Introduction to OOAD and the UML

Instructor: Dr. Hany H. Ammar

Dept. of Computer Science and Electrical Engineering, WVU

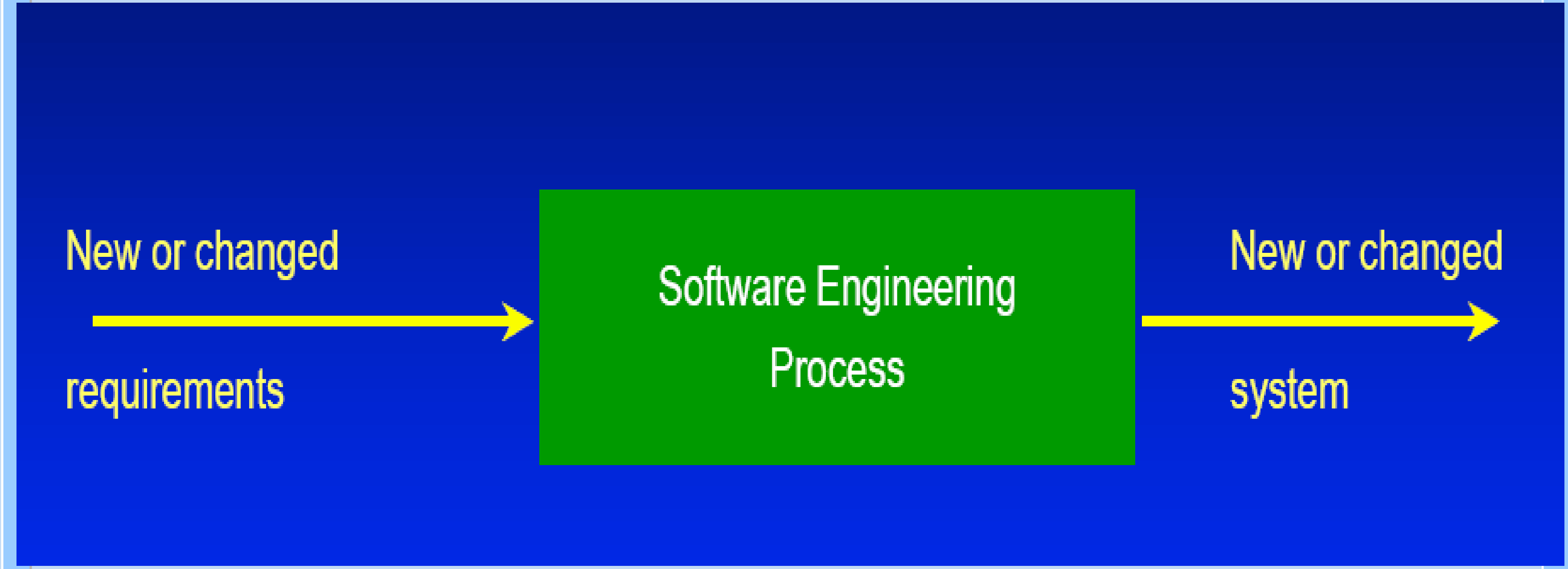
OUTLINE

- The development process
- Reviewing Object Oriented Analysis and Design
- Visual modeling and the Unified Modeling Language UML

OUTLINE

- The development process
  - Phases of system development
  - The Unified Process
- Object Oriented Analysis and Design
- Visual Modeling and the Unified Modeling Language UML

The Development Process

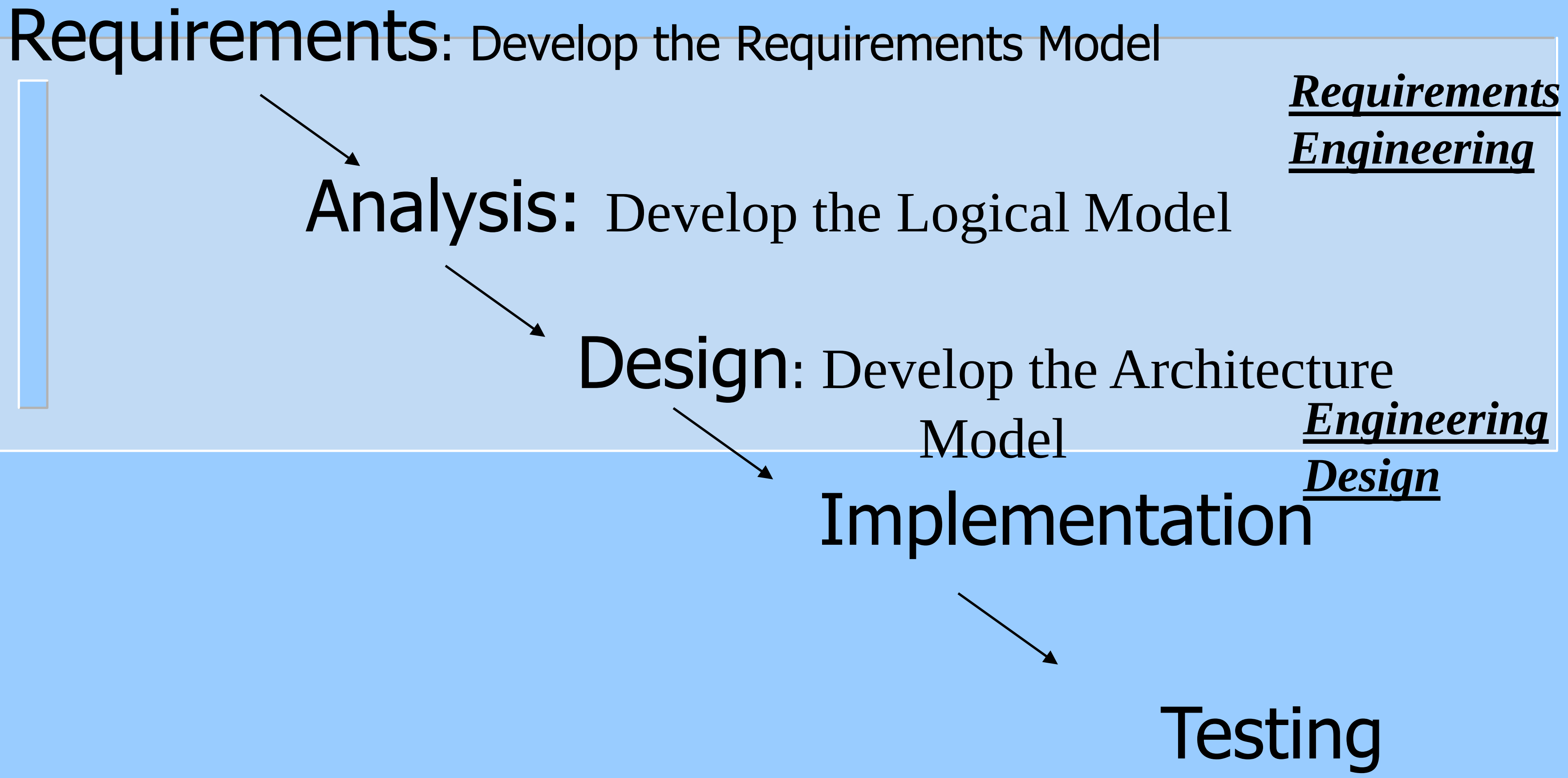


New or changed requirements

Software Engineering Process

New or changed system

Phases of System Development



Requirements: Develop the Requirements Model

Analysis: Develop the Logical Model

Design: Develop the Architecture Model

Implementation

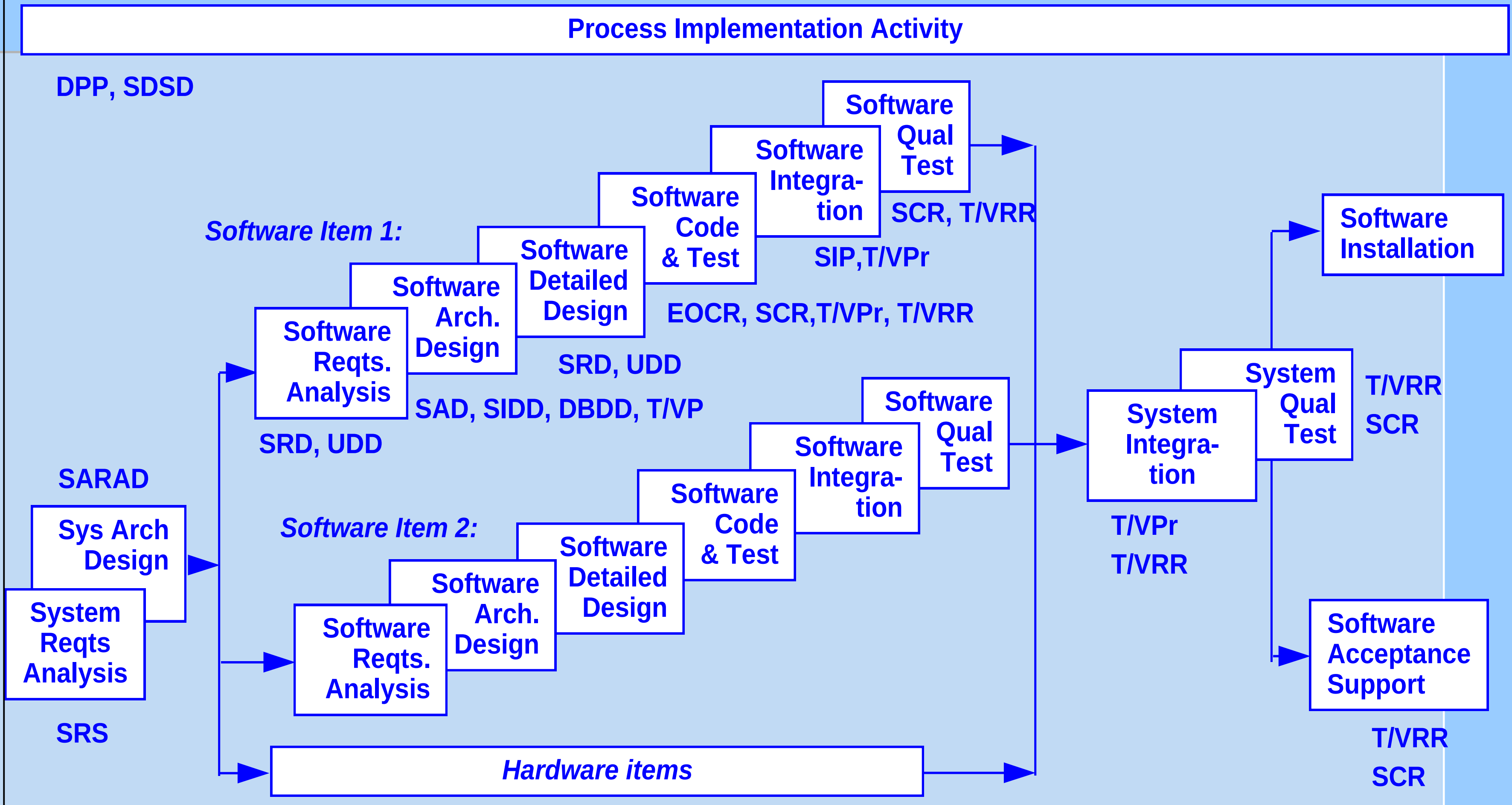
Testing

Requirements Engineering

Engineering Design

The IEEE 12207 Development Process

One example of applying 12207 to the Waterfall development strategy



Process Implementation Activity

DPP, SDSD

SARAD

Sys Arch Design

System Reqts Analysis

SRS

Software Item 1:

Software Reqts. Analysis

SRD, UDD

Software Arch. Design

SAD, SIDD, DBDD, T/VP

Software Detailed Design

SRD, UDD

Software Code & Test

EOCR, SCR,T/VPr, T/VRR

Software Integra-tion

SIP,T/VPr

Software Qual Test

SCR, T/VRR

Software Item 2:

Software Reqts. Analysis

Software Arch. Design

Software Detailed Design

Software Code & Test

Software Integra-tion

Software Qual Test

Hardware items

System Integra-tion

T/VPr

T/VRR

System Qual Test

T/VRR

SCR

Software Installation

Software Acceptance Support

T/VRR

SCR

Supporting Processes: Documentation, CM, QA, Verification, Validation, Joint Review, Audit, Problem resolution

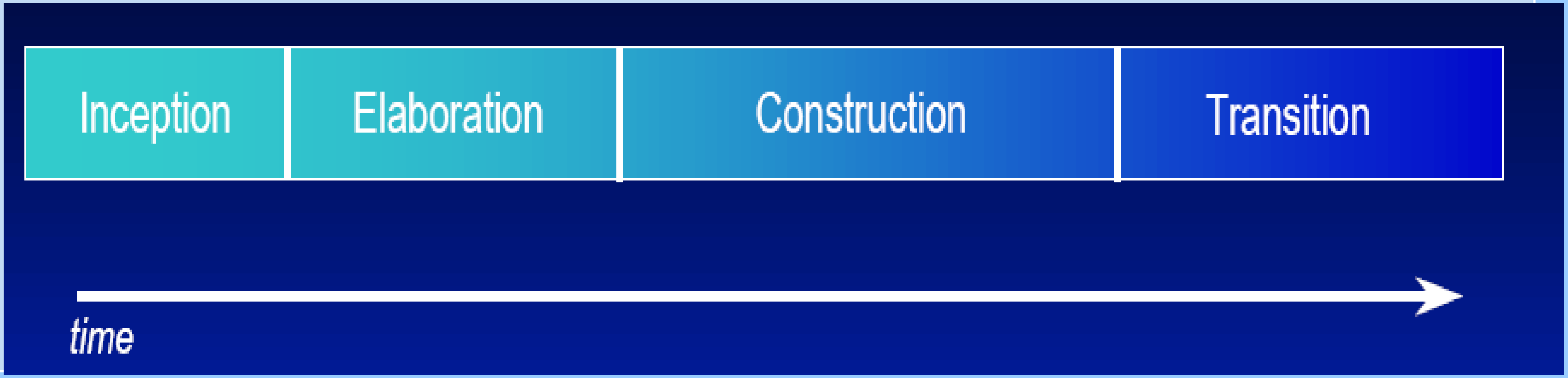
SCMP, SCMR, SCIR, SQAP, SQAR, SVRR, PR/PRR

Organizational Processes: Management, Infrastructure, Improvement, Training

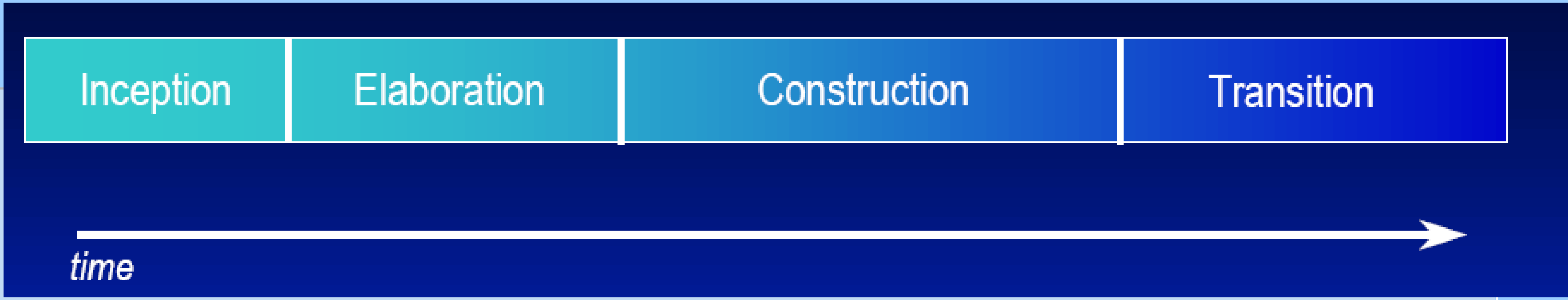
The Unified Process

(The Rational Unified Process (RUP), adopted by IBM for system development)

- Supports System Development Using the Unified Model Language (UML)
- Evolutionary process where the system is built iteratively and incrementally in several builds starting from the requirements phase
- Architecture-centric



The Unified Process

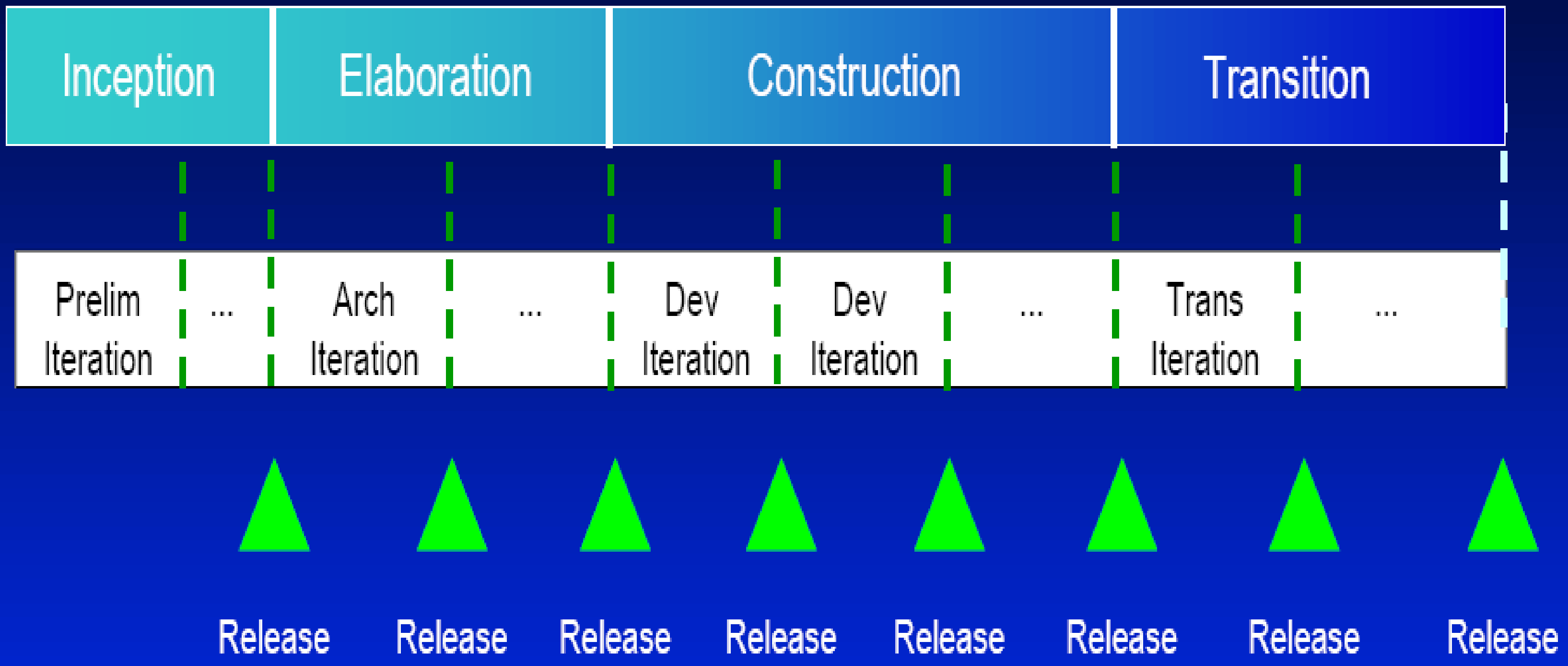


Inception: Define the scope of the system (identify all external entities with which the system will interact and define the nature of the interactions)

Elaboration: Specify features and develop the architecture

Construction: Build the system

Transition: Transition Product to its users



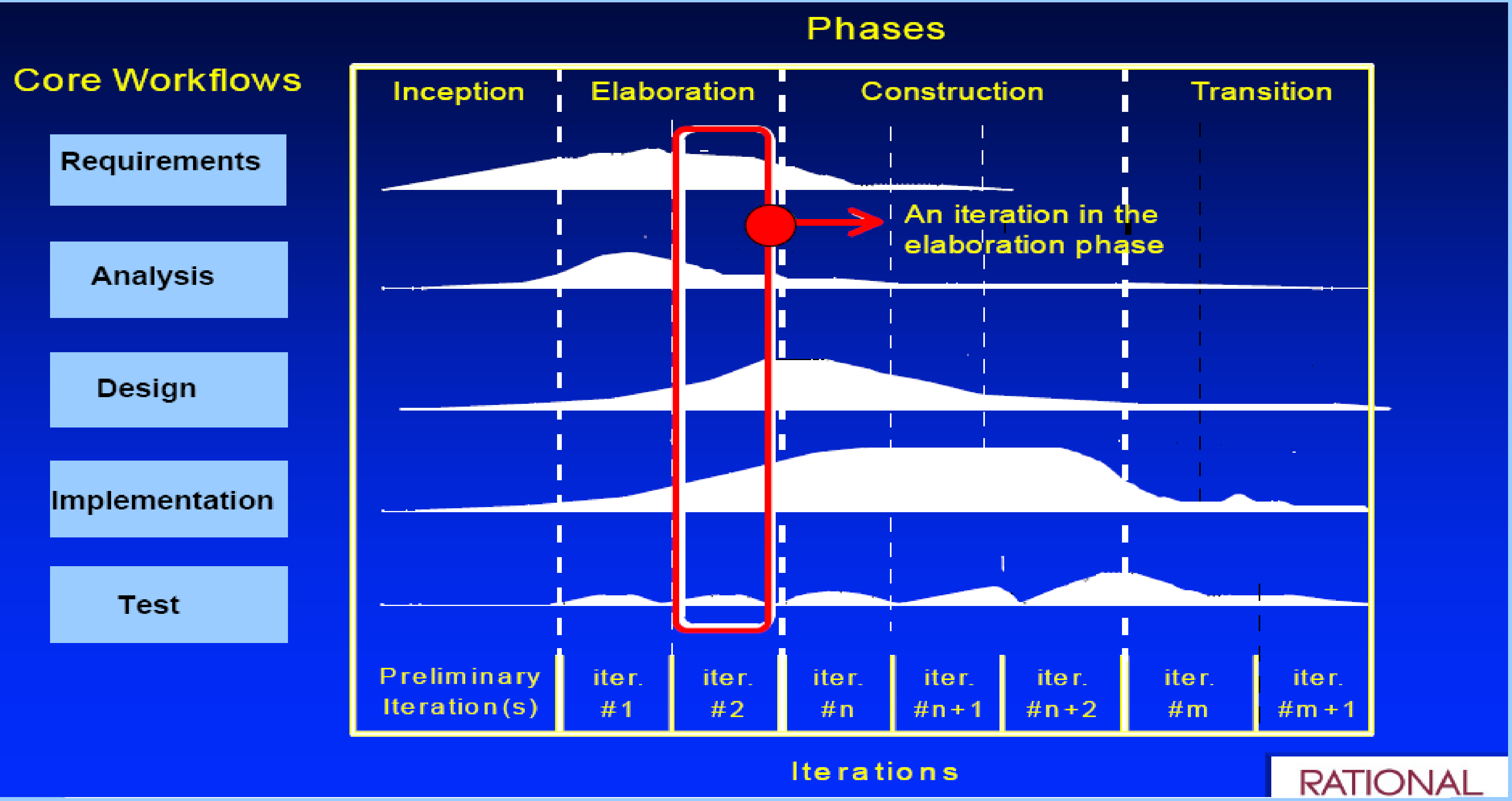
Inception | Elaboration | Construction | Transition

Prelim Iteration | ... | Arch Iteration | ... | Dev Iteration | Dev Iteration | ... | Trans Iteration | ...

