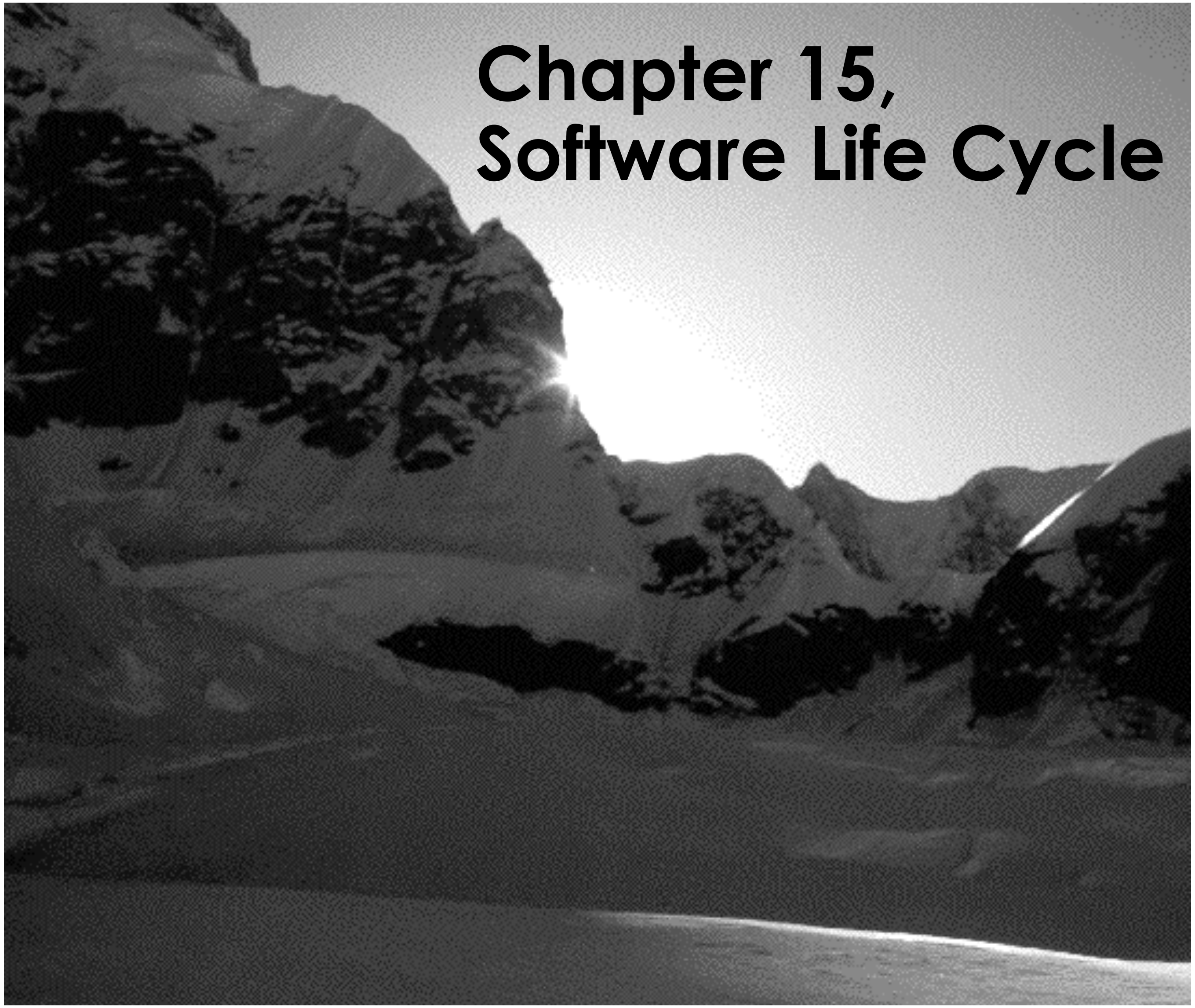
Object-Oriented Software Engineering

Using UML, Patterns, and Java



Chapter 15, Software Life Cycle

Lecture Road Map

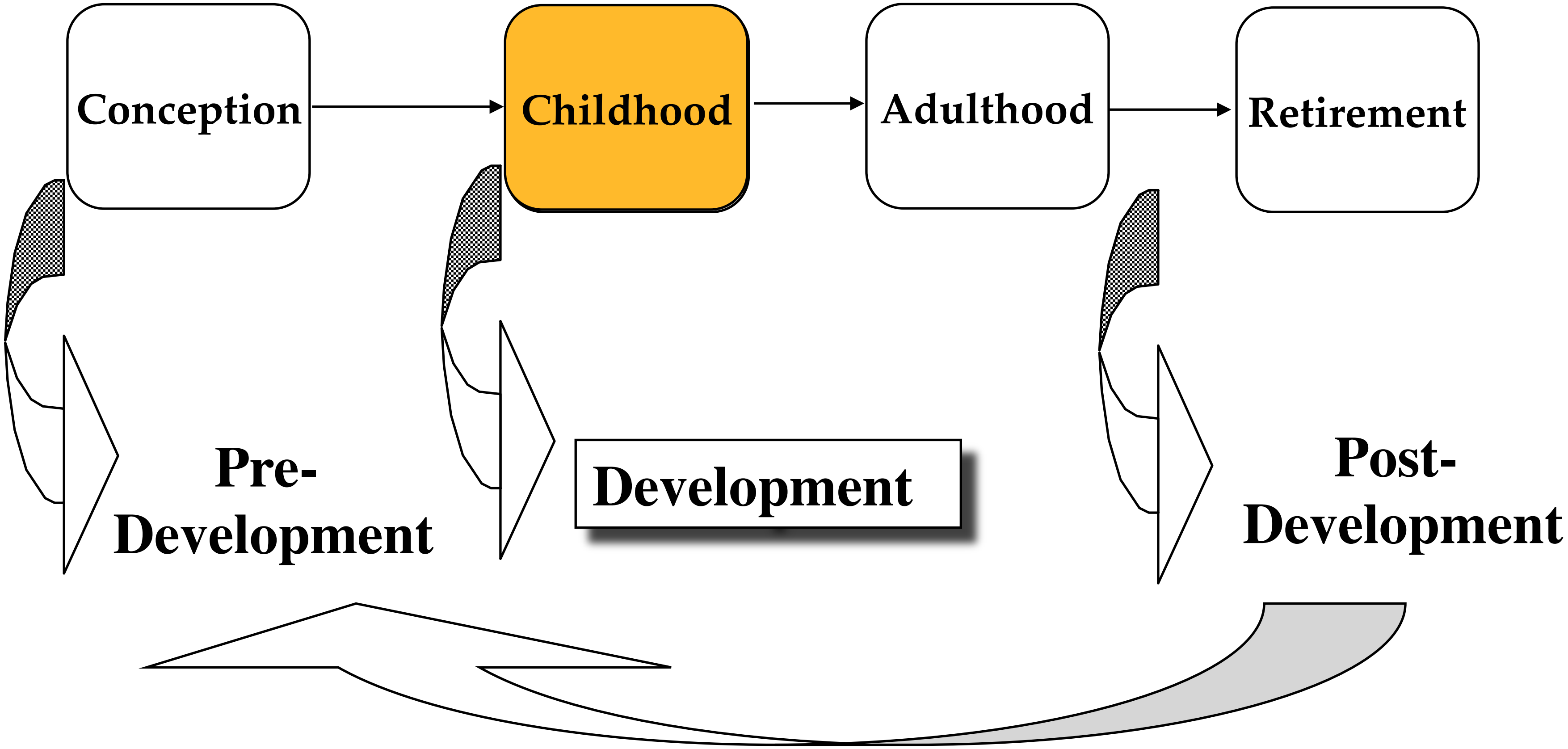
- Software Development as Application Domain
    - Modeling the software lifecycle
- IEEE Standard 1074 for Software Lifecycles
- Modeling the software life cycle
    - Sequential models
        - Pure waterfall model
        - V-model
    - Iterative models
        - Boehm's spiral model
        - Unified Process (in the next lecture)
    - Entity-oriented models
        - Issue-based model
- Capability Maturity Model

Inherent Problems with Software Development

- Requirements are constantly changing
  - The client might not know all the requirements in advance
- Frequent changes are difficult to manage
  - Identifying checkpoints for planning and cost estimation is difficult
- There is more than one software system
  - New system must often be backward compatible with existing system (“legacy system”)

Software Life Cycle

- The term “Lifecycle” is based on the metaphor of the life of a person:



Typical Software Life Cycle Questions

- ⇨ *Which activities* should we select for the software project?
- What are the *dependencies between activities*?
- How should we *schedule the activities*?
- To find these activities and dependencies we can use the same modeling techniques we use for software development:
  - Functional Modeling of a Software Lifecycle
    - Scenarios
    - Use case model
  - Structural modeling of a Software Lifecycle
    - Object identification
    - Class diagrams
  - Dynamic Modeling of a Software Lifecycle
    - Sequence diagrams, statechart and activity diagrams

Identifying Software Development Activities

- Questions to ask:
  - What is the problem?
  - What is the solution?
  - What are the best mechanisms to implement the solution?
  - How is the solution constructed?
  - Is the problem solved?
  - Can the customer use the solution?
  - How do we deal with changes that occur during the development? Are enhancements needed?

Software Development Activities (Example 1)

Requirements Analysis	What is the problem?
System Design	What is the solution?
Detailed Design	What are the best mechanisms to implement the solution?
Program Implementation	How is the solution constructed?
Testing	Is the problem solved?
Delivery	Can the customer use the solution?
Maintenance	Are enhancements needed?

Application Domain

Solution Domain

Software Development Activities (Example 2)

Requirements Analysis — What is the problem?

Application Domain

System Design — What is the solution?

Object Design — What are the best mechanisms to implement the solution?

Implementation — How is the solution constructed?

