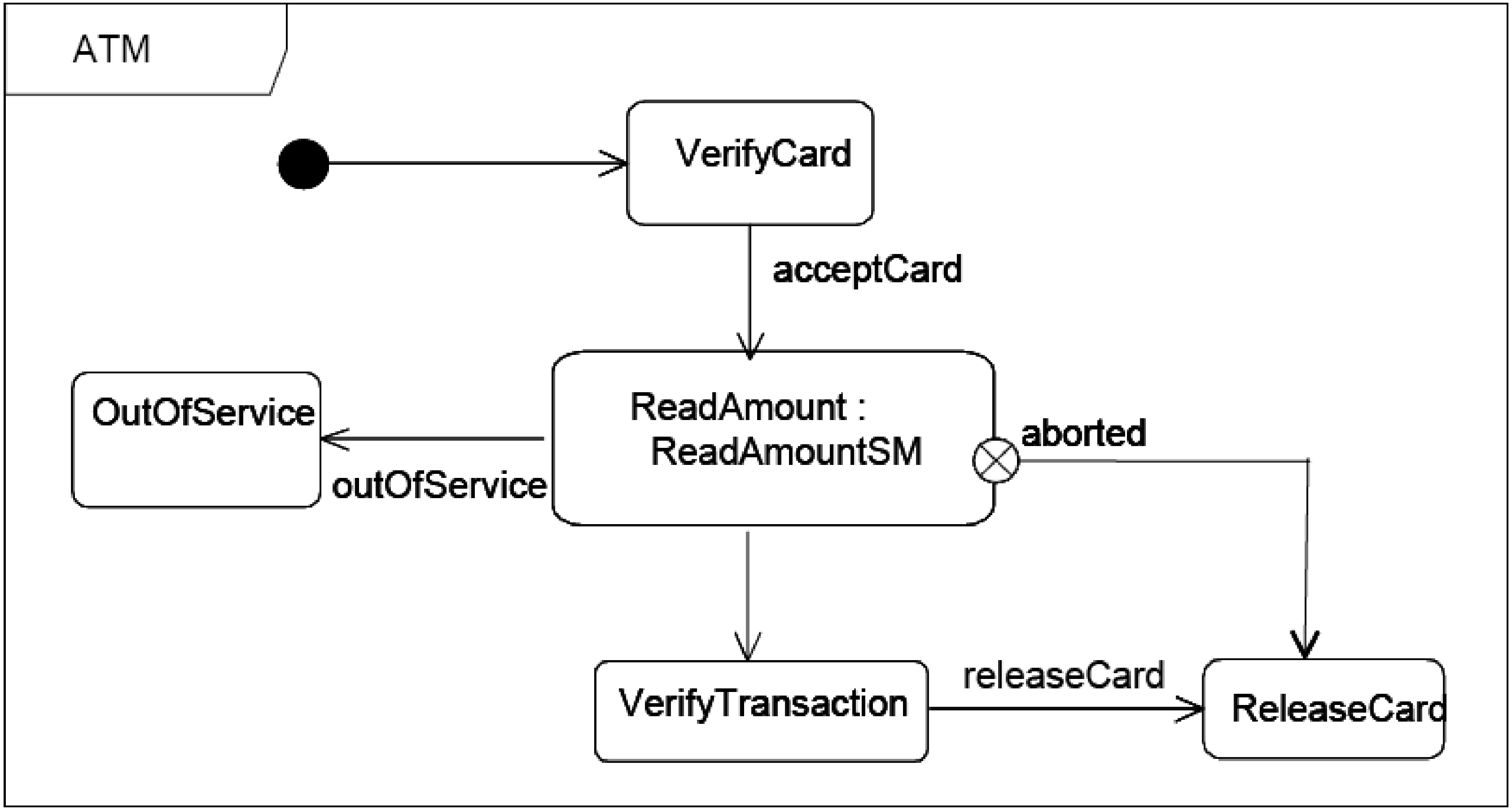


SysML

# Behavioral Constructs

## State Machine Diagram

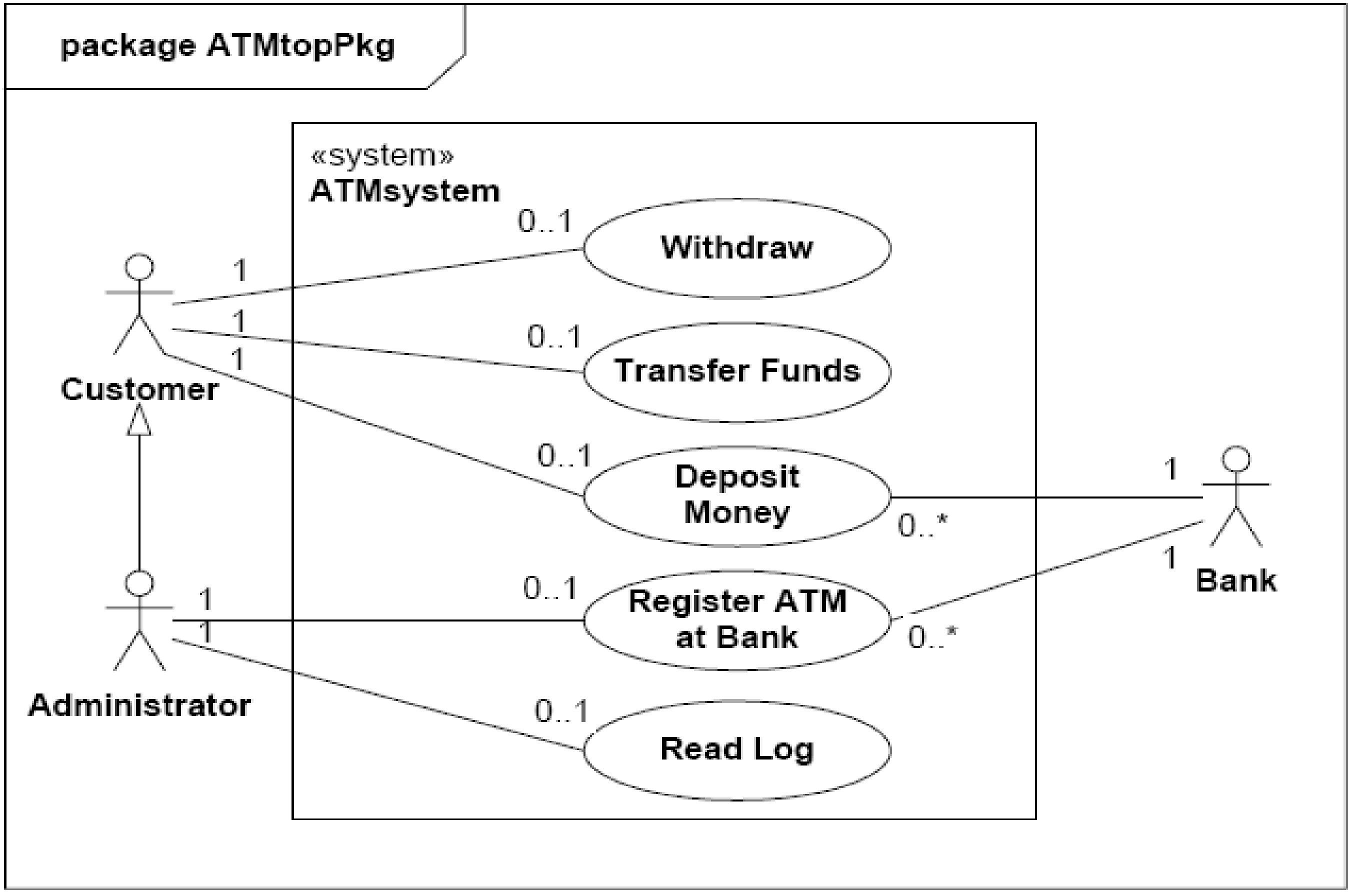
Represents behavior as the state history of an object in terms of\ transitions and states.



# Behavioral Constructs

## Use Case Diagram

Remains unchanged same as from UML 2.0



# Cross Cutting Constructs

## Requirement Diagram

- Requirement may specify a function ,a system must perform/performance condition a system must satisfy.