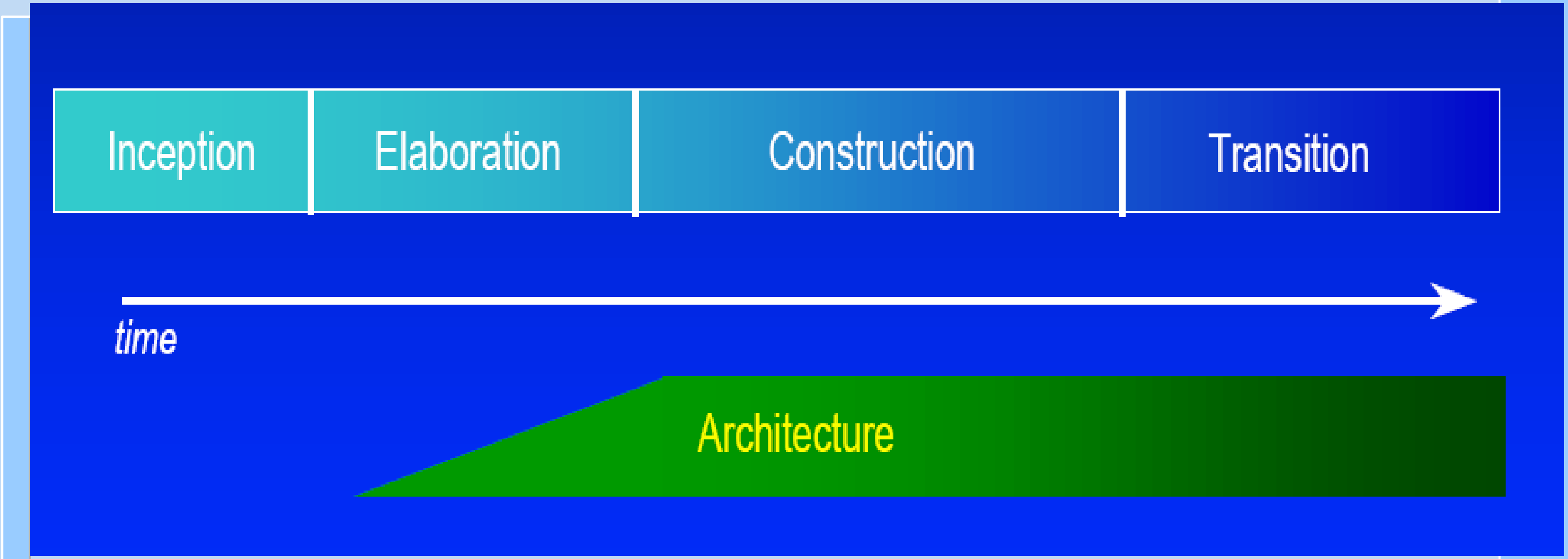
Release | Release | Release | Release | Release | Release | Release | Release

An iteration is a sequence of activities with an established plan and evaluation criteria, resulting in an executable release

The Unified Process



The Unified Process



The UP develops the architecture iteratively in successive Refinements during the Elaboration phase

OUTLINE

- The development process
- Reviewing Object Oriented Analysis and Design
  - Object-Oriented Analysis OOA
  - Object-Oriented Design OOD
- Visual Modeling and the Unified Modeling Language UML

Object Oriented Analysis and Design (OOAD)

Review of OOAD Basic Concepts

- Develops a system model using a set of interacting objects
- A Class:
  - A class is a description used to instantiate objects
- An Object:
  - Is an instance of a class, it has a name, attributes and their values, and methods
  - An object models an idea found in reality, (tangible or abstract)

Basic Concepts (cont’d)

- Attributes of a class
- Methods of a class (Services, Actions, Messages)
- Information hiding and Encapsulation: A technique in which an object reveals as little as possible about its inner workings (Private and Public methods or attributes).
- Inheritance defines a class hierarchy based on abstraction

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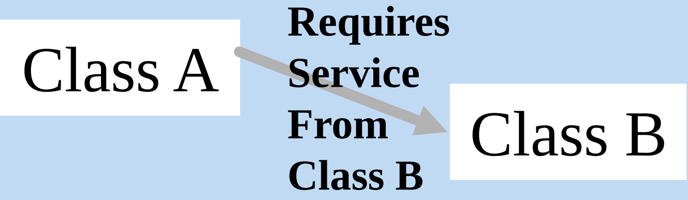
Object Oriented Analysis OOA

OOA Develops a Logical Model of the system as a set of interacting domain objects

- The model consists of two views
  - The *static* view: defines the classes and their dependencies

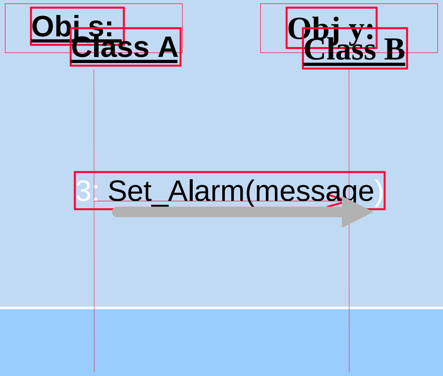


Class A

Requires Service From Class B

Class B

  - The *dynamic* view: models the scenarios of interactions between objects



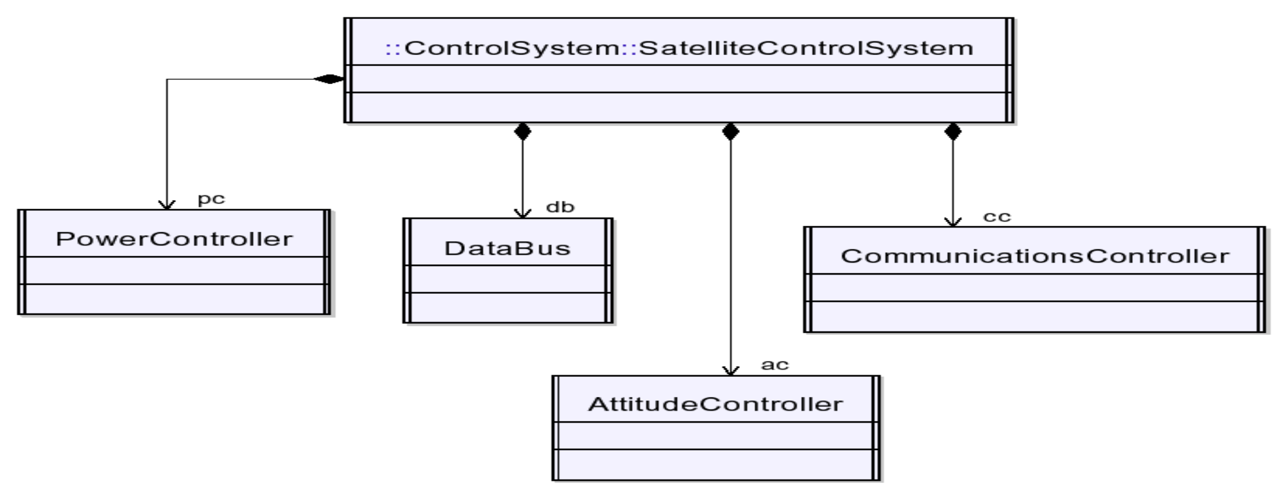
Obj s: Class A

Obj y: Class B

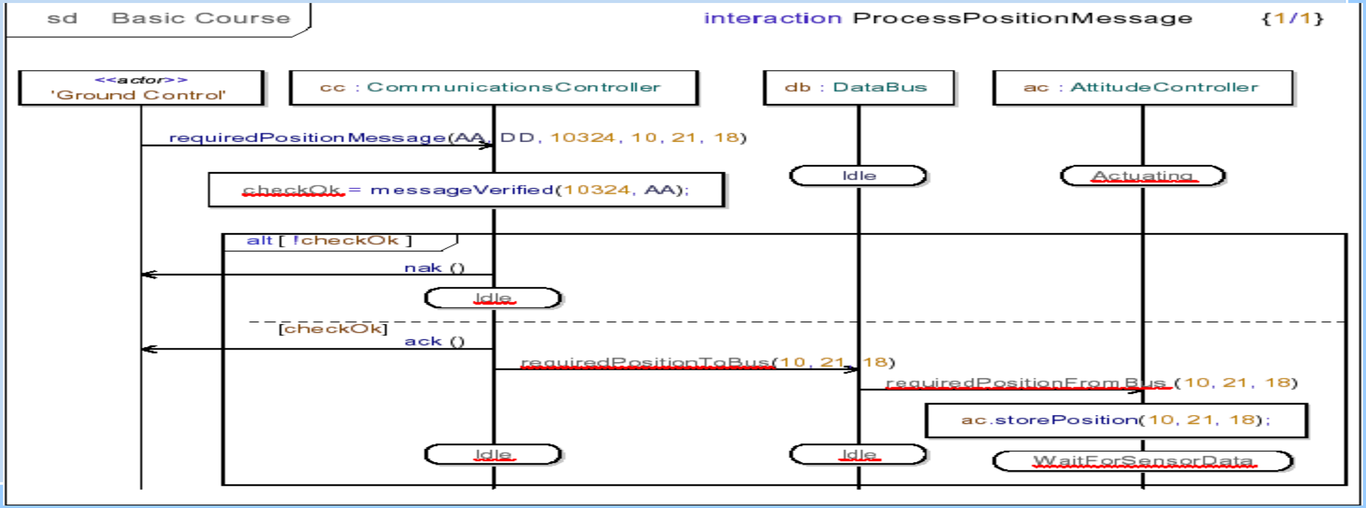
3: Set_Alarm(message)

OOA (cont.)

Example:
The Static Analysis Model
Class diagram



The dynamic Model:
A Scenario Of Interactions


sd Basic Course
interaction ProcessPositionMessage {1/1}
<<actor>>
'Ground Control'
cc : CommunicationsController
db : DataBus
ac : AttitudeController
requiredPositionMessage(AA, DD, 10324, 10, 21, 18)
Idle
Actuating
checkOk = messageVerified(10324, AA);
alt [!checkOk]
nak ()
Idle
[checkOk]
ack ()
requiredPositionToBus(10, 21, 18)
requiredPositionFromBus (10, 21, 18)
ac.storePosition(10, 21, 18);
Idle
Idle
WaitForSensorData

OOA (cont.)

OOA starts by identifying domain objects from the requirements model (Use-Case Models)

1. Discovering Objects

- *The Data Perspective*
  - In the problem space or external systems
  - Physical devices (sensors, actuators)
  - Events that need to be recorded (ex. Measurements)
  - Physical or geographical locations

OOA (cont’d)

- *The Functional Perspective*
  - What responsibilities does the object have? Ex. An event handler, a controller, monitors, sensors, etc.
- *The Behavioral Perspective*
  - Who does the object interact with? How?
  - Use a State Transition Diagrams to describe the object behavior

OOA (cont'd): ***Identifying Domain Objects from the requirements model***

In the statements of the requirements:

- An object may appear as a noun (ex. Measurement) or disguised in a verb (to measure)
- A method might appear as a verb (ex. Investigate) or disguised in a noun (investigation)
- Attributes describe some kind of characteristics for the object (adjectives). Attributes can be simple or complex. Complex attributes may lead to forming new objects. Attributes can also be nouns.

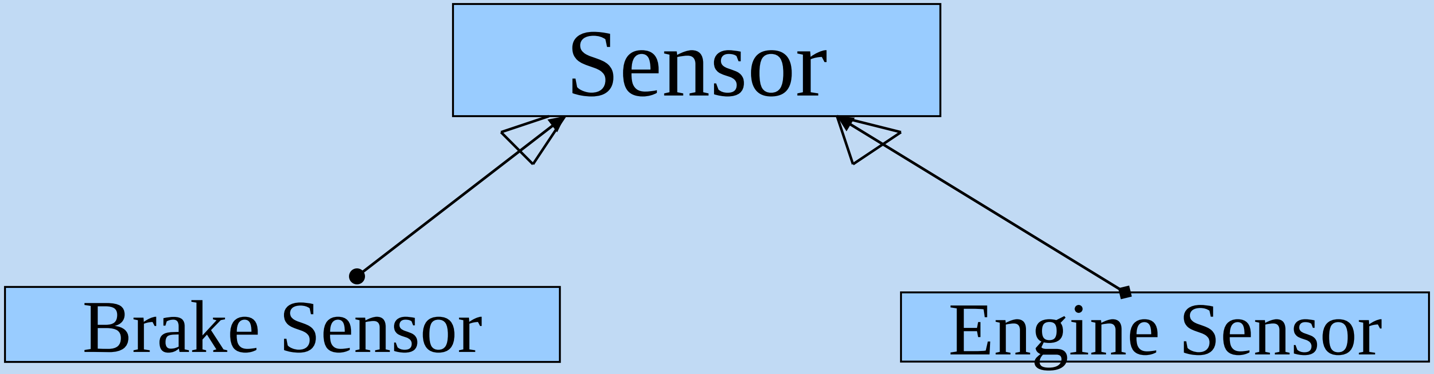
OOA (cont’d): ***Object Types***

- External Entities and their interfaces: Sensors, actuators, control panel, devices, operators, pilots
- Information Items : Displays, Commands, Requests, etc.
- Entities which establishes the context of the problem : Controller, monitors, schedulers

OOA (cont'd)

2. Define Class Hierarchies

- Generalization
  - Display → Login Display
- Specialization (IS_A)
  - Temperature_Sensor -> Sensor



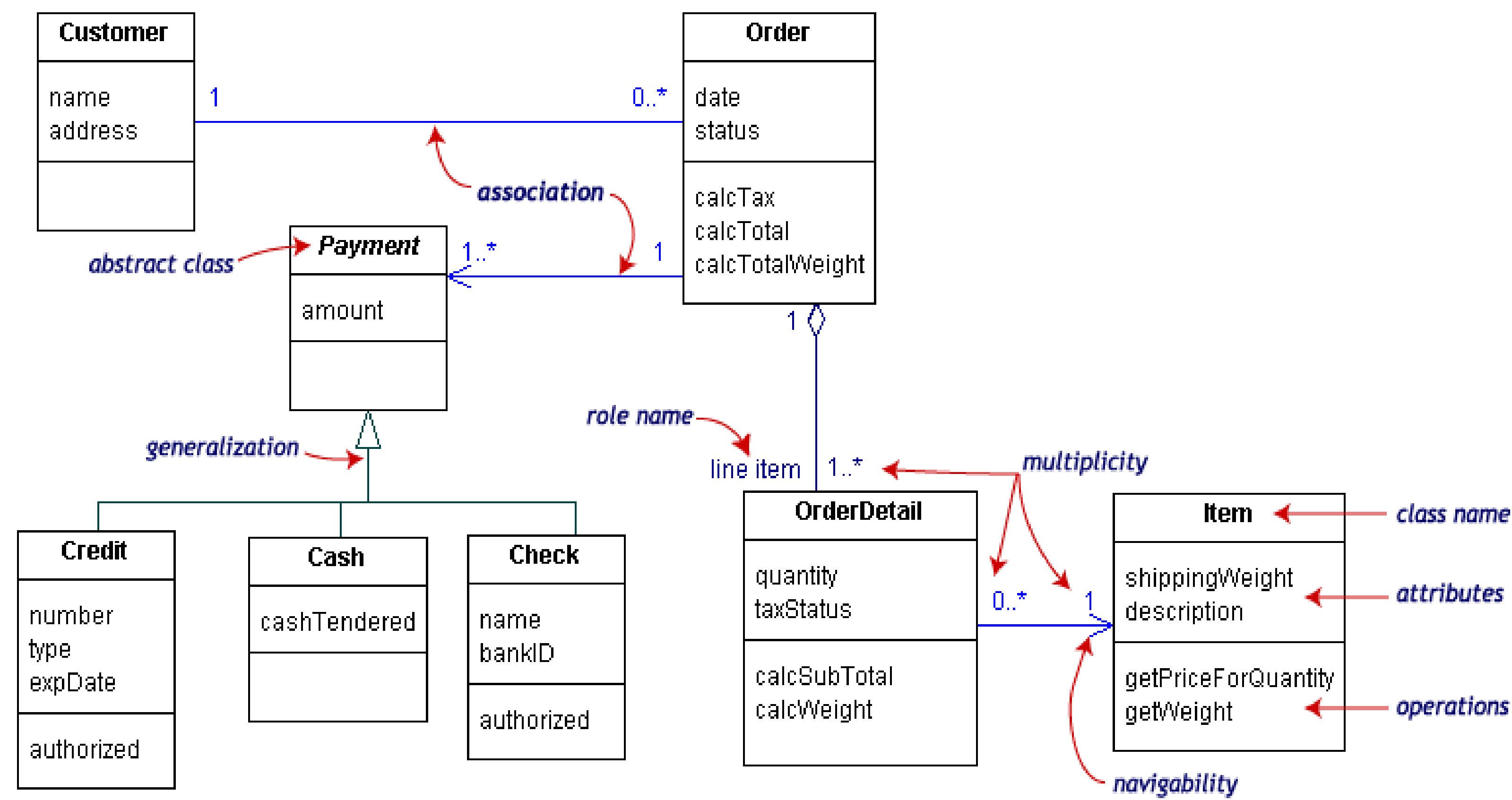
OOA (cont’d)

3. Class Relationships

- Types
  - Association
    - General form of dependency
  - Aggregation
    - An object may consist of other objects
  - Inheritance
- Cardinality (Multiplicity)
  - (Binary, Many, ..)