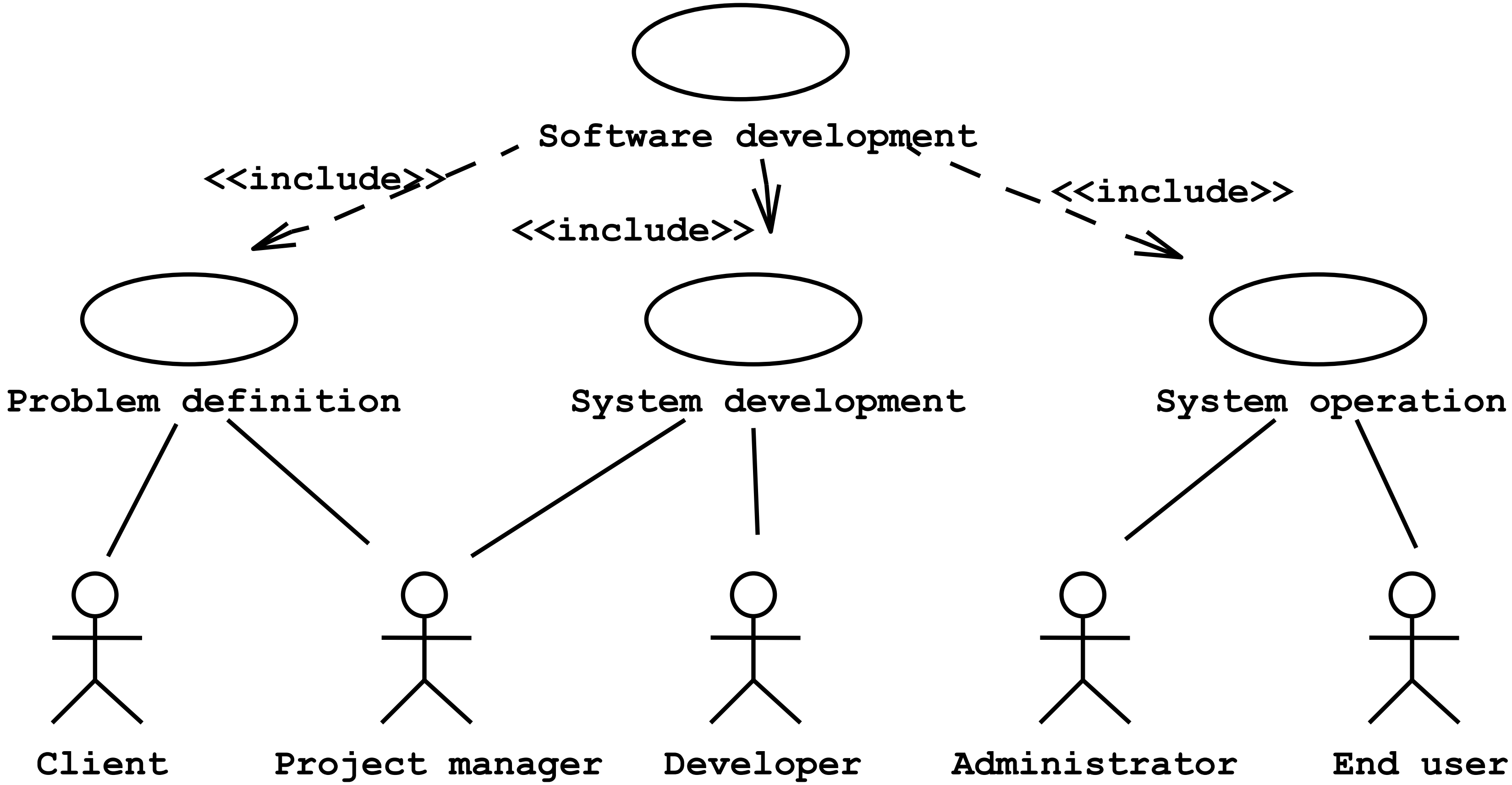
Solution Domain

Definitions

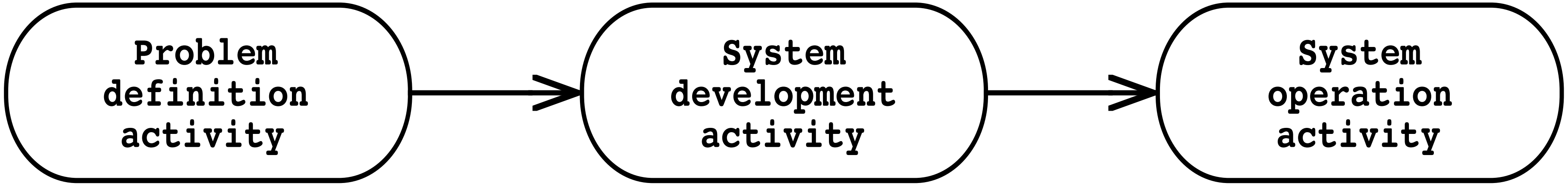
- Software life cycle:
  - Set of activities and their relationships to each other to support the development of a software system

- Software development methodology:
  - A collection of techniques for building models applied across the software life cycle