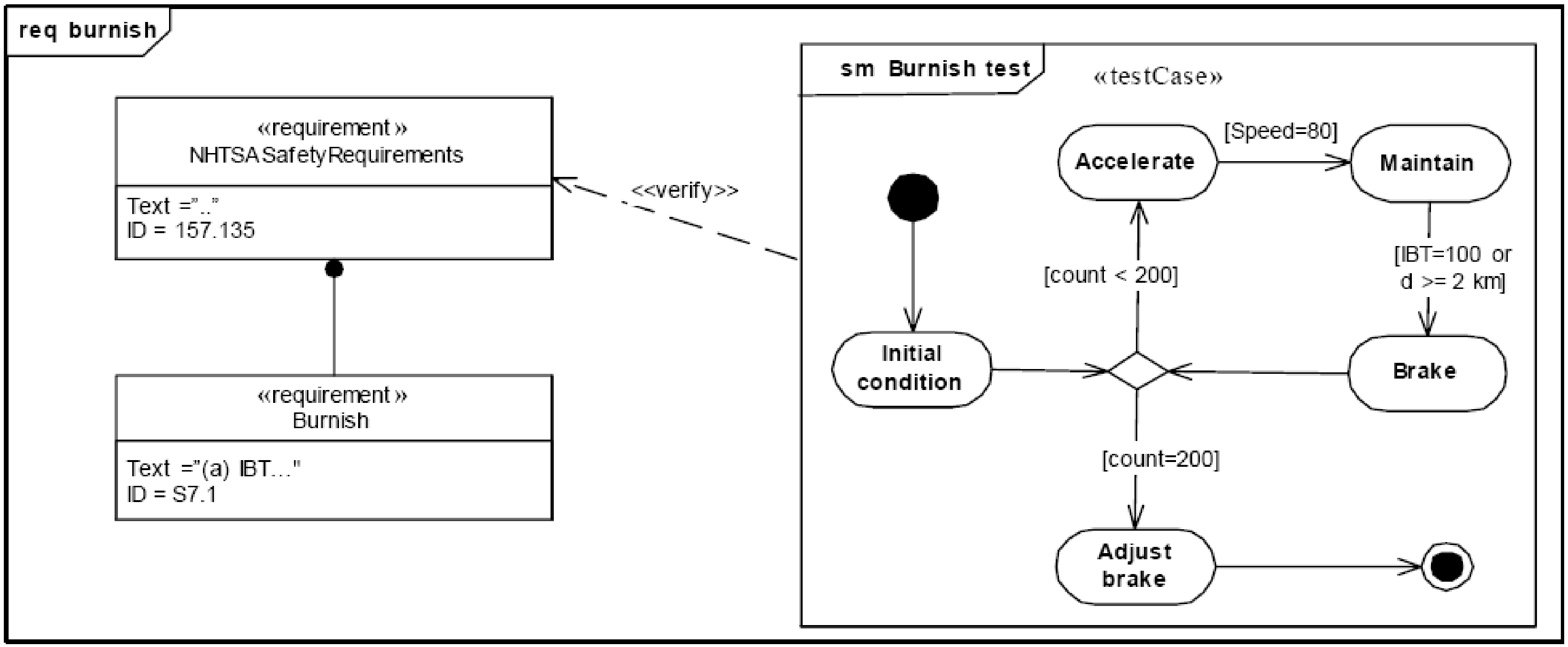
- Formalized to connect to other modeling elements( itself, analysis, design, testing and implementing elements) .

- Type of modeling element can be controlled by using the requirement diagram.

- Requirement may have its own property, hence computable value not only text.