OOA (cont'd)

Example of identifying Class diagrams with Relationships, Multiplicities, Attributes, and operations (E-Commerce)



OOA (cont’d)

4. **Object Attributes**
   - Discovering attributes of classes
   - Attribute types
     - Naming : Ex. SensorID, Account
     - Descriptive Ex. Card expiration date
     - Referential Ex. Referring to other objects

OOA (cont'd)

5. The Dynamic View: Object Behavior

- Discovering states, transitions between states, and conditions and actions
- Building the state diagrams of objects

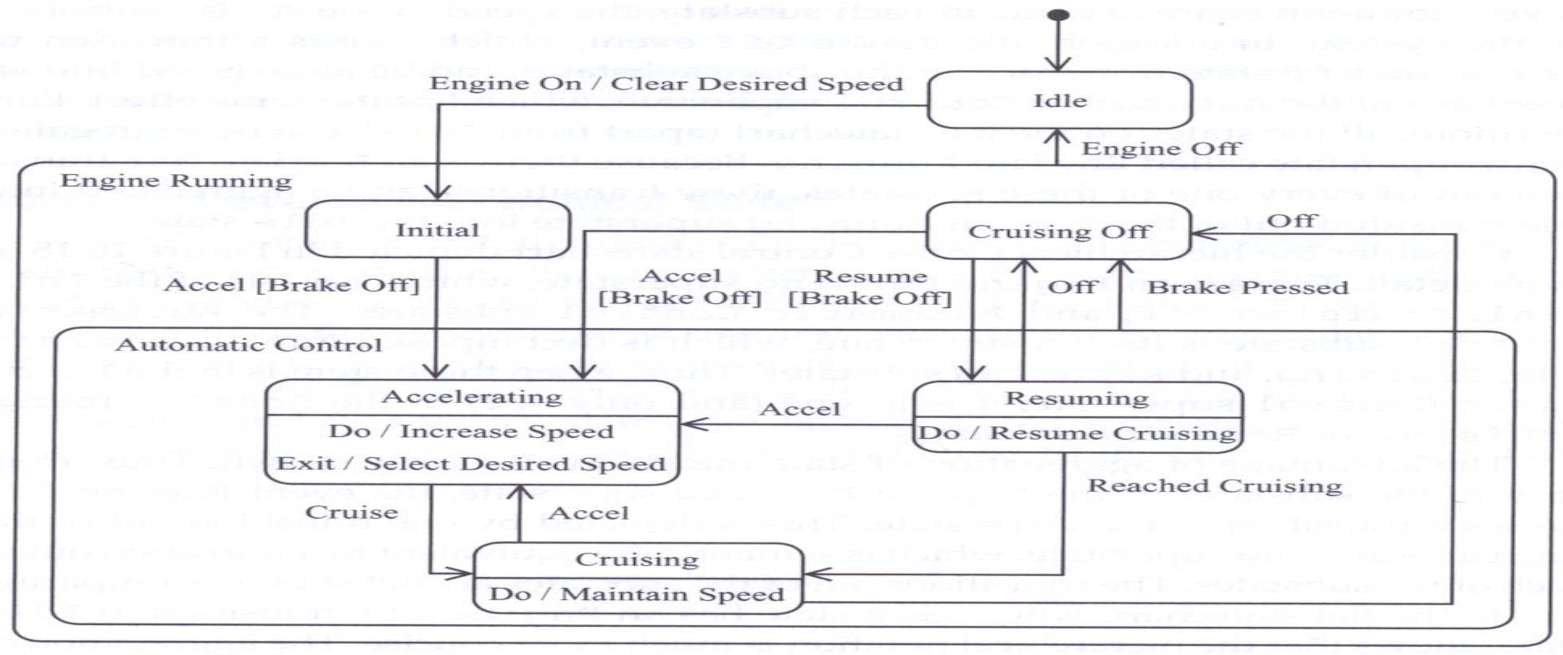


Figure 10.19 *Hierarchical Cruise Control statechart with activities and exit action*

OOA (cont’d)

6. **Object Services**
   - Implicit Services (create, modify, search, delete , etc.) ex. constructors
   - Services associated with messages
   - Services associated with object relationships
   - Services associated with attributes (accessor methods ex. get, set . ..)

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Object Oriented Design OOD

1. **Architecture Design**
   - The static view: structural description (defining the components and subsystems)
   - The Dynamic view (defining the interactions between components and subsystems)

2. **Detailed Design: Define detailed Class and object description**
   - Visibility (Private, protected, ..)
   - Containment (ex. Packages or Components)
   - Concurrency

OOD: Architecture Design

- Define the subsystems/components and their dependencies
- Interactions between components are defined in design sequence diagrams

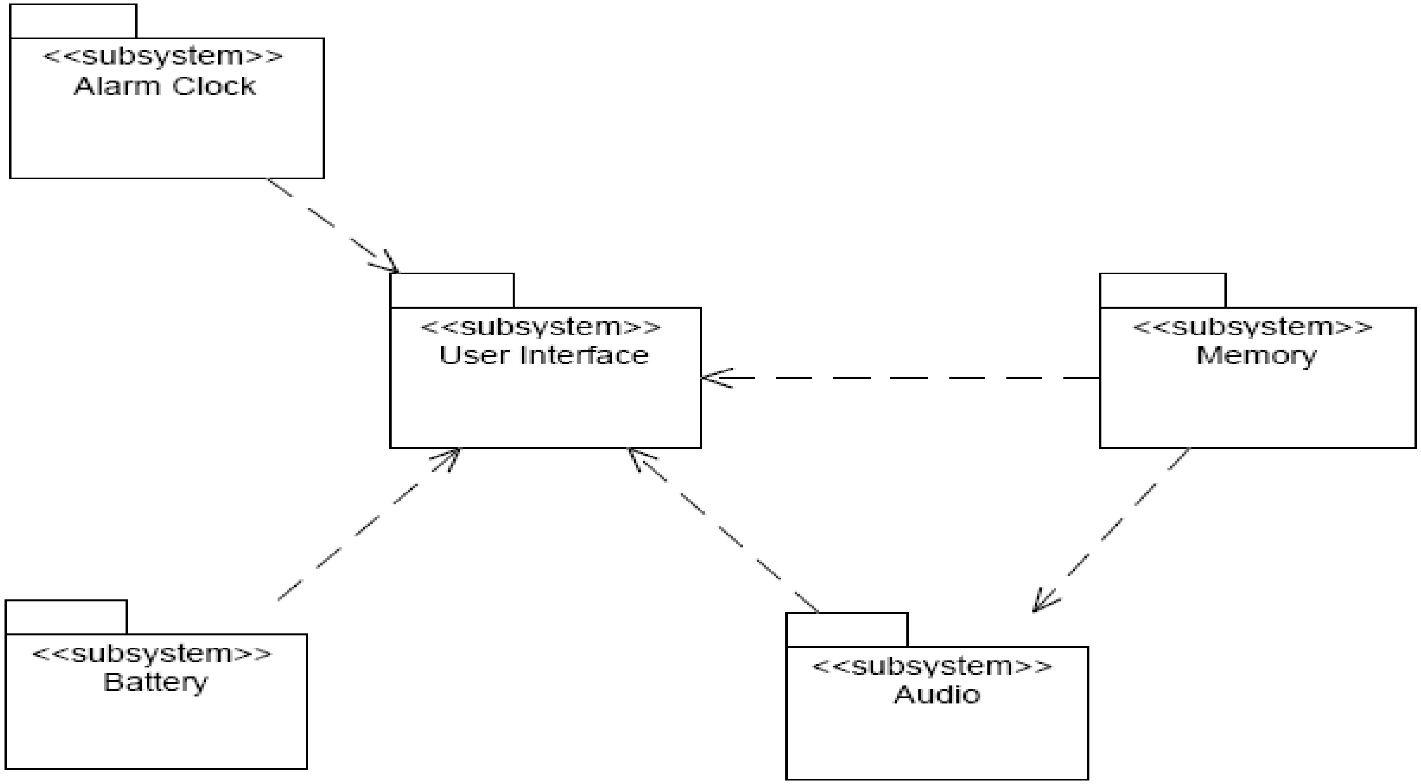

Figure 3.3: Subsystems in the sound recorder

OOD: Detailed Design

- Define the detailed design of each subsystem/component

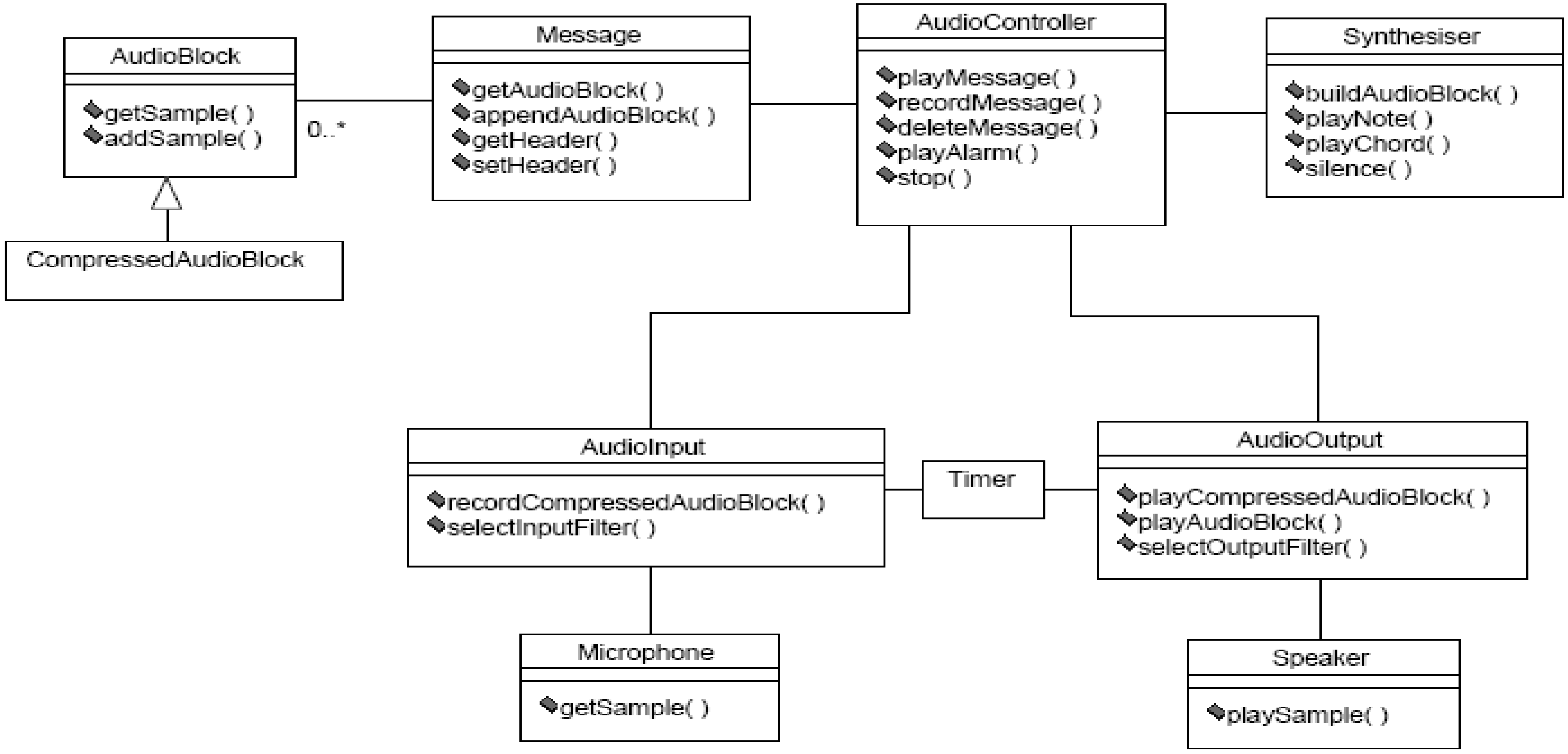

Figure 3.4: Audio subsystem class diagram

OOD: The Dynamic View

- Define design sequence diagrams for scenarios defined in the requirements model

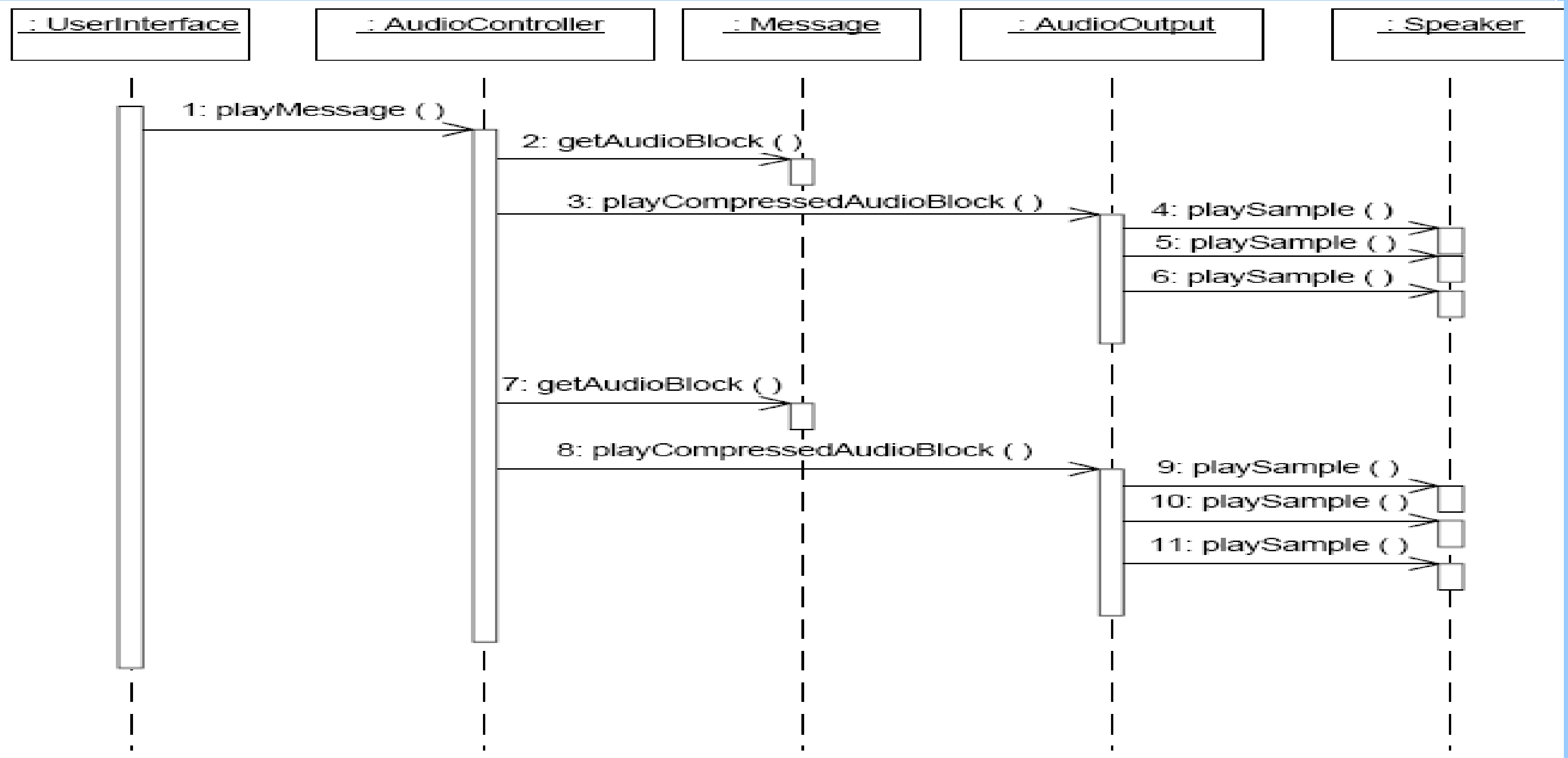

Figure 3.6: Play message sequence diagram

OOD (Cont'd)

3. **Design Refinement: Enhance Design Goodness Criteria** (e.g., using design patterns)
   - Coupling:
     - The manner and degree of interdependence between classes (objects)
   - Cohesion:
     - The degree and manner to which the services or tasks performed by a component or an object are related to each other.
   - Modularity
     - Understandability
     - Decomposability
   - Clarity
     - Simple classes, messages, methods

Summary of the Object-Oriented Analysis and Design (OOA) Methodology

- Based on describing the logical model of the system and the environment as a set of interacting objects
- Defines the external objects (actors) interacting with the system as well as the internal objects that the system must contain
- Defines the static architecture of objects and the dynamic behavioral interactions between them
- Defines the internal dynamic behavior of objects

OUTLINE

- The development process
- Reviewing Object Oriented Analysis and Design
- Introducing visual modeling and the Unified Modeling Language UML

Visual Modeling and the Unified Modeling Language UML

- What is the UML?
- UML Concepts
- UML Development - Overview

The Unified Modeling Language UML

What is the UML?

- UML stands for Unified Modeling Language
- The UML is the standard language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system
- It can be used with all processes, throughout the development life cycle, and across different implementation technologies.

UML Concepts

The UML may be used to:

- Develop a Requirements Model
  1. Use Case diagrams - Define the scope, and display the boundary of a system & its major functions using ***use cases*** and ***actors***
  2. System Sequence diagrams - Illustrate use case realizations or scenarios of interactions between the actors and the system
- Develop the Analysis model
  1. Class diagrams - Represent a static structure of a system
  2. State Charts - Model the behavior of objects

UML Concepts

- Develop the architecture design model
  1. Class diagrams: Represent the static architecture using packages or subsystems
  2. Design Sequence diagrams – Represent the dynamic interactions between the design objects

- Develop the physical architecture implementation model
  - component & deployment diagrams - Reveal the physical implementation architecture

Visual Modeling and the Unified Modeling Language UML

- What is the UML?
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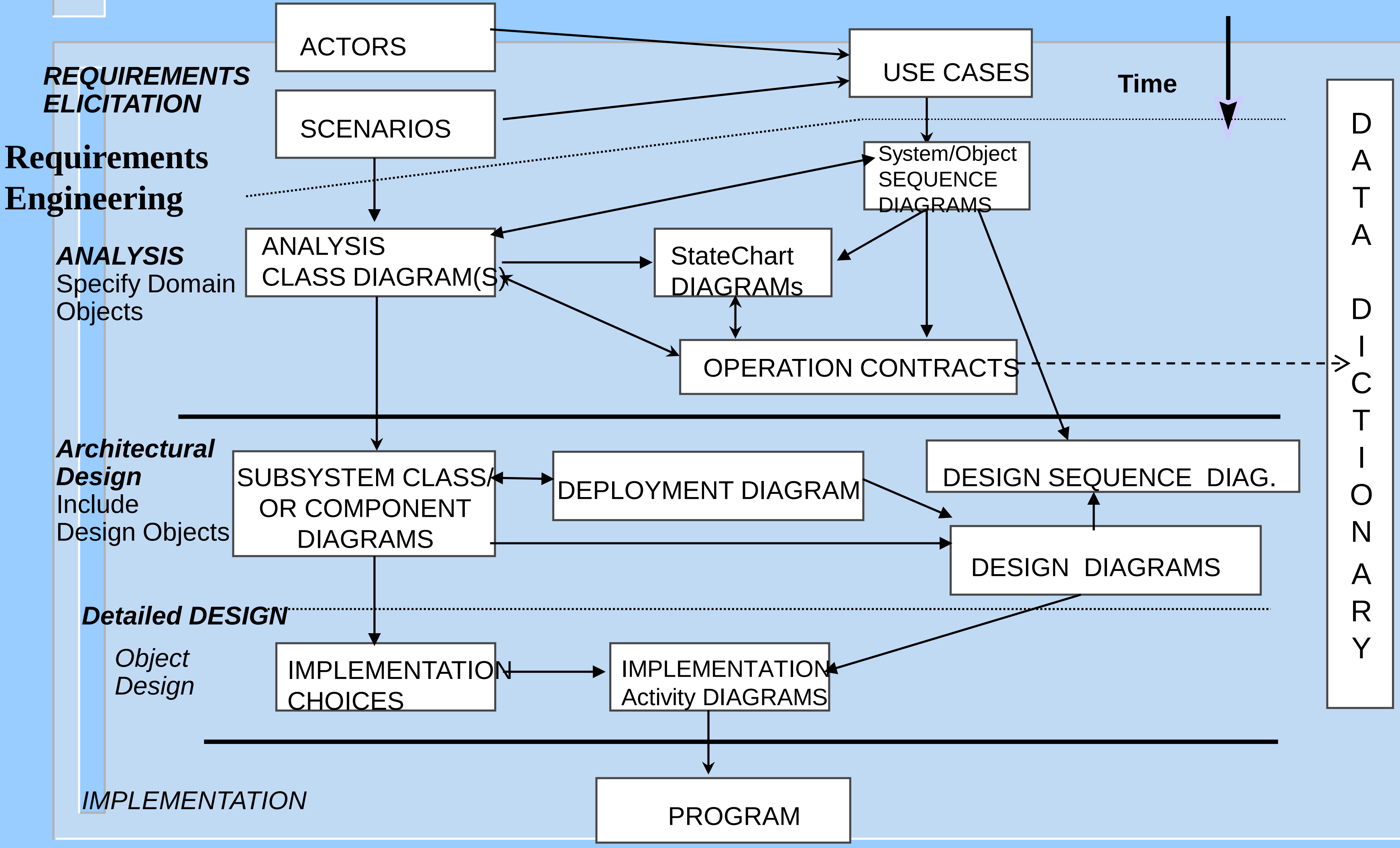
UML Development - Overview