Functional Model of a simple life cycle model

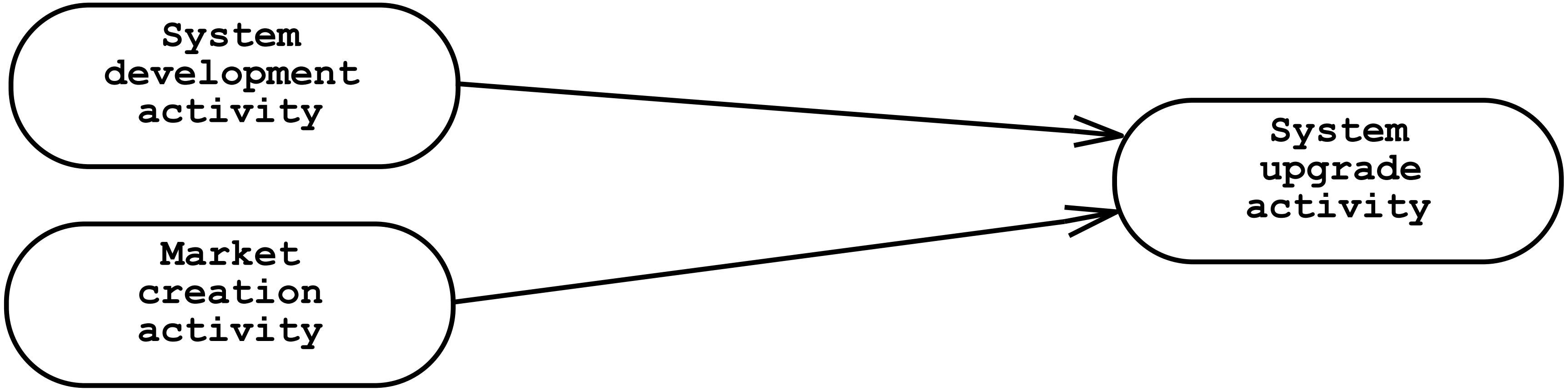


Activity Diagram for the same Life Cycle Model


Problem definition activity
System development activity
System operation activity

Software development goes through a linear progression of states called software development activities

Another simple Life Cycle Model

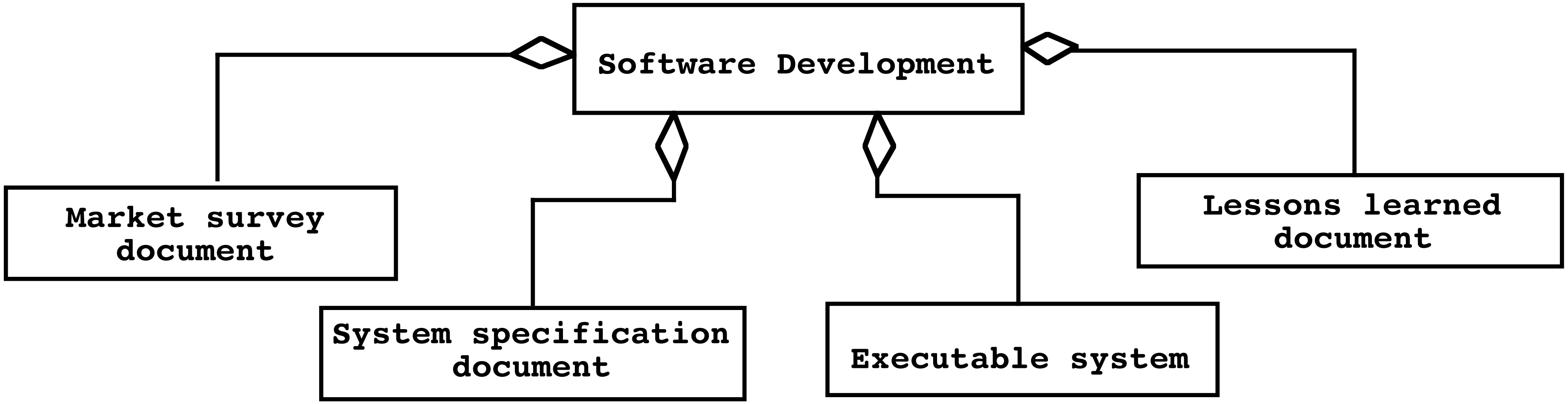


System Development and Market creation can be done in parallel. They must be done before the system upgrade activity