# Cross Cutting Constructs

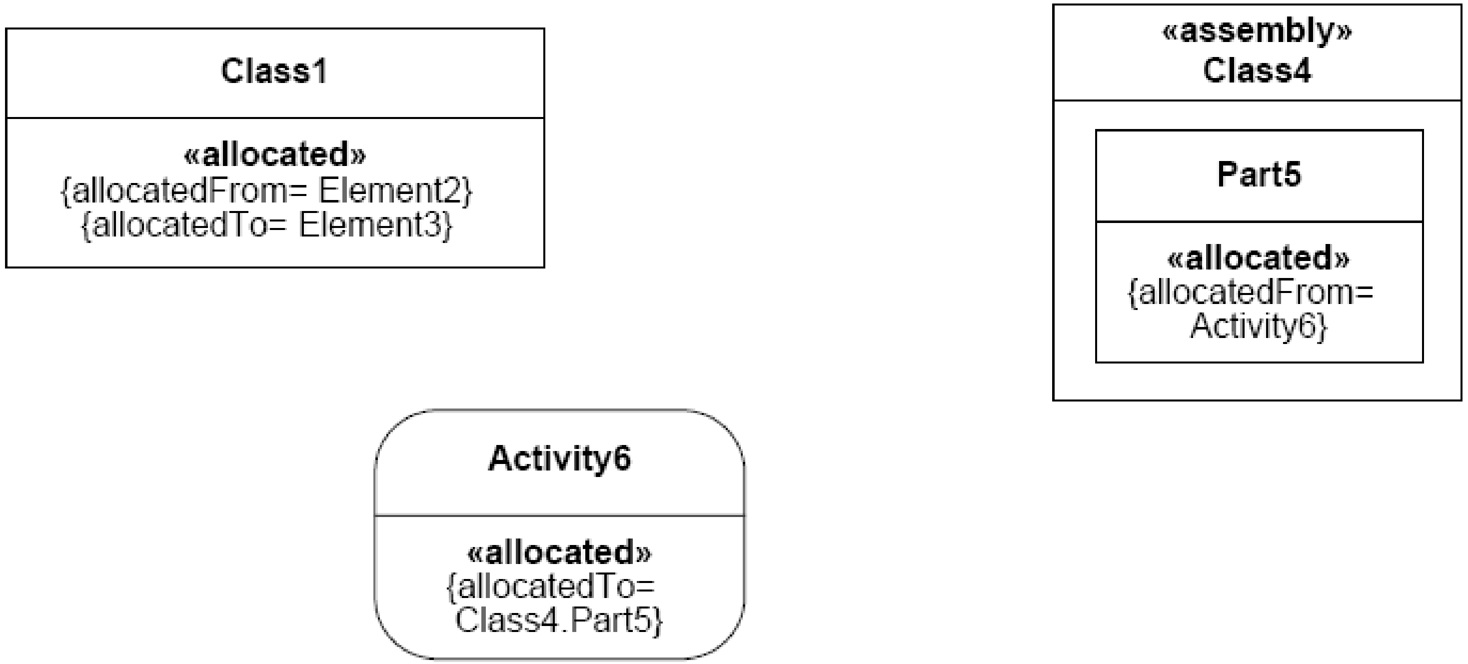
## Requirement Diagram



# Cross Cutting Constructs

## Allocation Diagram

- Term used by SE's to denote organized cross-association of elements within the various structures /hierarchies of a user model. Support allocation in broad sense.



# Auxiliary Constructs

Includes notations and elements for the following auxiliary items –

- Item Flows
- Views & View Points – View formed by importing the elements from other packages.
- Additional Data types – Complex/ Real
- Dimensional Quantities – Fundamental type that defines basic type of values expressed as quantity.
- Probability Distribution – Parametric constraints that constrain properties
- Property value Constraints

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No. Still has a long way to go.

Shortcomings of SysML still present as of now …

1. No **comprehensive verification and validation techniques**.
2. No provision to do trade studies related to a product.
3. No testing support.
4. Fully executable functional behavior
5. No support for decision trees.

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# Bibliography


- SysML Specification
- UML SuperStructure specification
- Borland :Practical UML
- Systems Modeling Language (SysML) – Artisan Software white paper
- Software Architecture : David Garlan
- ***Modeling Real-Time Systems – Challenges and Work Directions : Joseph Sifakis***
- MDA Specification
- Lots of Google…..

# SysML

- Abstract view on things
- Modeling Requirement of RT Systems
- OMG’ s MDA
- UML overview
- Finally…. SysML spec.
- Case Study
- Is it the anecdote we look for ??
- Still to come ……
- Bibliography
- Something different…..