REQUIREMENTS ELICITATION

Requirements Engineering

ANALYSIS
Specify Domain
Objects

Architectural Design
Include
Design Objects

Detailed DESIGN

Object Design

IMPLEMENTATION

A Model of embedded systems development

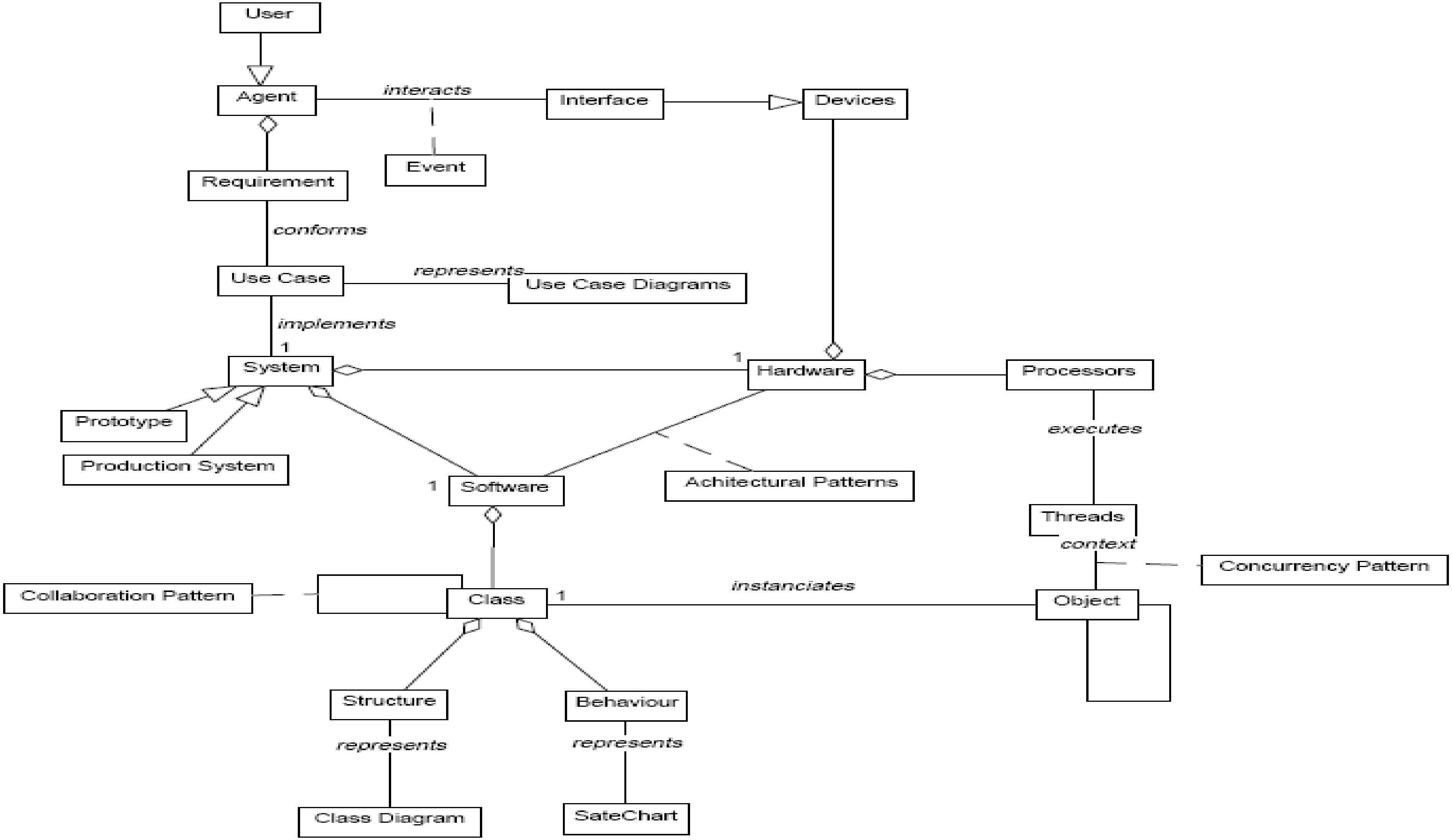


Figure 9.1: Embedded systems design class diagram

Visual Modeling and the Unified Modeling Language UML

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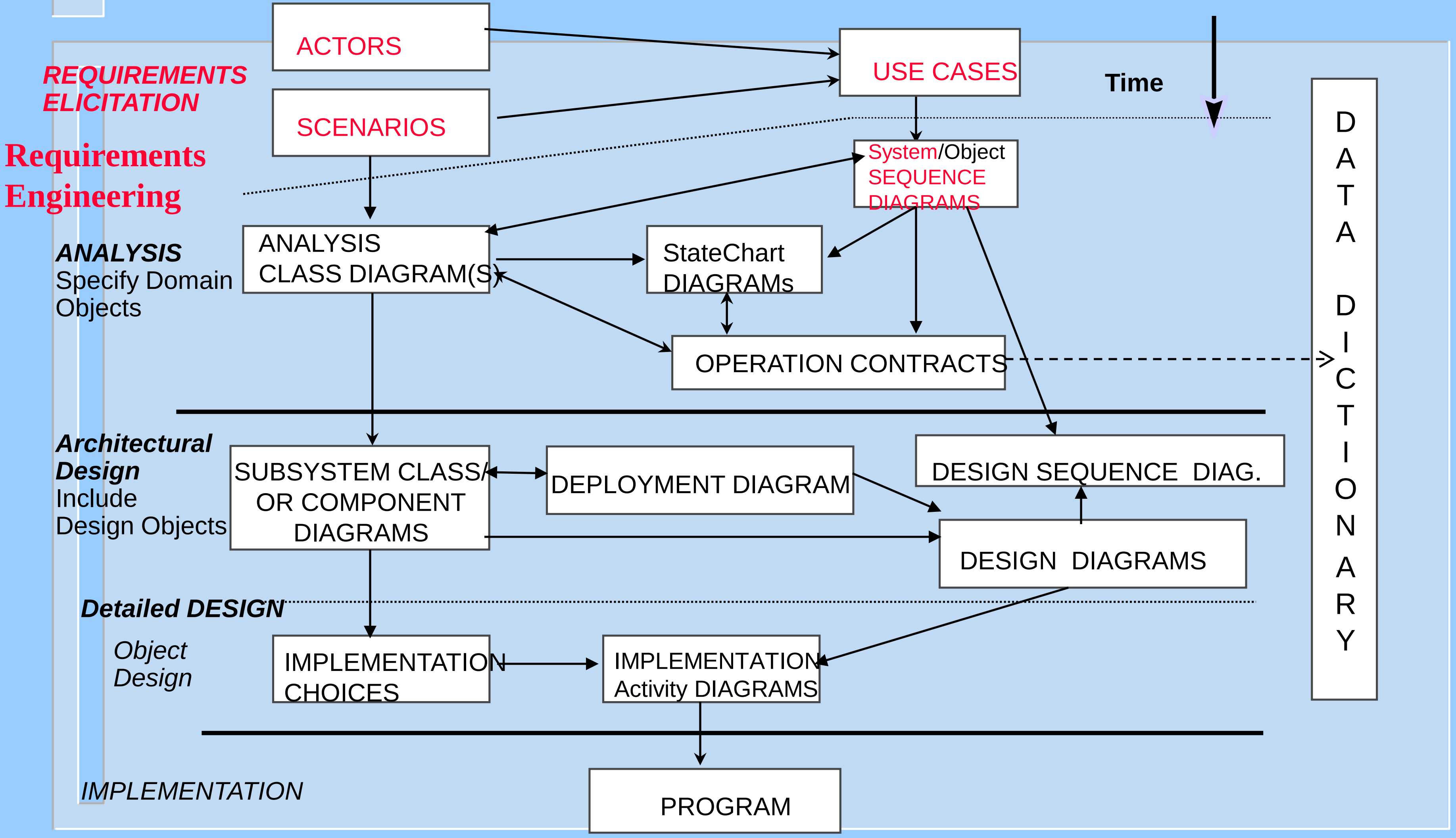
    - Requirements Elicitation

UML Development - Overview



REQUIREMENTS ELICITATION

Requirements Engineering

ACTORS

SCENARIOS

USE CASES

Time

System/Object SEQUENCE DIAGRAMS

ANALYSIS
Specify Domain Objects

ANALYSIS CLASS DIAGRAM(S)

StateChart DIAGRAMs

OPERATION CONTRACTS

D A T A D I C T I O N A R Y

Architectural Design
Include Design Objects

SUBSYSTEM CLASS/ OR COMPONENT DIAGRAMS

DEPLOYMENT DIAGRAM

DESIGN SEQUENCE DIAG.

DESIGN DIAGRAMS

Detailed DESIGN

Object Design

IMPLEMENTATION CHOICES

IMPLEMENTATION Activity DIAGRAMS

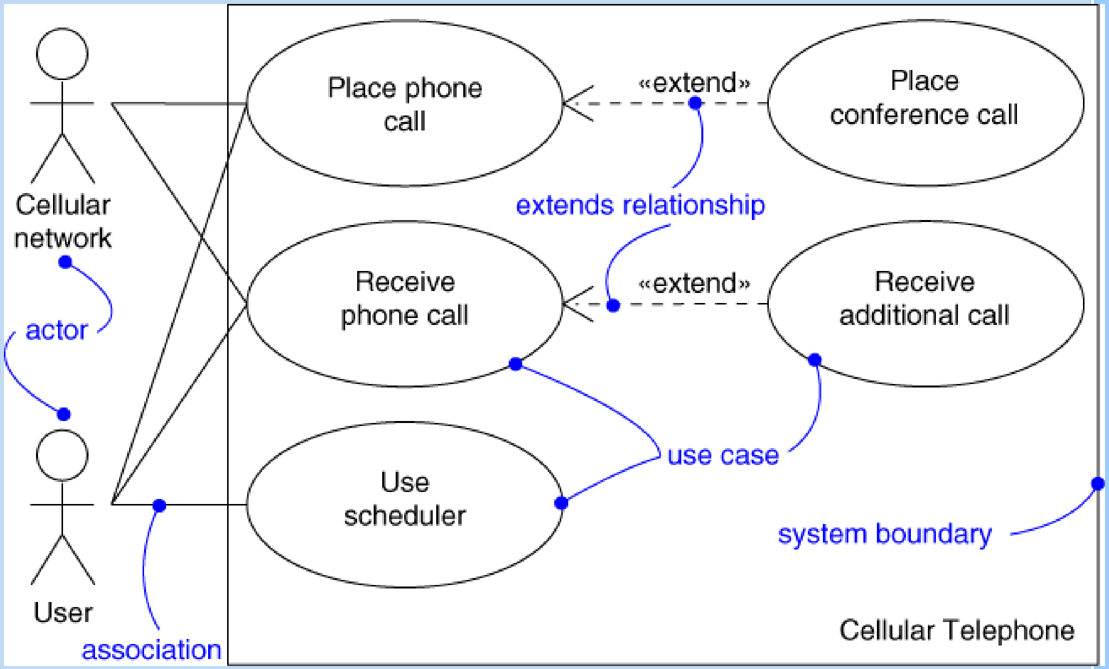
IMPLEMENTATION

PROGRAM

UML Use Case Diagrams:
The Requirements Model

Defining Actors (External objects)

- An actor is an object that must interact with the system under development



UML Use Case Diagrams: The Requirements Model

Defining Use Cases

- A use case captures the user requirements, it is a pattern of behavior the system exhibits
  - Each use case is a sequence of related interactions performed by an actor and the system in a dialogue
- Actors are examined to determine their needs
  - Each actor must have association with at least one use case
  - Use cases can be related to each other

UML Use Case Diagrams: The Requirements Model

Case Study

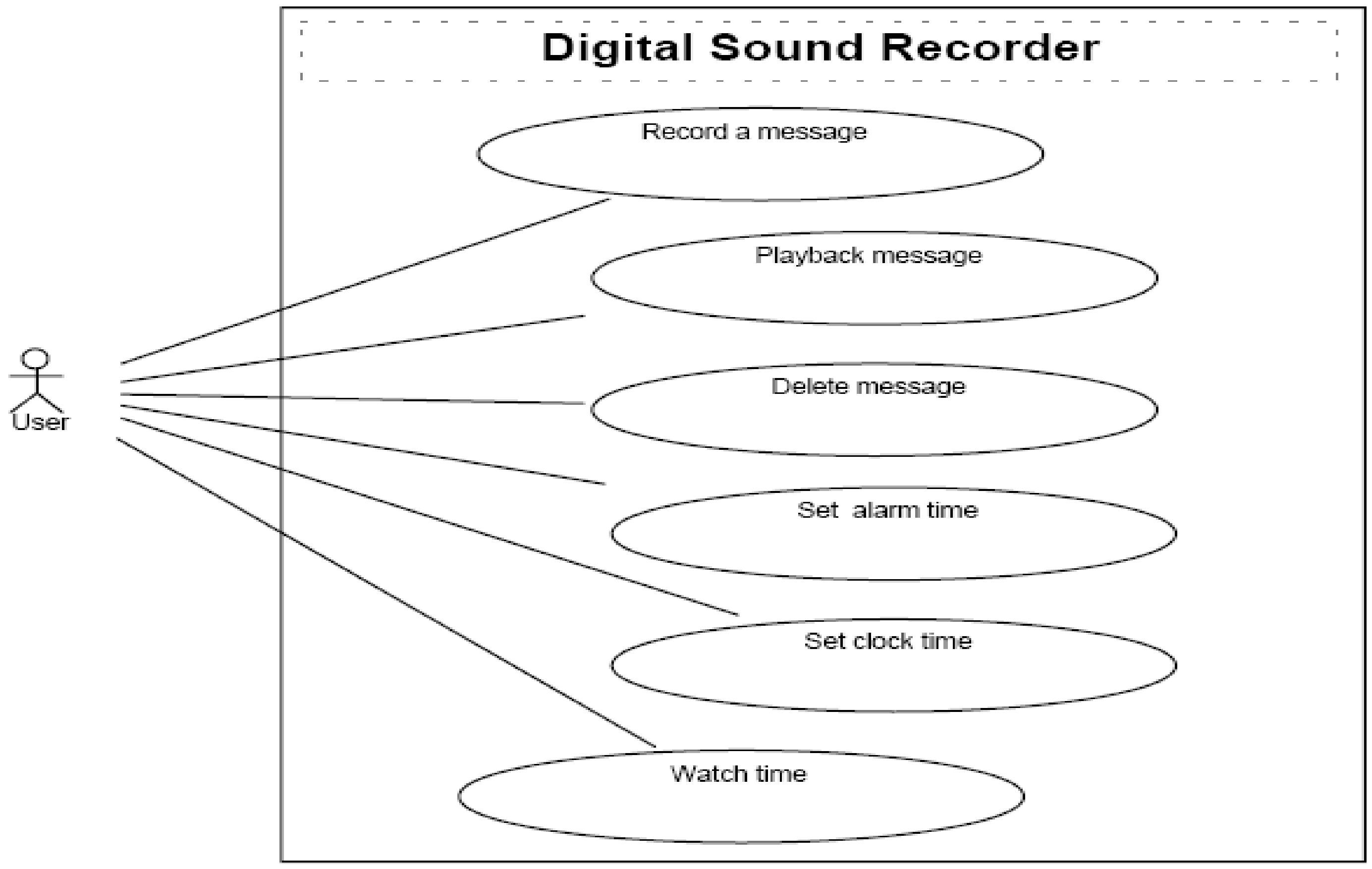


Figure 2.3: Use Case diagram

UML Use Case Diagrams: The Requirements Model

Documenting Use Cases

- A flow of events document is created for each use cases
  - Written from an actor point of view
- Details what the system must provide to the actor when the use cases is executed
- Typical contents
  - How the use case starts and ends
  - Normal flow of events
  - Alternate flow of events
  - Exceptional flow of events

UML Use Case Diagrams:
The Requirements Model

Use Case Realizations: Object Interaction diagrams

- The use case diagram presents an outside view of the system
- Interaction diagrams capture the scenarios of the functional requirements
- They describe how use cases are realized as interactions among societies of objects (objects interact to accomplish a function of the system)
- UML supports two types of interaction diagrams: Sequence diagrams, and Collaboration diagrams

UML Use Case Diagrams: The Requirements Model

Digital Sound Recorder Case Study

- A sequence diagram displays object interactions arranged in a time sequence capturing a specific *scenario* of interactions in a *use case* supported by the system

Time

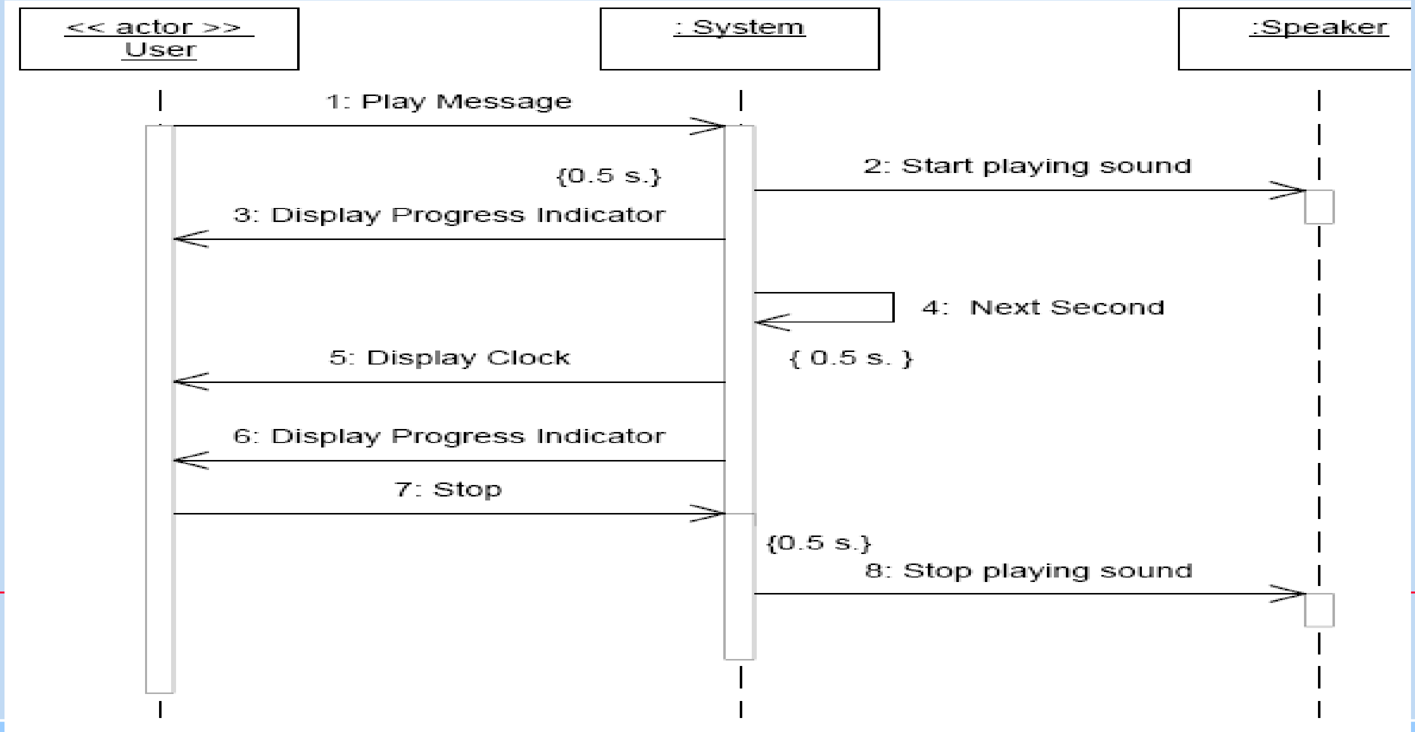


Figure 2.4: Playing message scenario

Visual Modeling and the Unified Modeling Language UML

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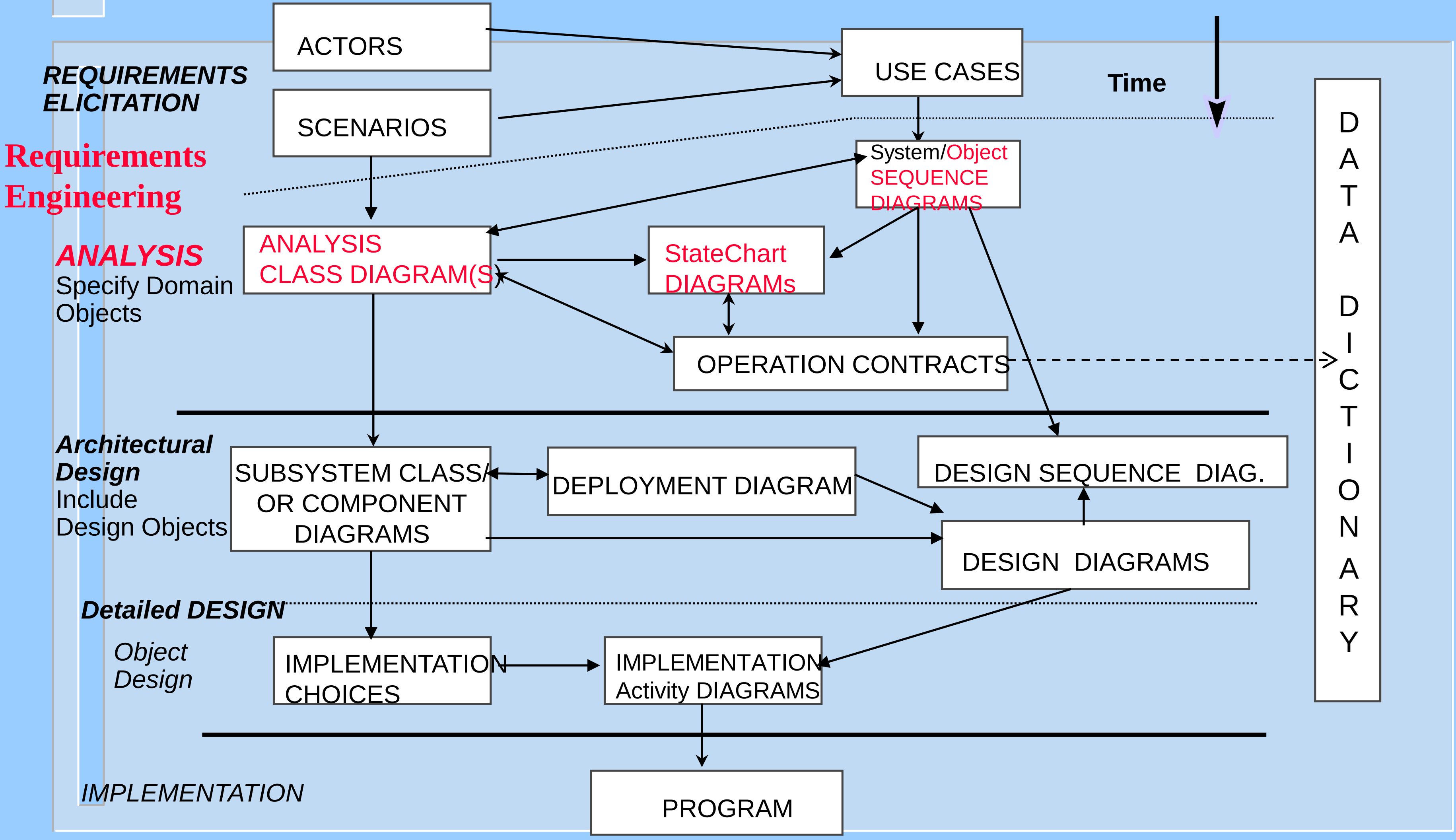
UML Development - Overview



REQUIREMENTS ELICITATION

Requirements Engineering

ACTORS

SCENARIOS

USE CASES

Time

System/Object SEQUENCE DIAGRAMS

ANALYSIS

Specify Domain Objects

ANALYSIS CLASS DIAGRAM(S)

StateChart DIAGRAMs

OPERATION CONTRACTS

D A T A D I C T I O N A R Y

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DEPLOYMENT DIAGRAM

DESIGN SEQUENCE DIAG.