Two Major Views of the Software Life Cycle

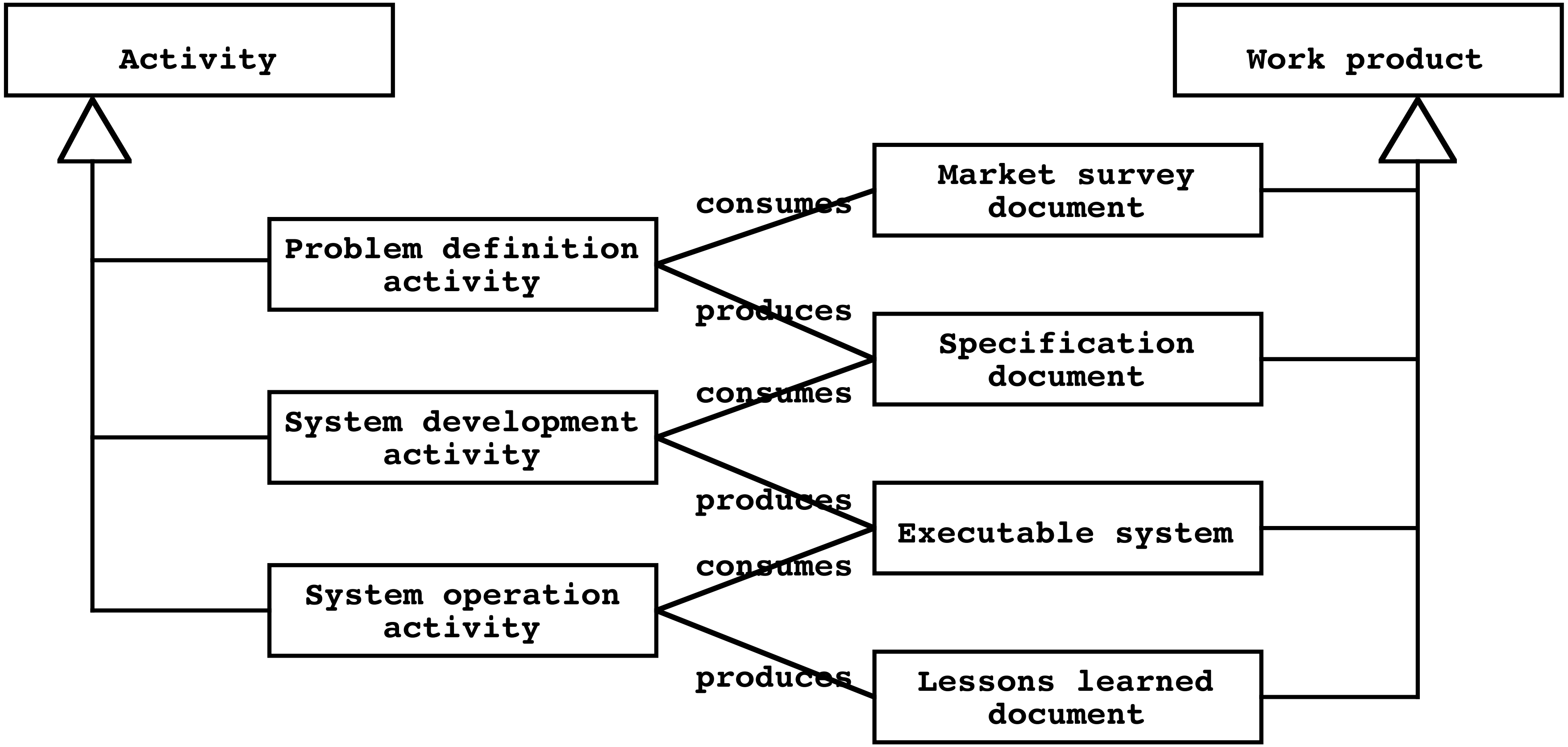
- Activity-oriented view of a software life cycle
  - Software development consists of a set of development activities
  - all the examples so far
- Entity-oriented view of a software life cycle
  - Software development consists of the creation of a set of deliverables.