DESIGN DIAGRAMS

Detailed DESIGN

Object Design

IMPLEMENTATION CHOICES

IMPLEMENTATION Activity DIAGRAMS

IMPLEMENTATION

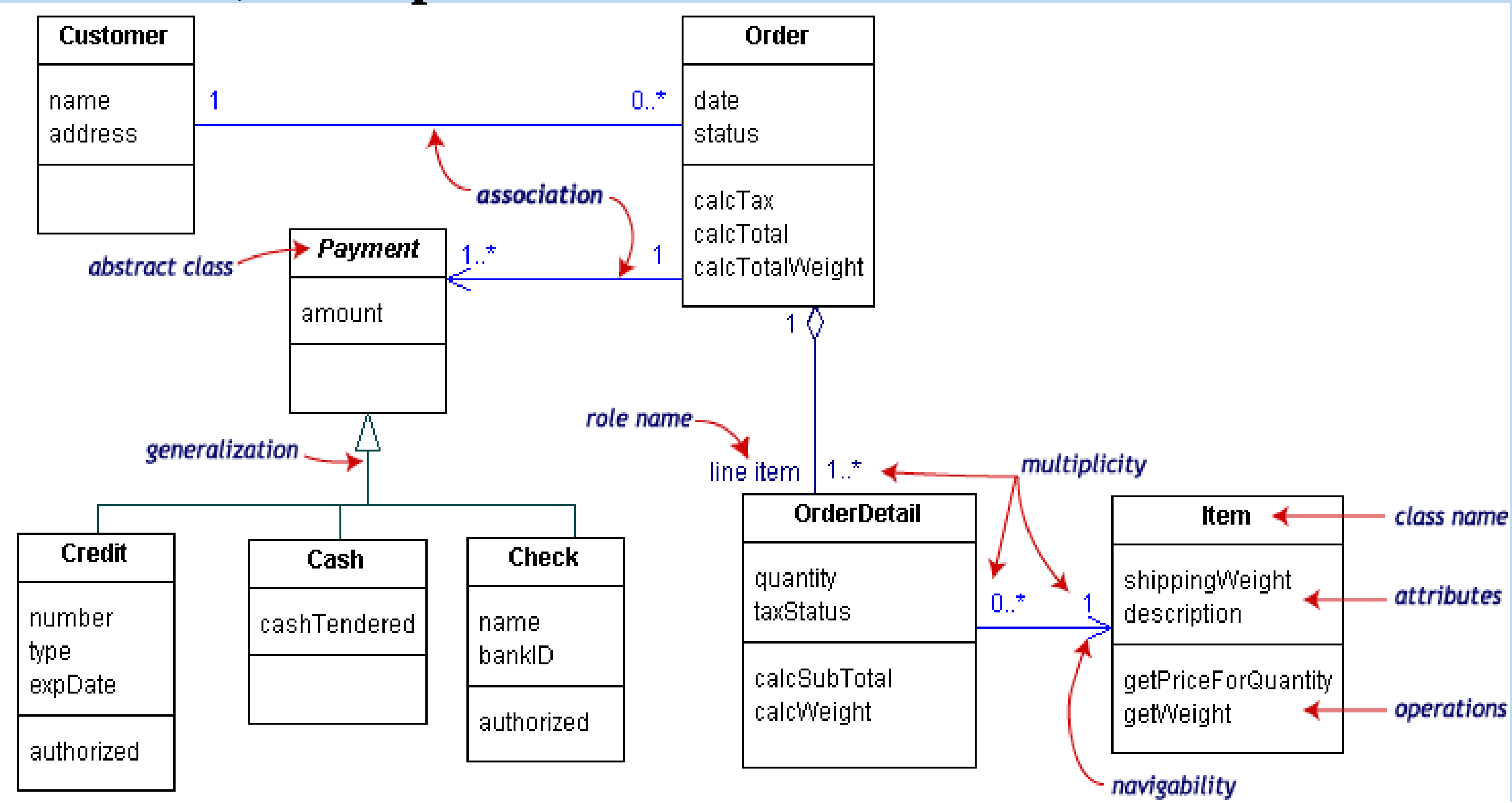
PROGRAM

UML Class Diagrams:
The Analysis Model

- A class diagram shows the existence of classes and their relationships in the logical view of a system
- UML modeling elements in class diagrams
  1. Classes and their structure and behavior
  2. Association, aggregation, and inheritance relationships
  3. Multiplicity and navigation indicators
  4. Role names

UML Class Diagrams: The Analysis Model

Define Classes, Relationships, Multiplicities, Attributes, and operations



UML Class Diagrams:

The Analysis Model

Digital Sound Recorder Case Study

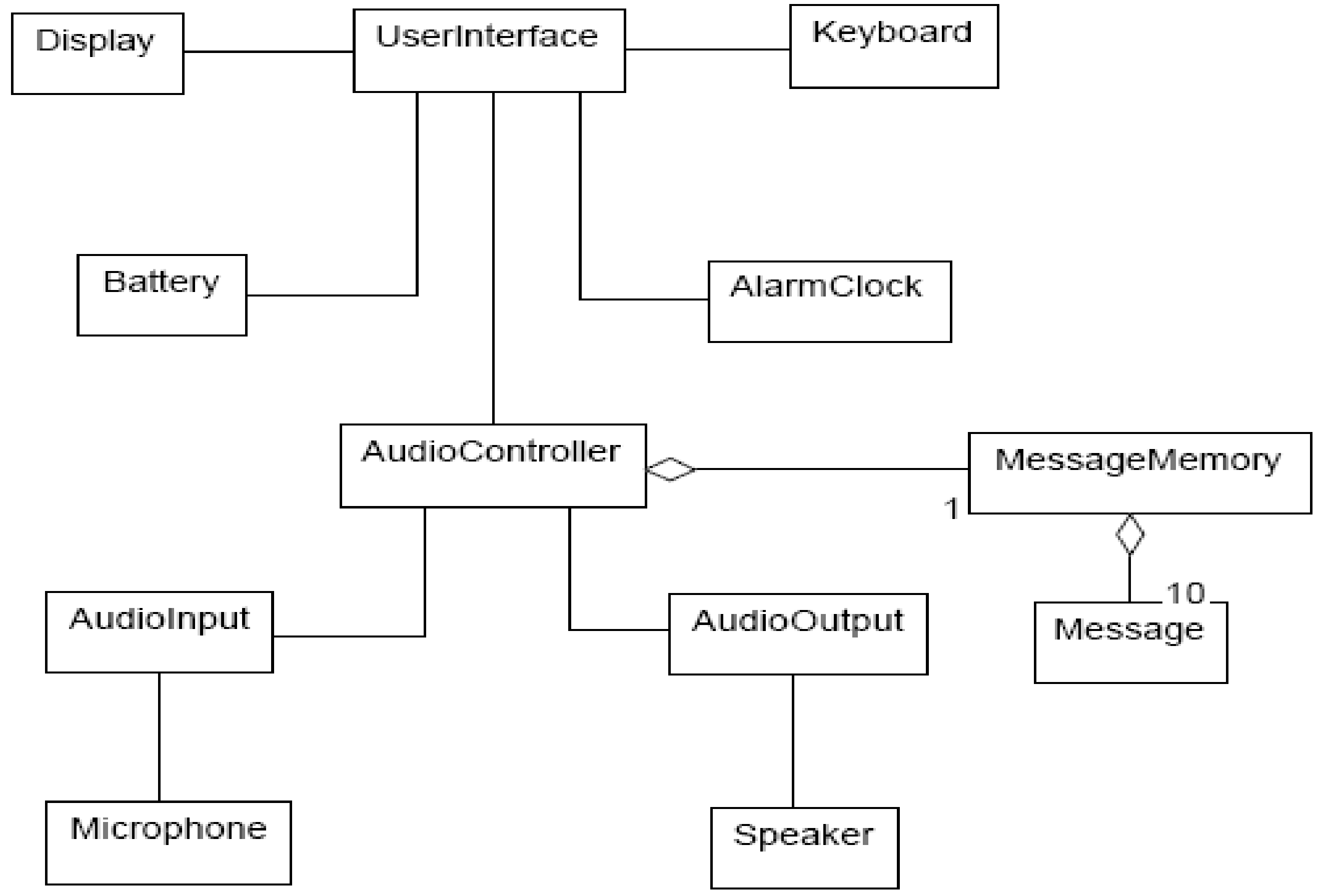


Figure 3.2: Sound Recorder class diagram

UML State charts:
The Analysis Model

The State of an Object

- A state transition diagram shows
  - The life history of a given class
  - The events that cause a transition from one state to another
  - The actions that result from a state change
- State transition diagrams are created for objects with significant dynamic behavior

UML State charts: The Analysis Model

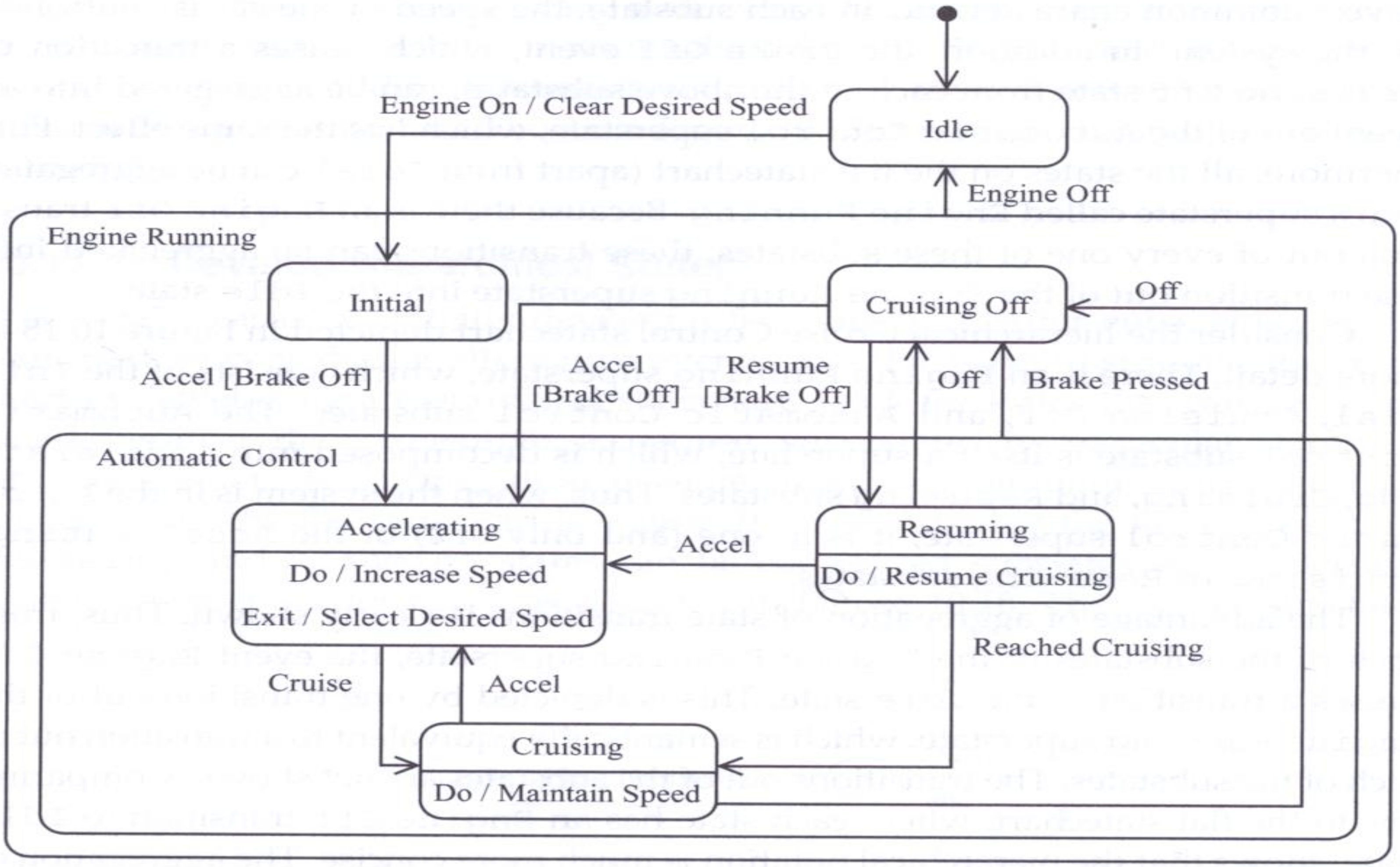


Figure 10.19 *Hierarchical Cruise Control statechart with activities and exit action*

UML State charts:

The Analysis Model

Digital Sound Recorder Case Study

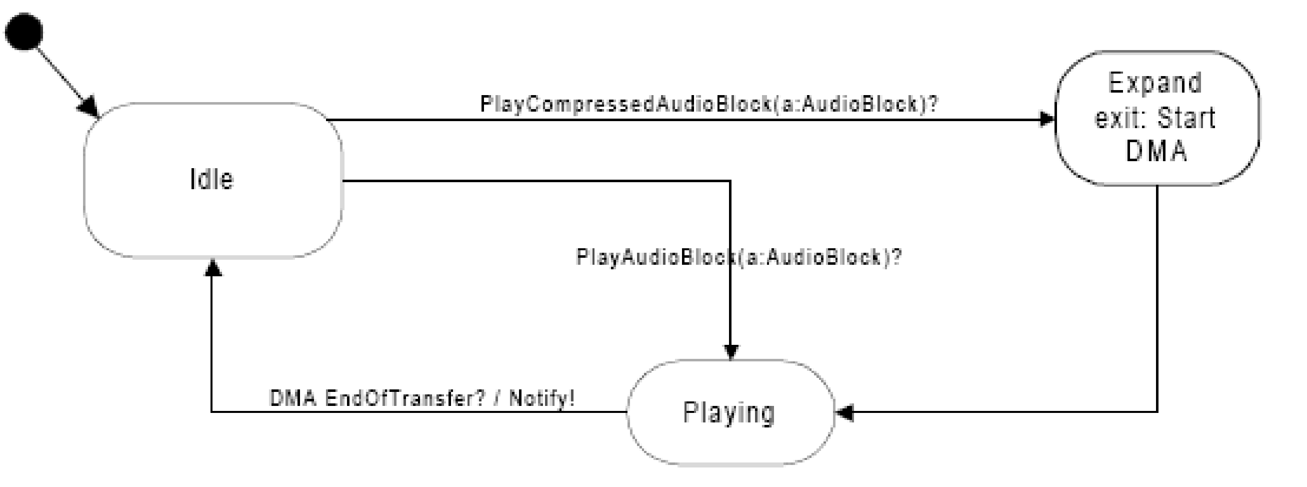

Idle
PlayCompressedAudioBlock(a:AudioBlock)?
Expand
exit: Start
DMA
PlayAudioBlock(a:AudioBlock)?
DMA EndOfTransfer? / Notify!
Playing

Figure 4.3: AudioOutput statechart

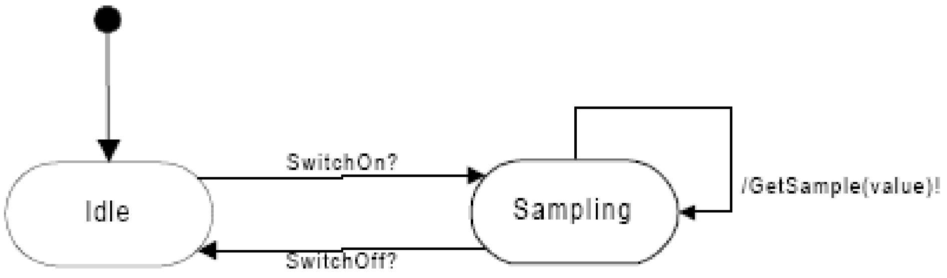


Figure 4.4: Microphone statechart

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  - The Design Model

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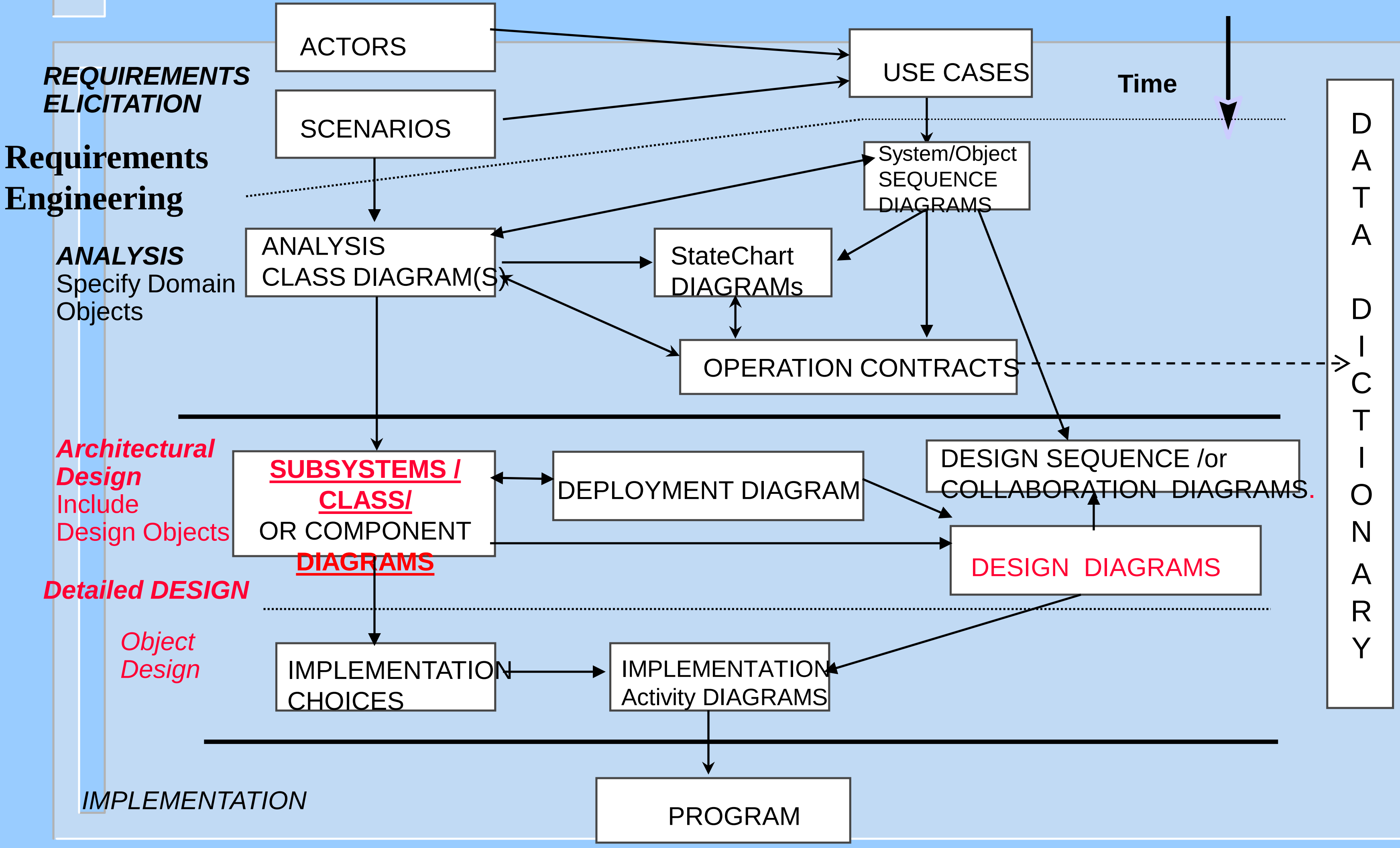

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Architectural Design
Include Design Objects

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StateChart DIAGRAMs
OPERATION CONTRACTS
D A T A D I C T I O N A R Y
SUBSYSTEMS / CLASS/ OR COMPONENT DIAGRAMS
DEPLOYMENT DIAGRAM
DESIGN SEQUENCE /or COLLABORATION DIAGRAMS.
DESIGN DIAGRAMS
IMPLEMENTATION CHOICES
IMPLEMENTATION Activity DIAGRAMS
PROGRAM

Object Oriented Design OOD

1. **Architecture Design (Subsystem/Component Diagrams)**
   - The static view: structural description (defining the components and subsystems)
   - The Dynamic view (defining the interactions between components and subsystems)
2. **Detailed Design: Define detailed Class and object description**
   - Visibility (Private, protected, ..)
   - Containment (ex. Packages or Components)
   - Concurrency

UML Class Diagrams:

Architecture Design: The static view

Digital Sound Recorder Case Study

- Define the subsystems/components and their dependencies
- Interactions between components are defined in design sequence diagrams

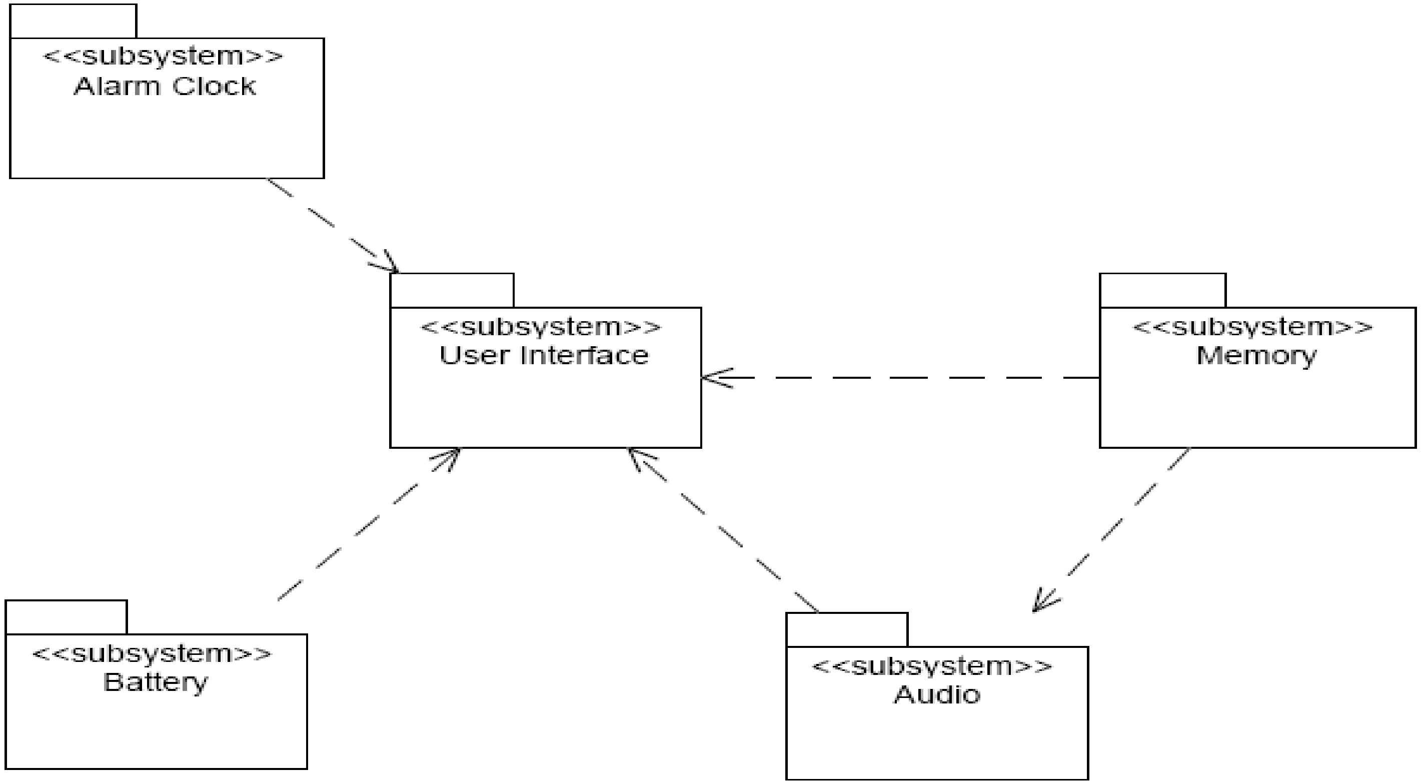


Figure 3.3: Subsystems in the sound recorder

UML Class Diagrams:
Detailed Design: The static view

Digital Sound Recorder Case Study

- Define the detailed design of each subsystem/component

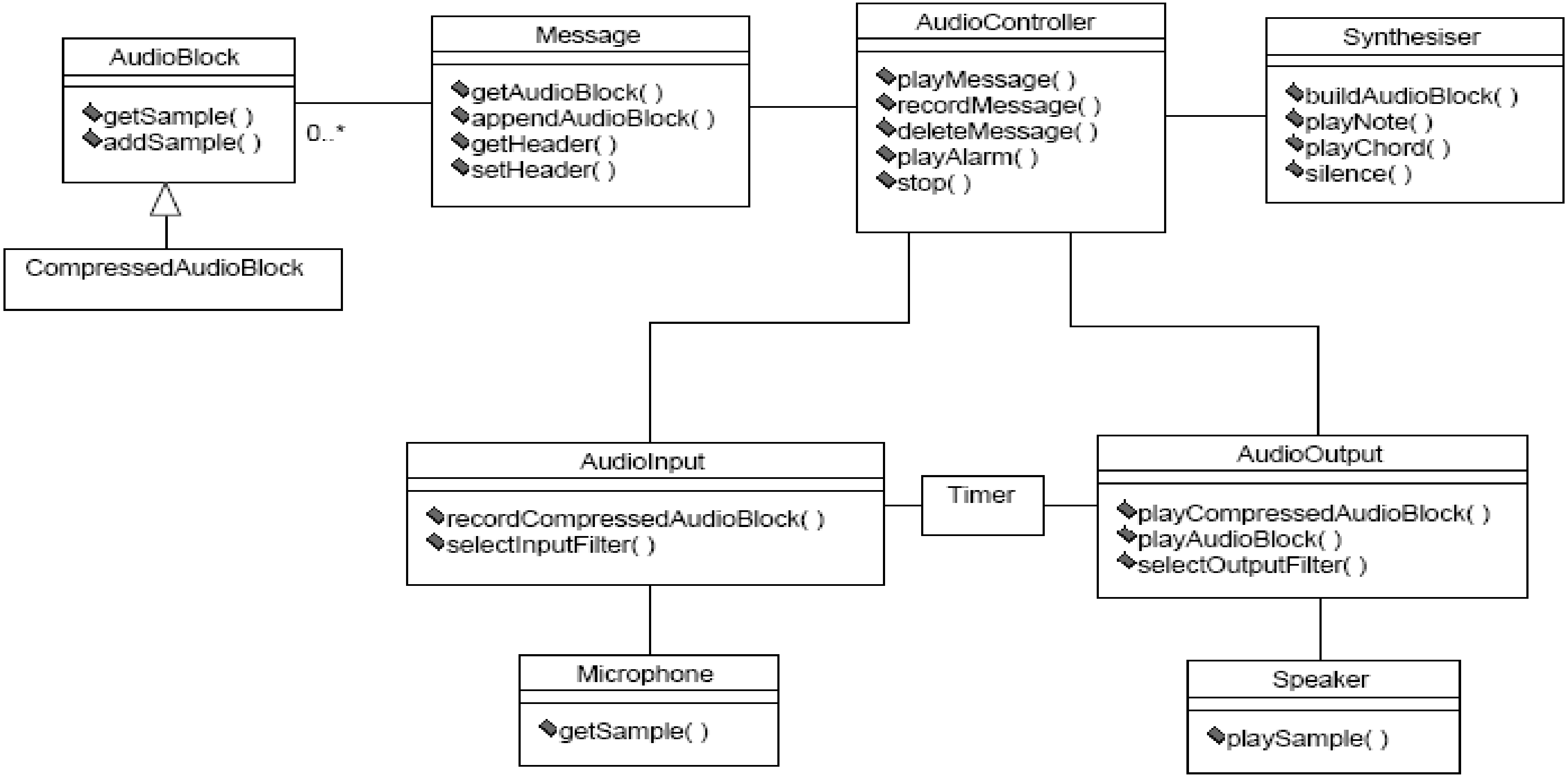
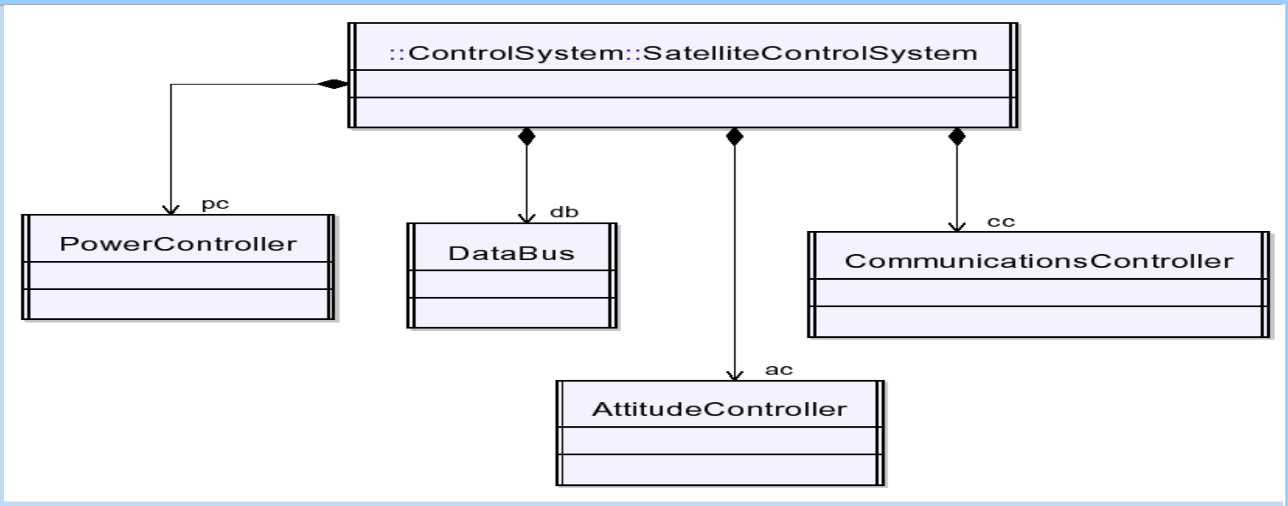


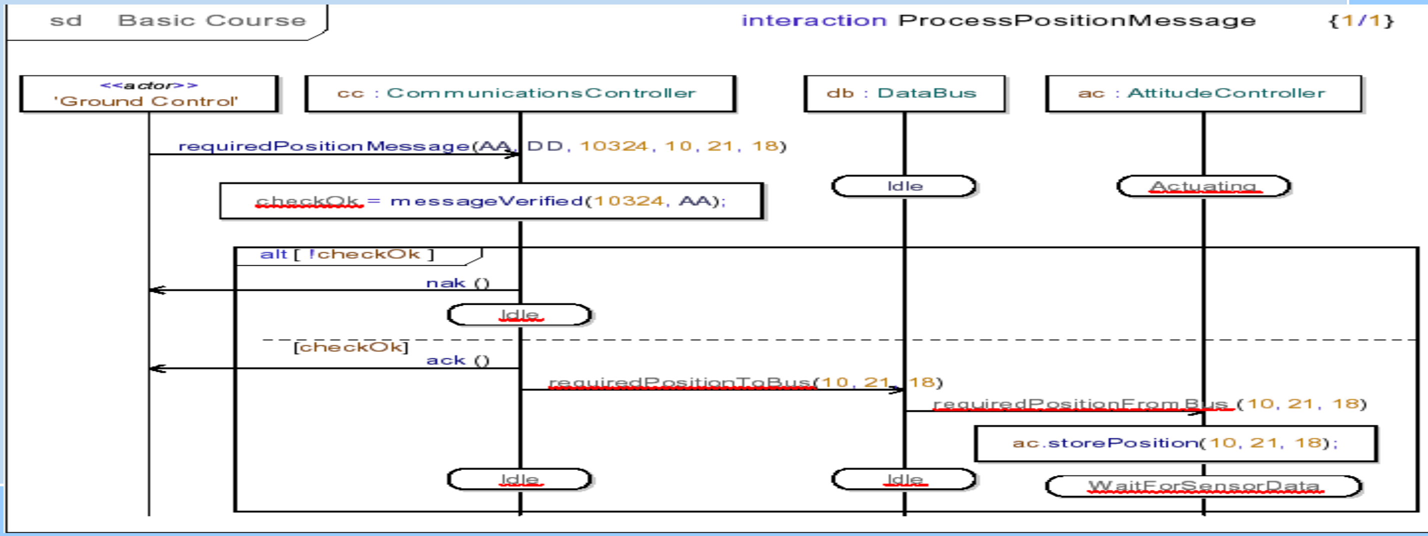
Figure 3.4: Audio subsystem class diagram

Recall: OOA (cont.) Satellite Control Example

Example: The Static Analysis Model Class diagram



The dynamic Model: A Scenario Of Interactions

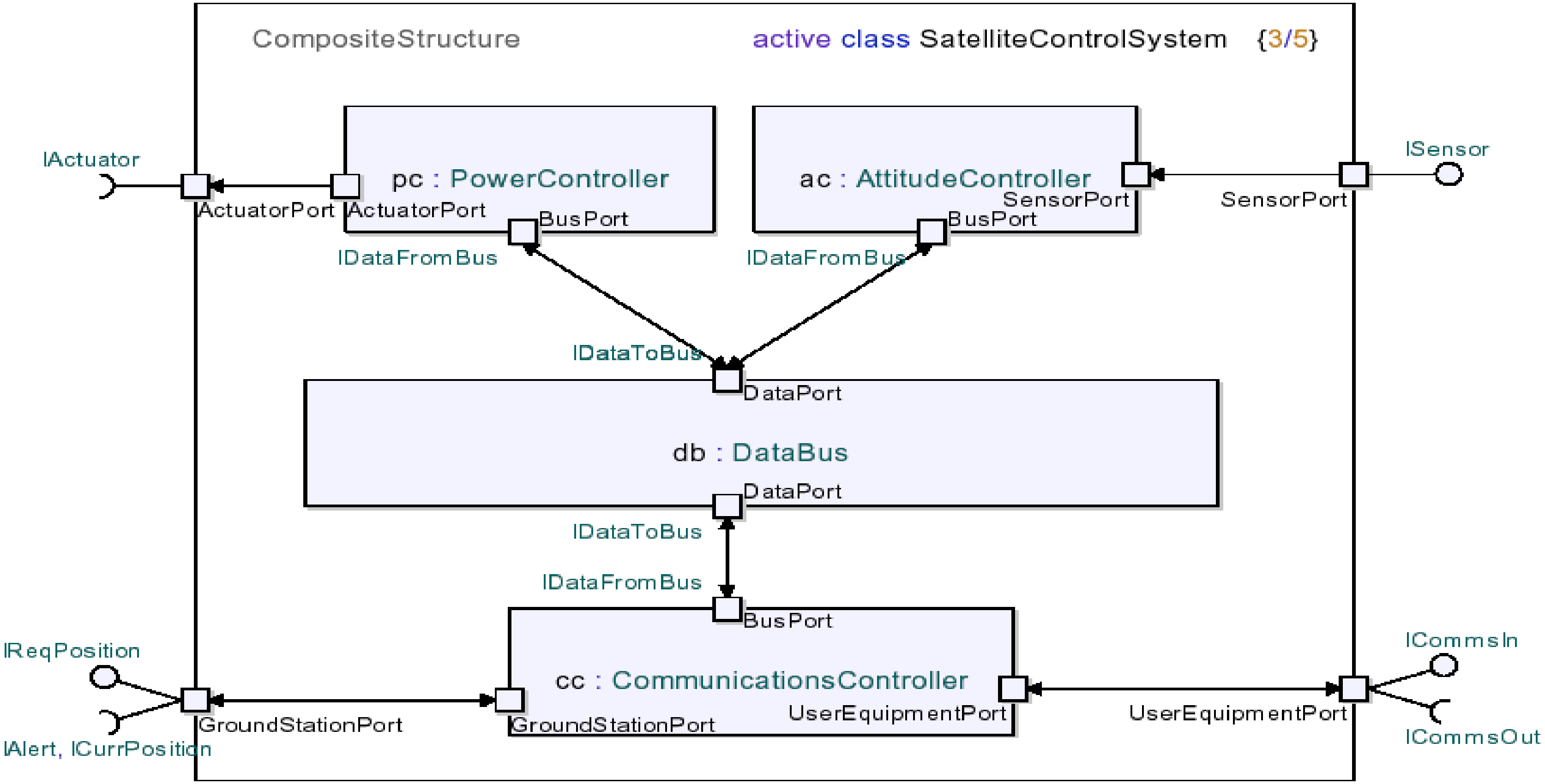

sd Basic Course
interaction ProcessPositionMessage {1/1}
<<actor>>
'Ground Control'
cc : CommunicationsController
db : DataBus
ac : AttitudeController
requiredPositionMessage(AA, DD, 10324, 10, 21, 18)
Idle
Actuating
checkOk = messageVerified(10324, AA);
alt [!checkOk]
nak ()
Idle
[checkOk]
ack ()
requiredPositionToBus(10, 21, 18)
requiredPositionFromBus (10, 21, 18)
ac.storePosition(10, 21, 18);
Idle
Idle
WaitForSensorData

UML Class Diagrams:

Detailed Design: The static view

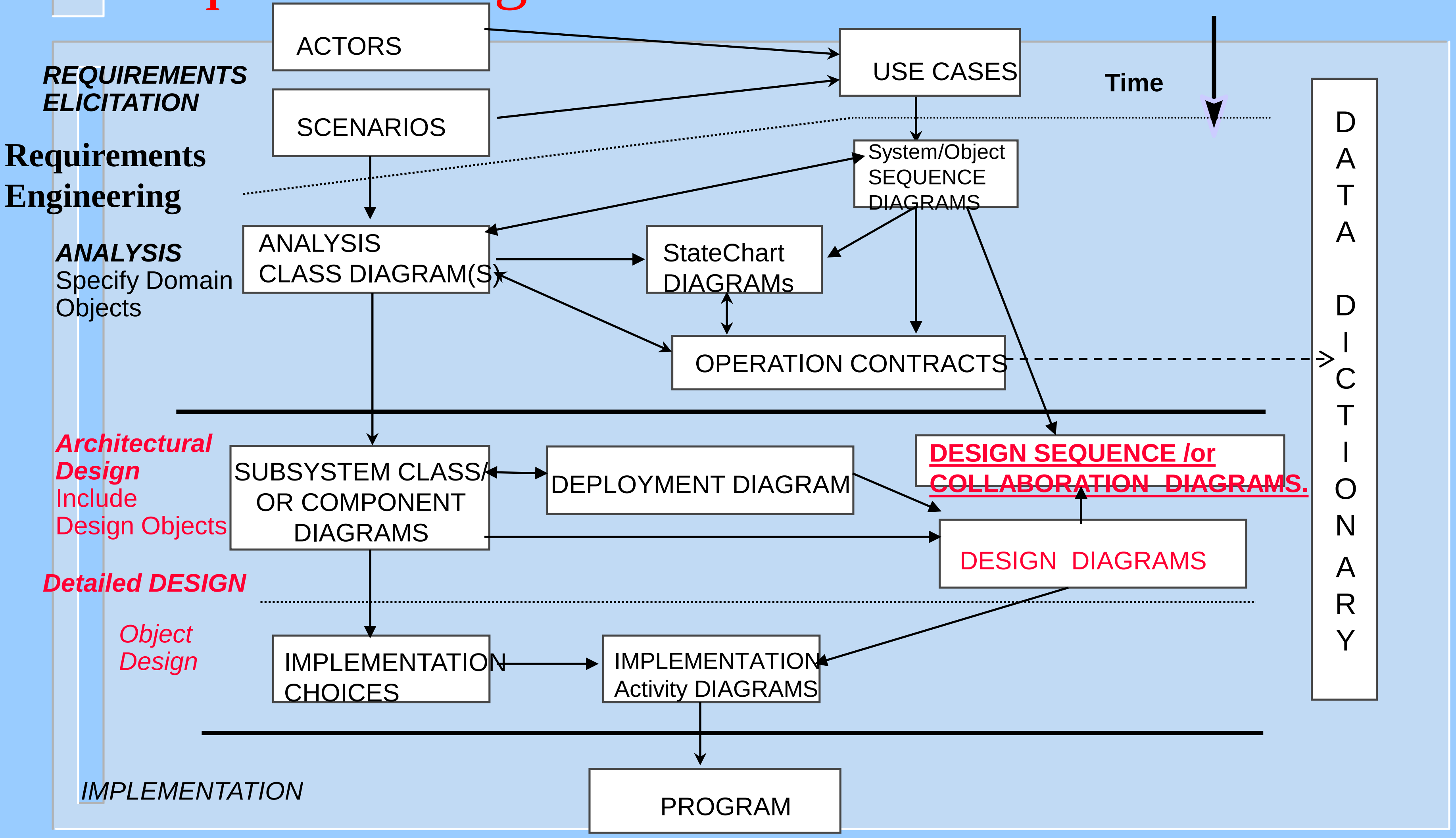
Composite Structure Diagrams (UML2)