Entity-centered view of Software Development

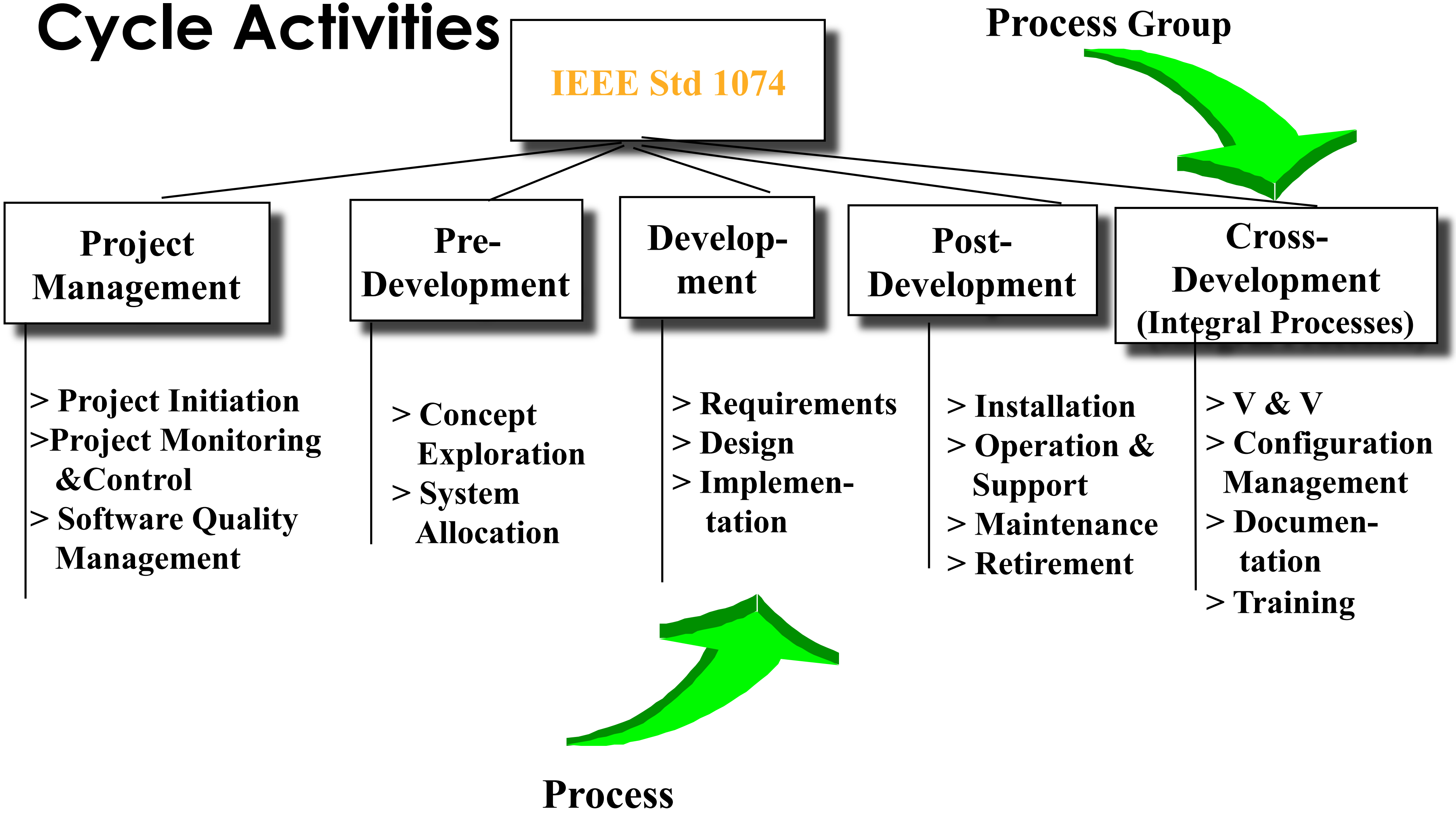


Software development consists of the creation of a set of deliverables

Combining Activities and Entities in One View

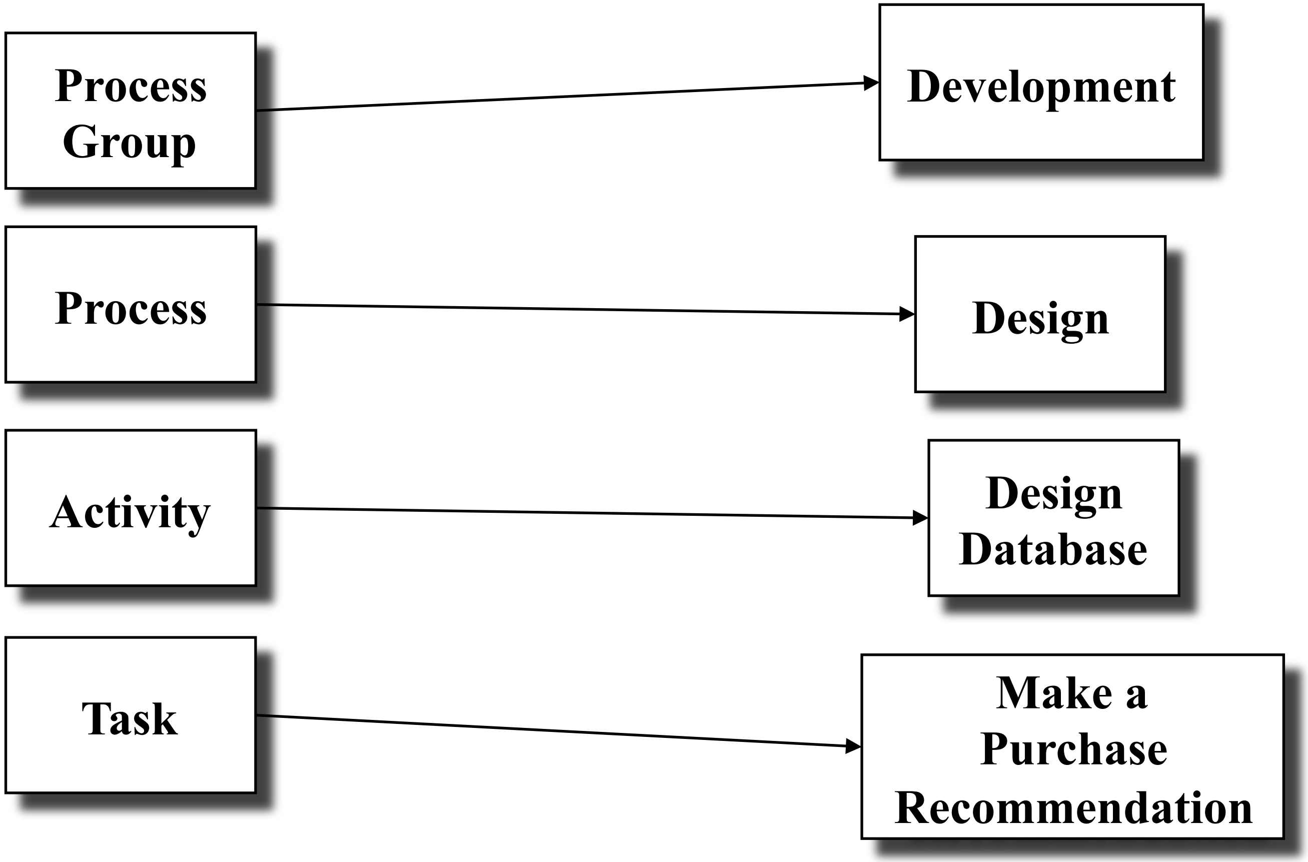


IEEE Std 1074: Standard for Software Life Cycle Activities

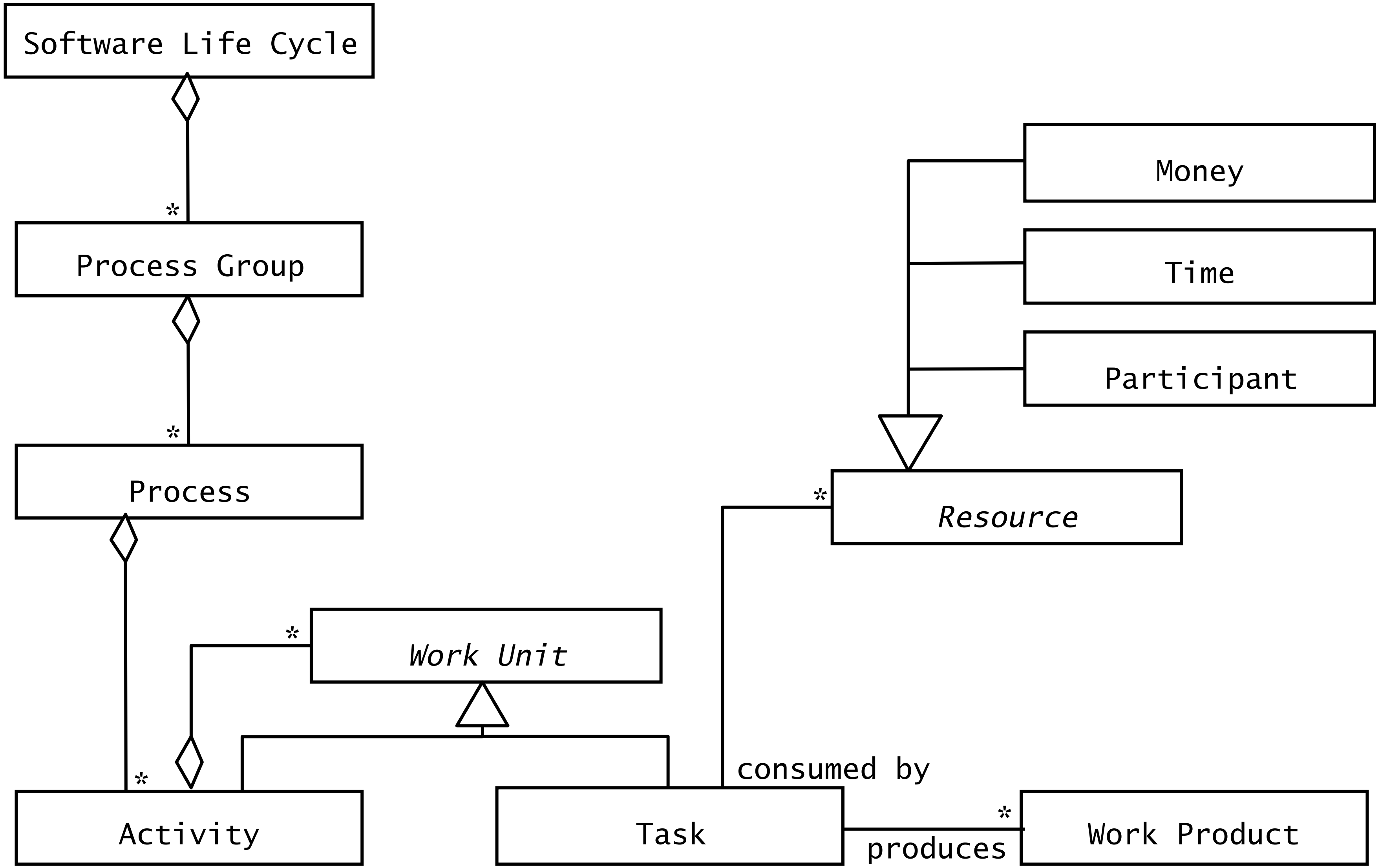


Processes, Activities and Tasks

- Process Group: Consists of a set of processes
- Process: Consists of activities
- Activity: Consists of sub activities and tasks



Object Model of the IEEE 1074 Standard



Process Maturity

- A software development process is mature
  - if the development activities are well defined and
  - if management has some control over the quality, budget and schedule of the project
- Process maturity is described with
  - a set of maturity levels and
  - the associated measurements (metrics) to manage the process
- Assumption:
  - With increasing maturity the risk of project failure decreases
- CMM: Capability Maturity Model (SEI,Humphrey)

CMM levels

- ▷ Initial Level

  also called ad hoc or chaotic

- ▷ Repeatable Level

  Process depends on individuals ("champions")

- ▷ Defined Level

  Process is institutionalized (sanctioned by management)

- ▷ Managed Level

  Activities are measured and provide feedback for resource allocation (process itself does not change)

- ▷ Optimizing Level

  Process allows feedback of information to change process itself

What does Process Maturity Measure?