Satellite Control Example



UML Development – Overview

Detailed Design: The dynamic view, Design Sequence Diagrams



UML Sequence Diagrams:

Detailed Design: The dynamic view

Digital Sound Recorder Case Study

- Define design sequence diagrams for scenarios defined in the requirements model

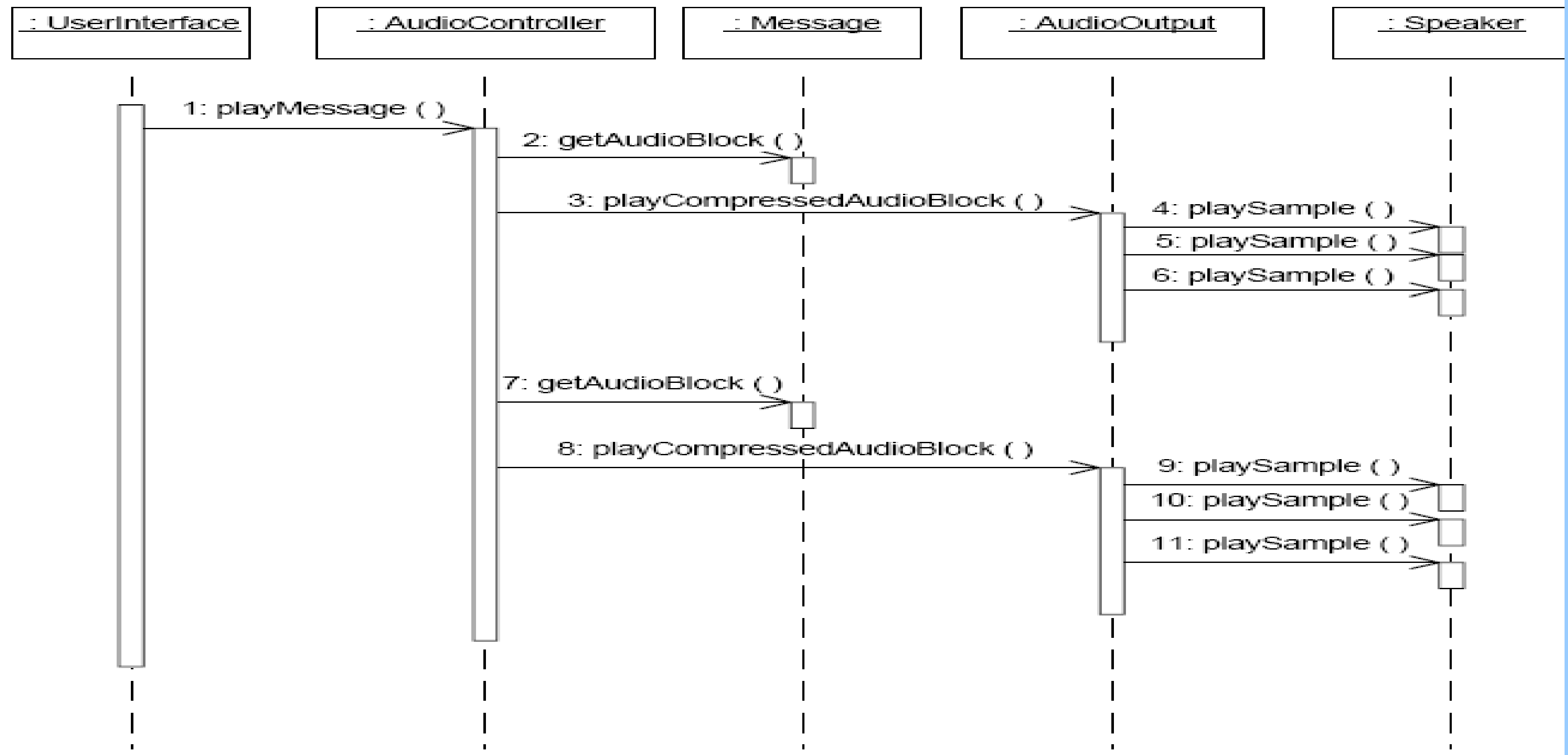


Figure 3.6: Play message sequence diagram

Detailed Design: The dynamic view, UML Collaboration Diagrams

This diagram has similar information as in sequence diagrams with no time axis

Digital Sound Recorder Case Study

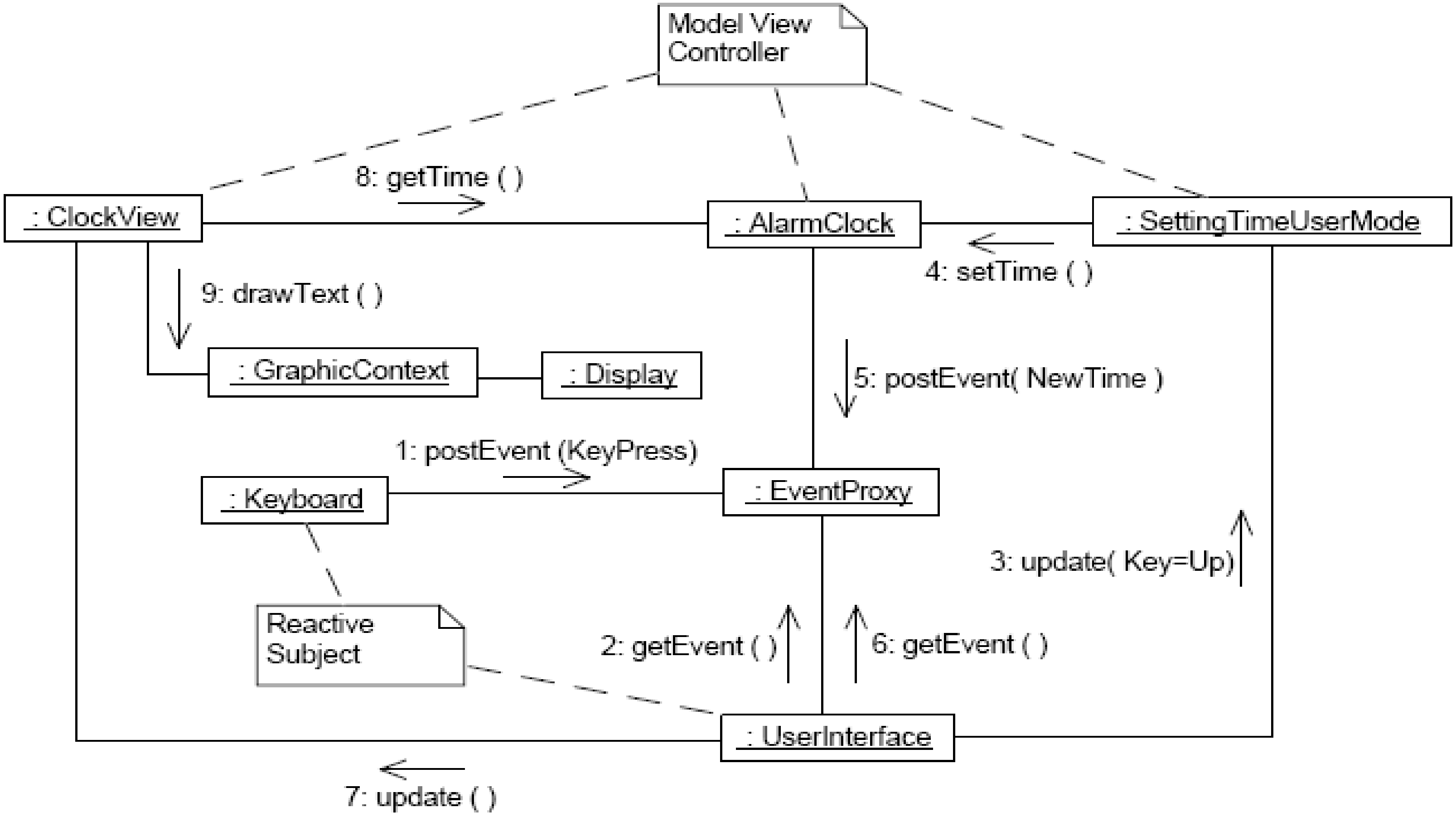


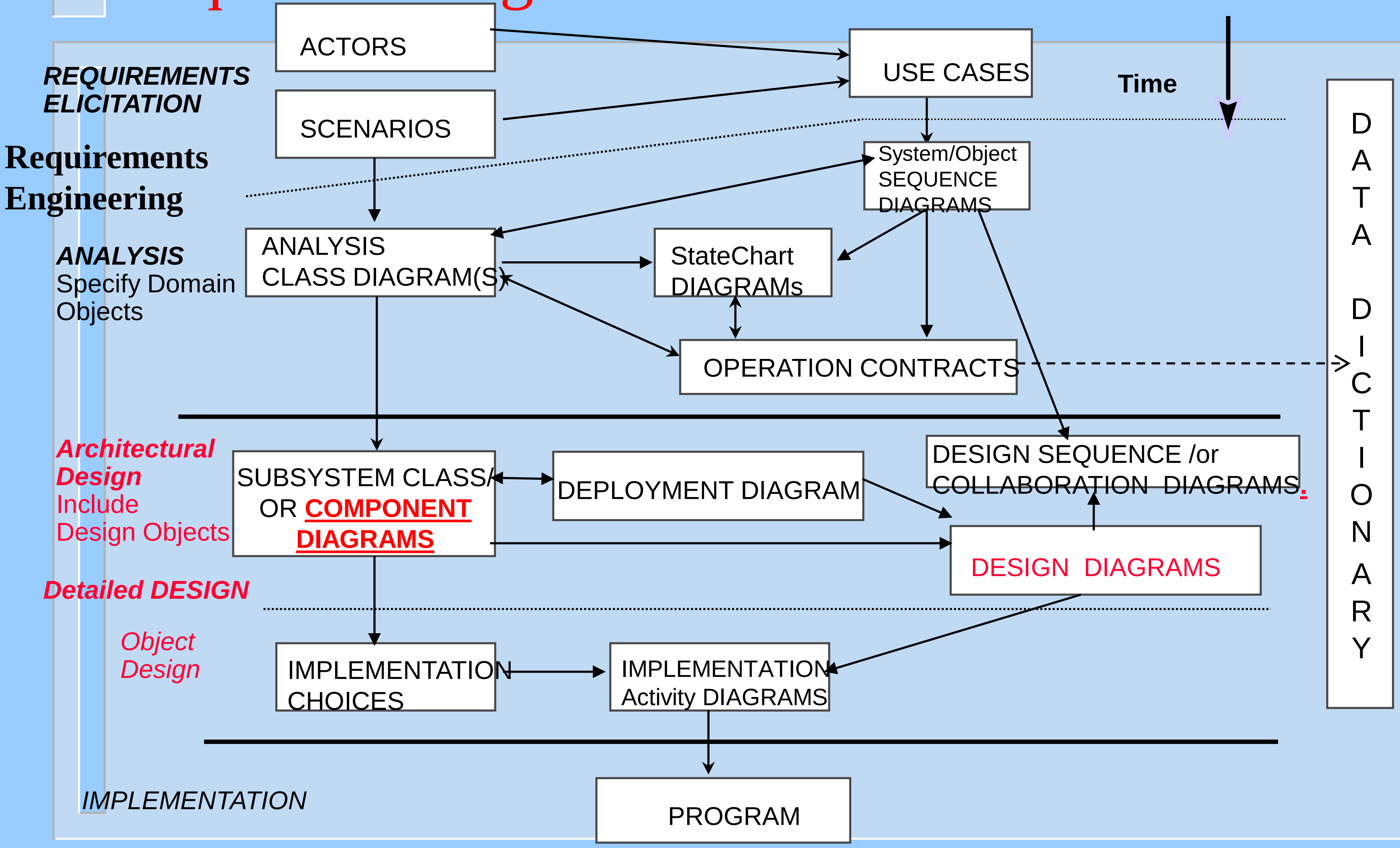
Figure 6.3: A Model-View-Controller collaboration

UML Component and Deployment Diagrams

- Component diagrams illustrate the organizations and dependencies among software components
- A component may be
  - A source code component
  - A run time components or
  - An executable component

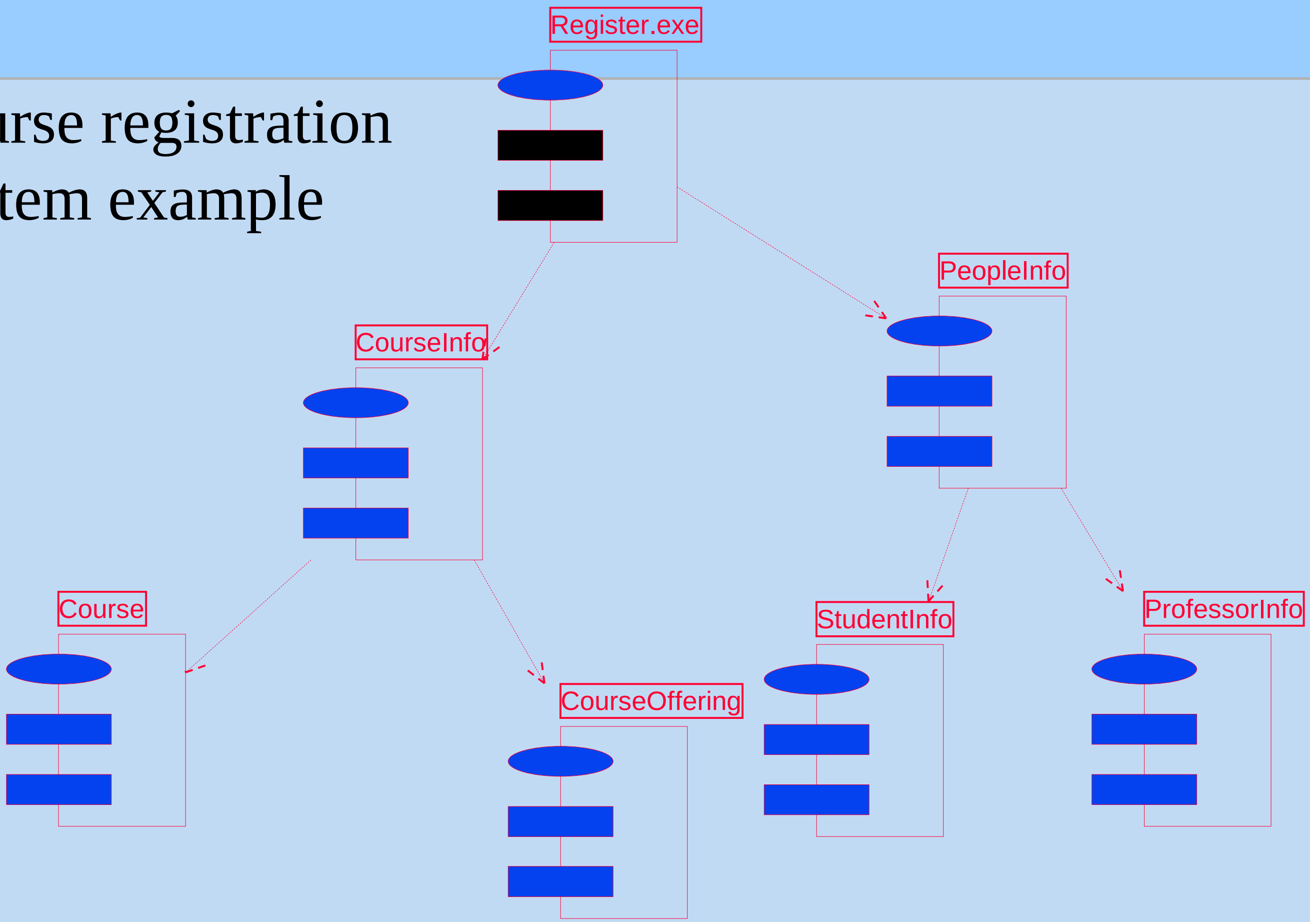
UML Development – Overview

Detailed Design: The dynamic view, Design Sequence Diagrams


ACTORS
USE CASES
Time
REQUIREMENTS ELICITATION
SCENARIOS
Requirements Engineering
System/Object SEQUENCE DIAGRAMS
ANALYSIS Specify Domain Objects
ANALYSIS CLASS DIAGRAM(S)
StateChart DIAGRAMs
OPERATION CONTRACTS
D A T A D I C T I O N A R Y
Architectural Design Include Design Objects
SUBSYSTEM CLASS/ OR COMPONENT DIAGRAMS
DEPLOYMENT DIAGRAM
DESIGN SEQUENCE /or COLLABORATION DIAGRAMS.
DESIGN DIAGRAMS
Detailed DESIGN
Object Design
IMPLEMENTATION CHOICES
IMPLEMENTATION Activity DIAGRAMS
IMPLEMENTATION
PROGRAM

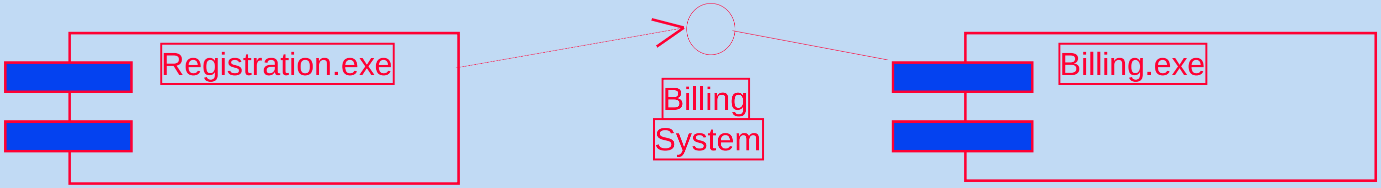
Component Diagram

Course registration System example



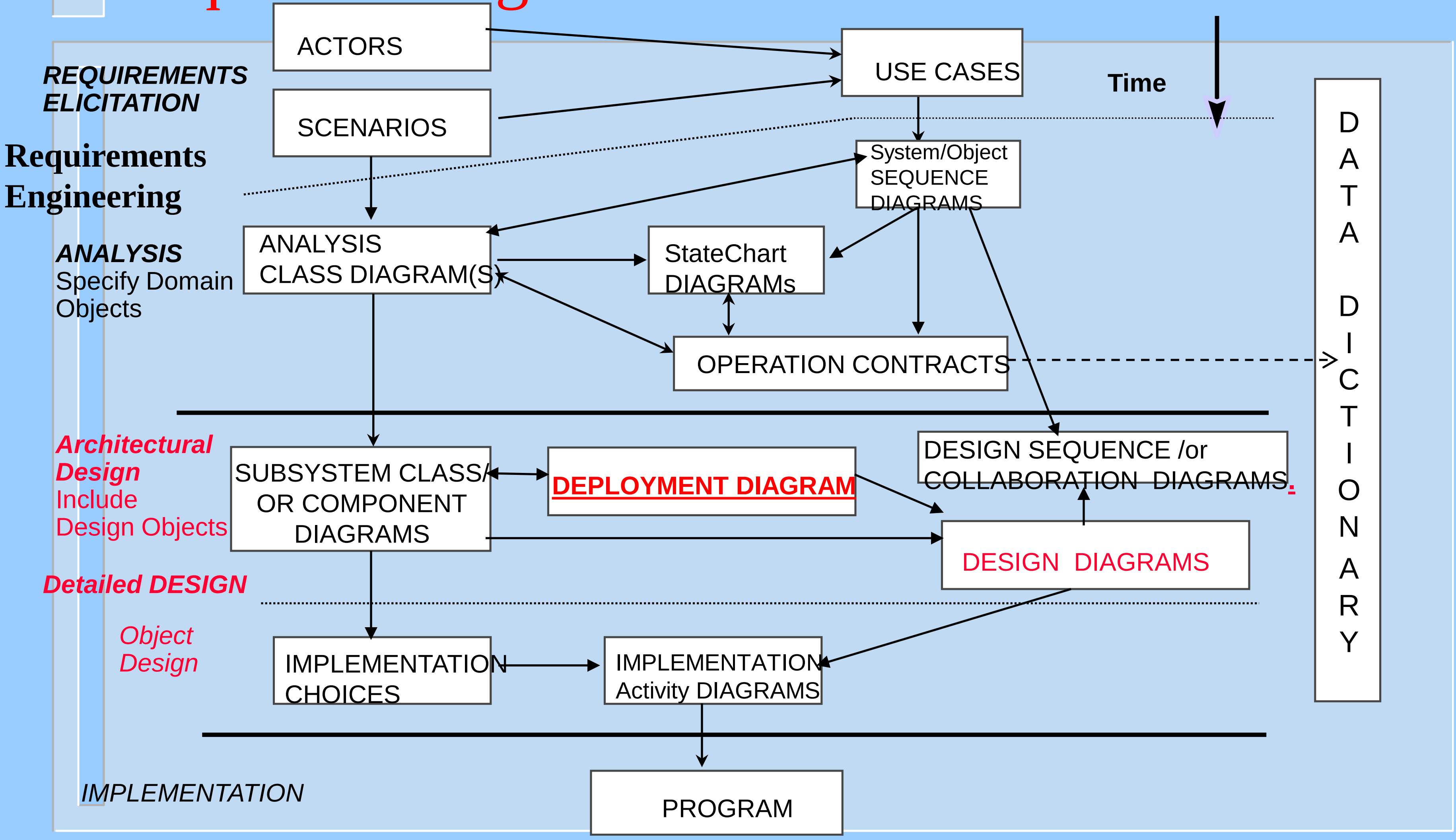
Component Diagram: Components Interfaces

- The interfaces to a component may be shown on a component diagram



UML Development – Overview

Detailed Design: The dynamic view, Design Sequence Diagrams



ACTORS

USE CASES

SCENARIOS

Time

REQUIREMENTS ELICITATION

Requirements Engineering

System/Object SEQUENCE DIAGRAMS

ANALYSIS
Specify Domain Objects

ANALYSIS CLASS DIAGRAM(S)

StateChart DIAGRAMs

OPERATION CONTRACTS

D A T A D I C T I O N A R Y

Architectural Design
Include Design Objects

SUBSYSTEM CLASS/ OR COMPONENT DIAGRAMS

DEPLOYMENT DIAGRAM

DESIGN SEQUENCE /or COLLABORATION DIAGRAMS.

DESIGN DIAGRAMS

Detailed DESIGN

Object Design

IMPLEMENTATION CHOICES

IMPLEMENTATION Activity DIAGRAMS

IMPLEMENTATION

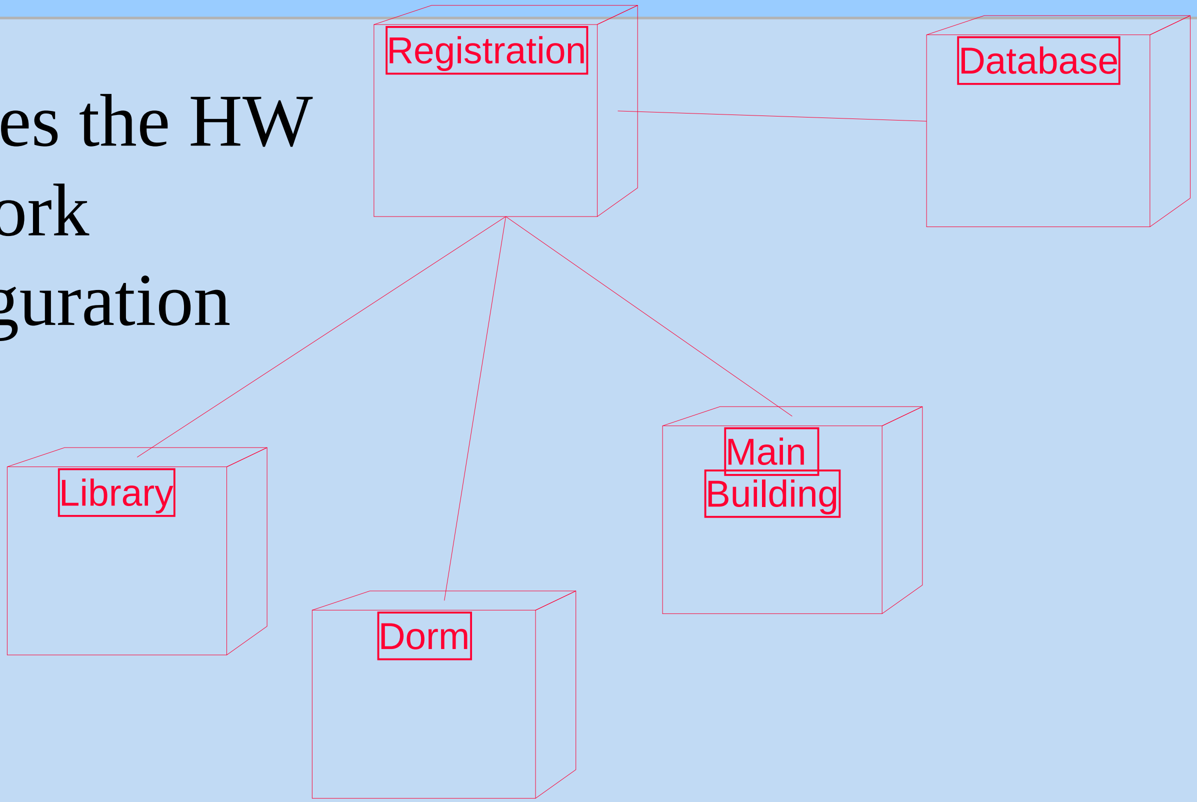
PROGRAM

Deploying the System

- The deployment diagram shows the configuration of run-time processing elements and the software processes living on them
- The deployment diagram visualizes the distribution of components across the enterprise (the servers of a distributed network).

Deployment Diagram

Defines the HW Network configuration



Deployment Diagram

Digital Sound Recorder Case Study

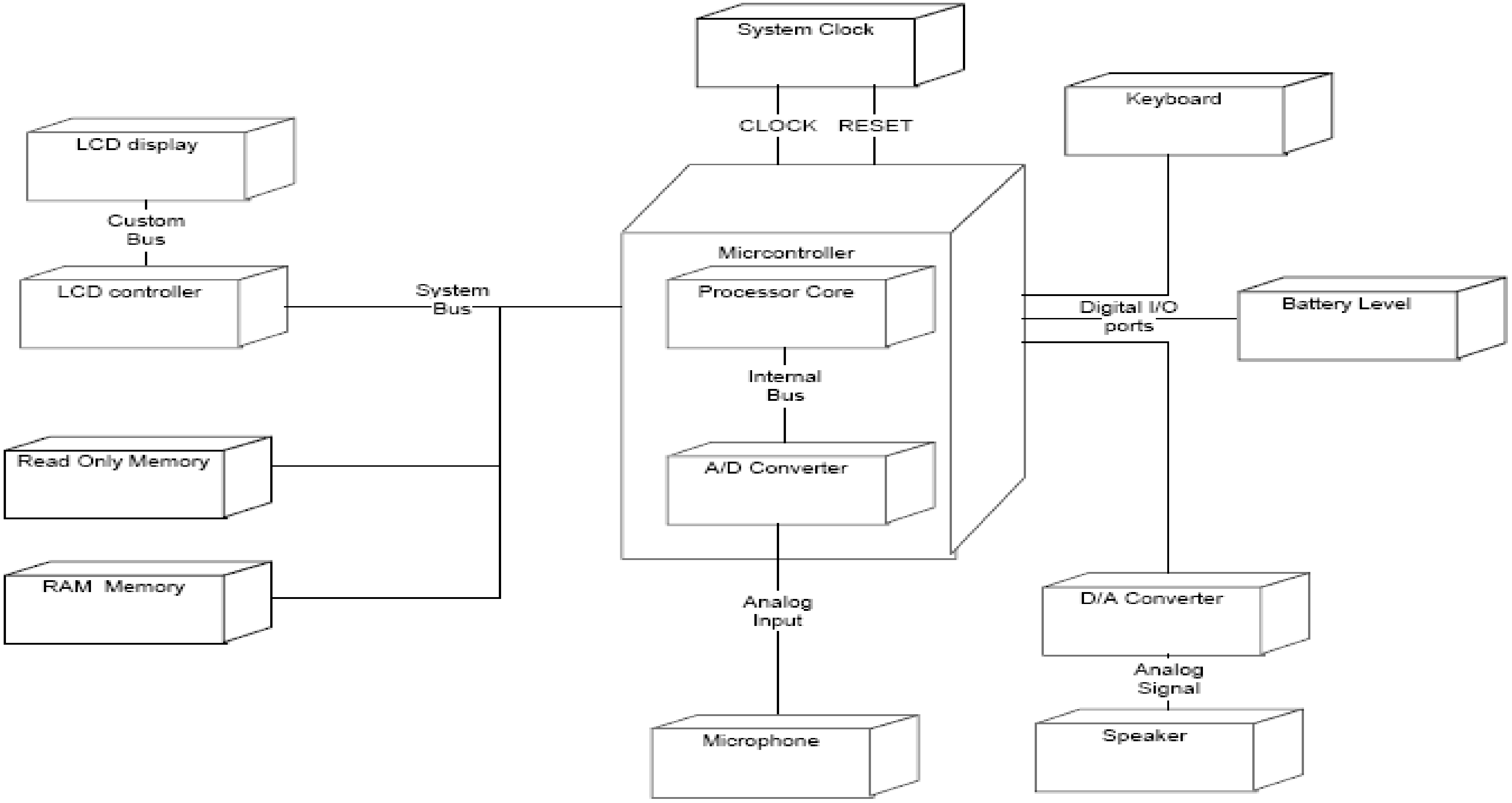


Figure 5.1: Hardware architecture of the digital sound recorder

Extending the UML

- Stereotypes can be used to extend the UML notational elements
- Stereotypes may be used to classify and extend associations, inheritance relationships, classes, and components using the notation <<stereotype>>.
- Examples: 1. Class stereotypes: Interface, control, entity, utility, exception,
  - 2. Use Case relation stereotypes: includes and extends,
  - 3. Component stereotypes: subsystem
  - 4. Design pattern instances

Class and Components stereotypes

e.g., <<external timer>>, <<coordinator>>, <<control>>

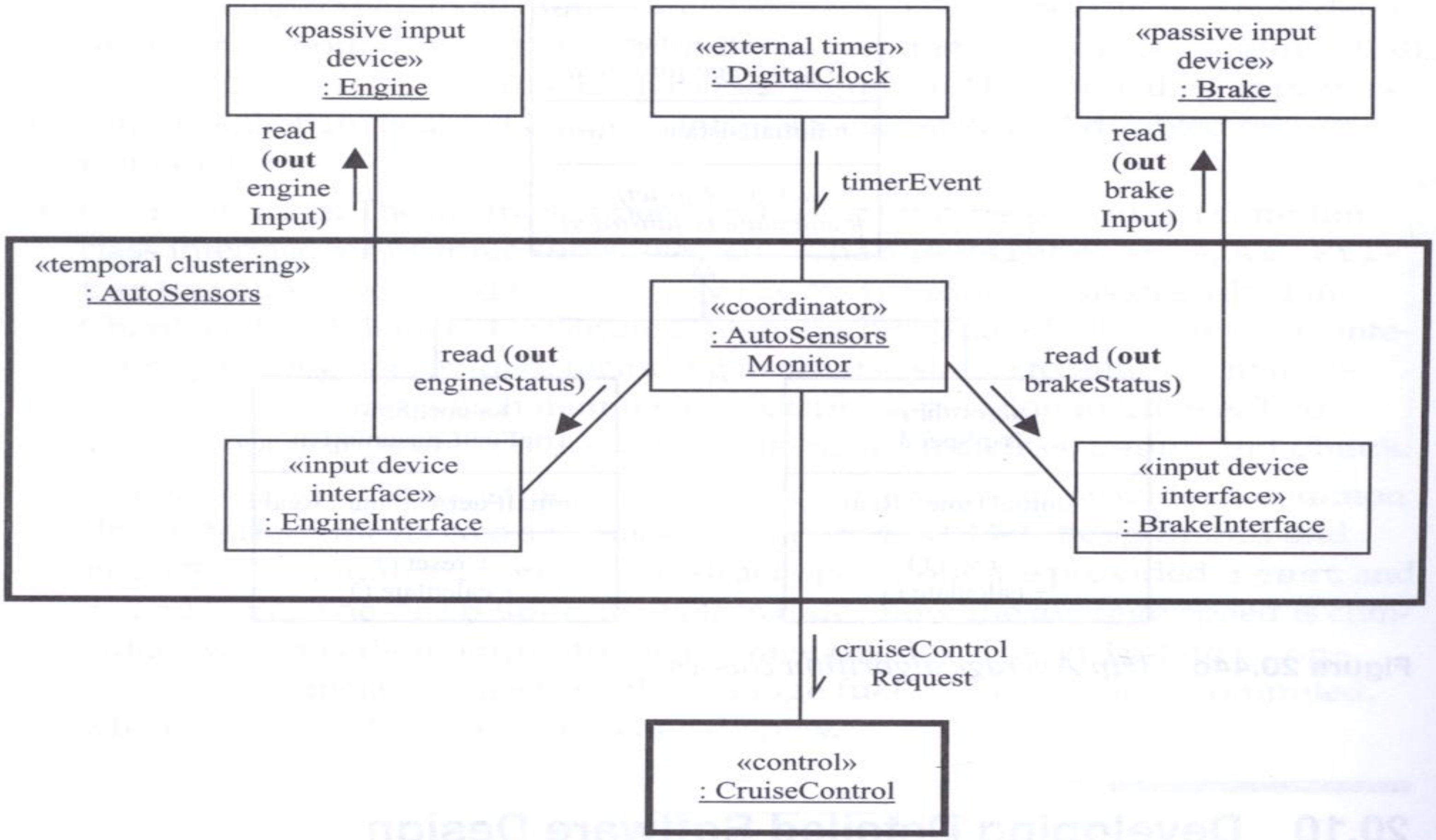
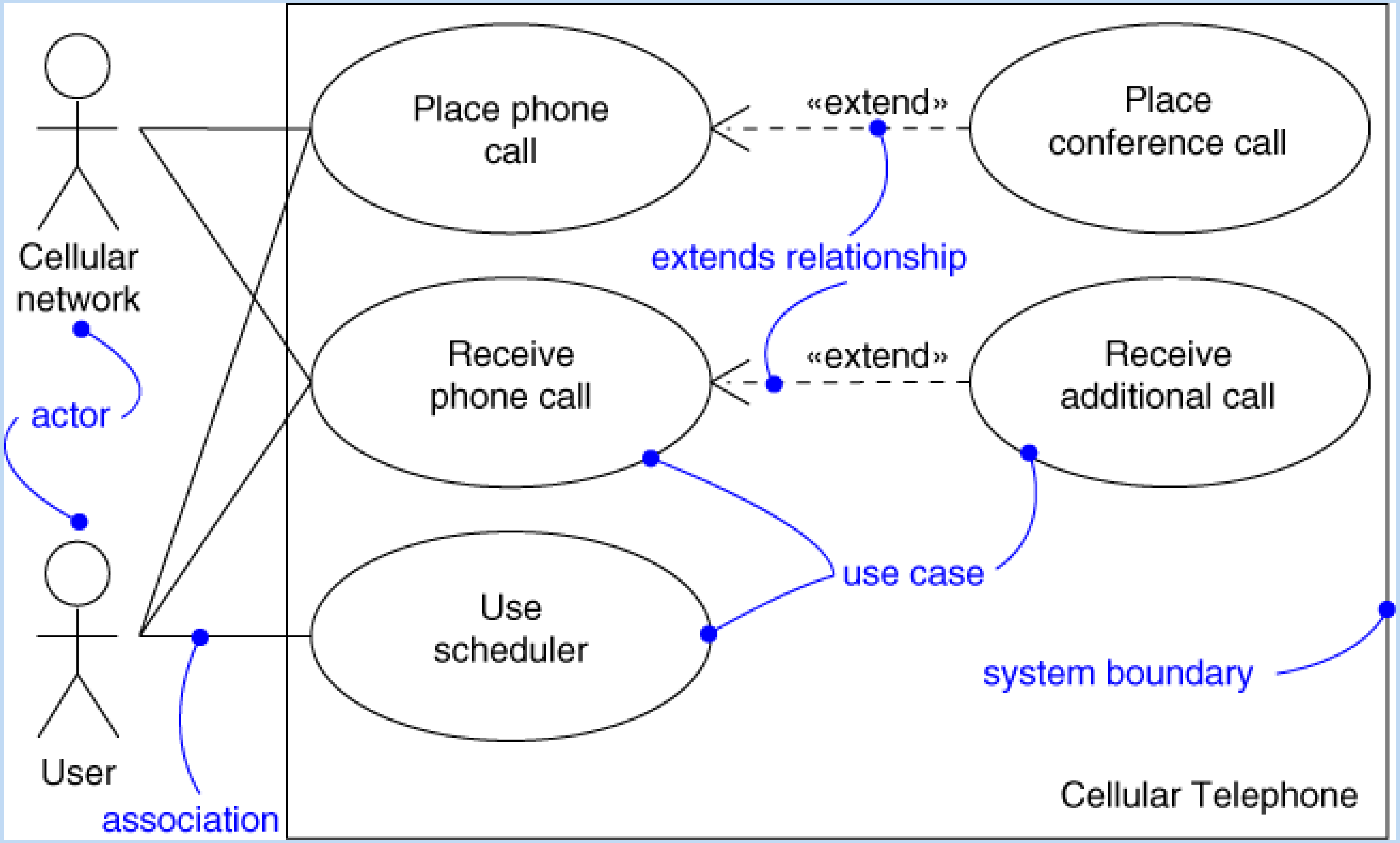

«passive input device» : Engine
read (out engine Input)
«external timer» : DigitalClock
timerEvent
«passive input device» : Brake
read (out brake Input)
«temporal clustering» : AutoSensors
«coordinator» : AutoSensors Monitor
read (out engineStatus)
read (out brakeStatus)
«input device interface» : EngineInterface
«input device interface» : BrakeInterface
cruiseControl Request
«control» : CruiseControl

Figure 20.45 *Detailed software design of Auto Sensors task*

Use Case relation stereotypes

<<extend>>



Component stereotypes: subsystem

<<client subsystem>>, <<server subsystem>>

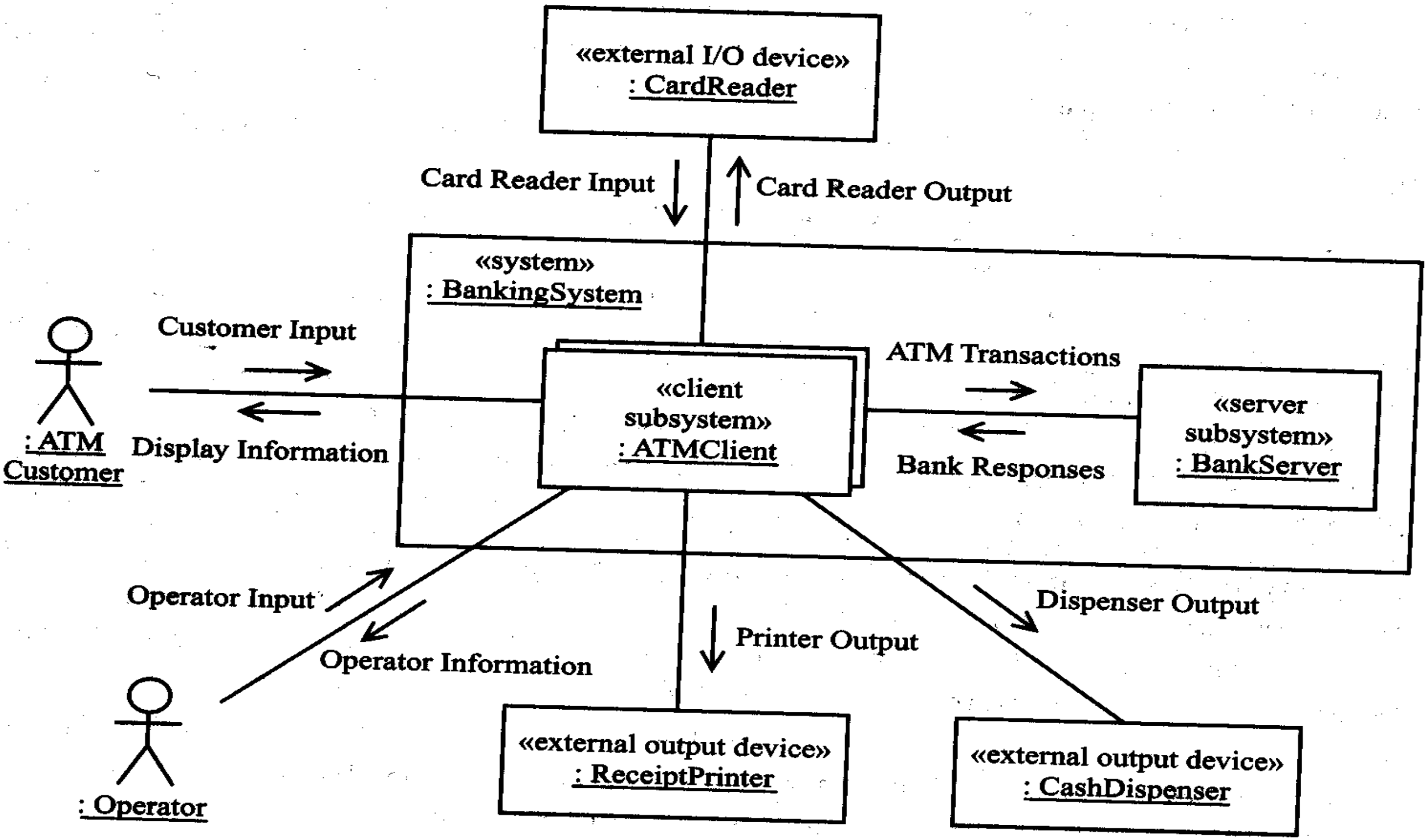


Figure 12.6 *Example of subsystem design: high-level collaboration diagram for Banking System*

Summary of UML

http://en.wikipedia.org/wiki/List_of_Unified_Modeling_Language_tools

- The UML is the standard language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system
  - It can be used with all processes, throughout the development life cycle, and across different implementation technologies.