- The real indicator of process maturity is the level of predictability of project performance (quality, cost, schedule).
- Level 1: Random, unpredictable performance
- Level 2: Repeatable performance from project to project
- Level 3: Better performance on each successive project
- Level 4: Substantial improvement (order of magnitude) in one dimension of project performance
- Level 5: Substantial improvements across all dimensions of project performance.

Key Process Areas

- To achieve a specific level of maturity, the organization must demonstrate that it addresses all the key process areas defined for that level.
- There are no key process areas for Level 1
- KPA Level 2: Basic software project management practice
- KPA Level 3: Infrastructure for single software life cycle model
- KPA Level 4: Quantitative understanding of process and deliverables
- KPA Level 5: Keep track of technology and process changes

Pros and Cons of Process Maturity

- Benefits:
  - Increased control of projects
  - Predictability of project cost and schedule
  - Objective evaluations of changes in techniques, tools and methodologies
  - Predictability of the effect of a change on project cost or schedule
- Problems:
  - Need to watch a lot (“Big brother“, „big sister“)
  - Overhead to capture, store and analyse the required information
- Agile Methodologies
  - Deemphasize the importance of process maturity

    => Lecture on Methodologies

Lecture Road Map

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  - Iterative models
    - Boehm’s spiral model (Unified Process in the next lecture)
  - Entity-oriented models
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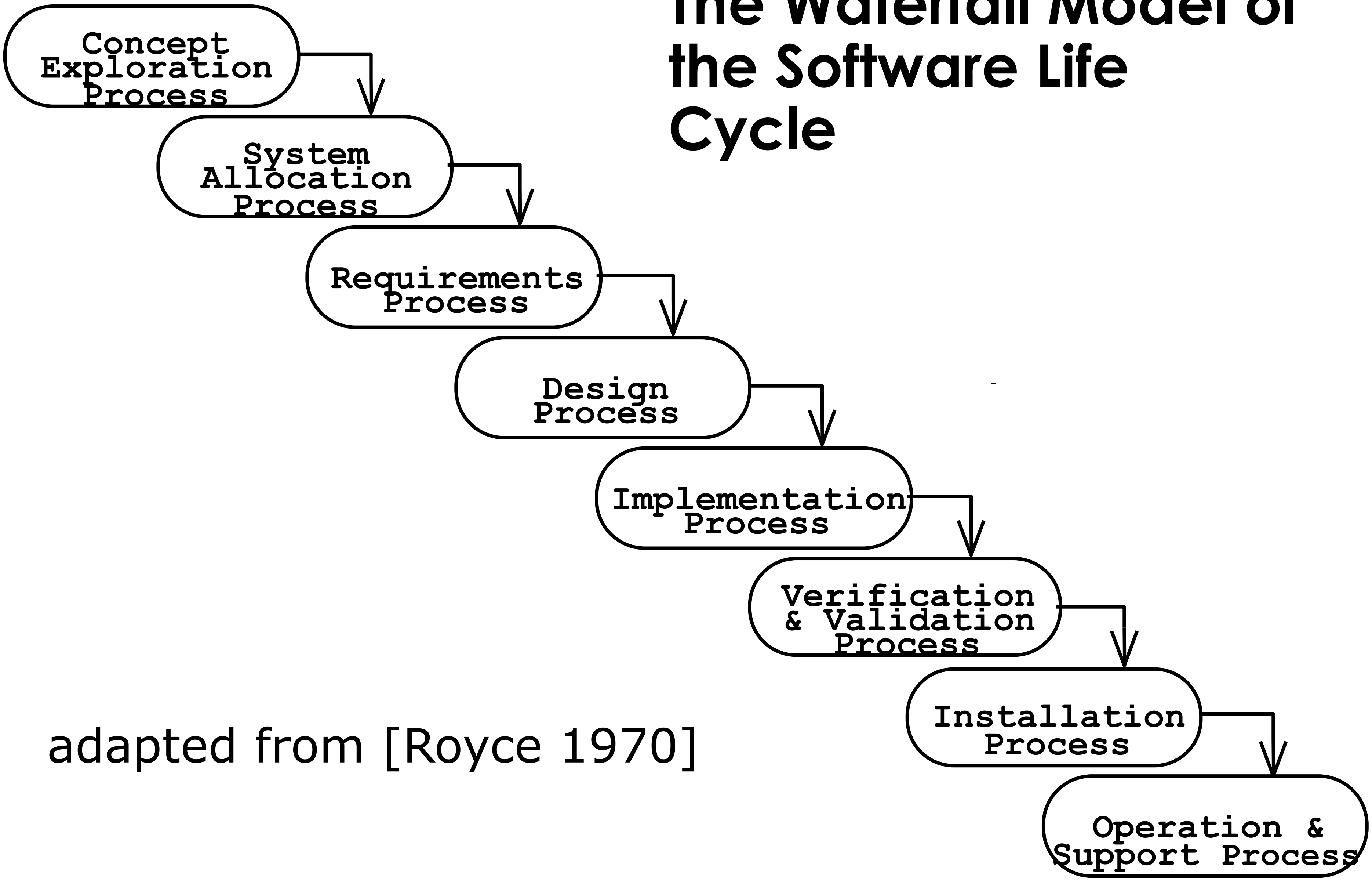
The Waterfall Model of the Software Life Cycle

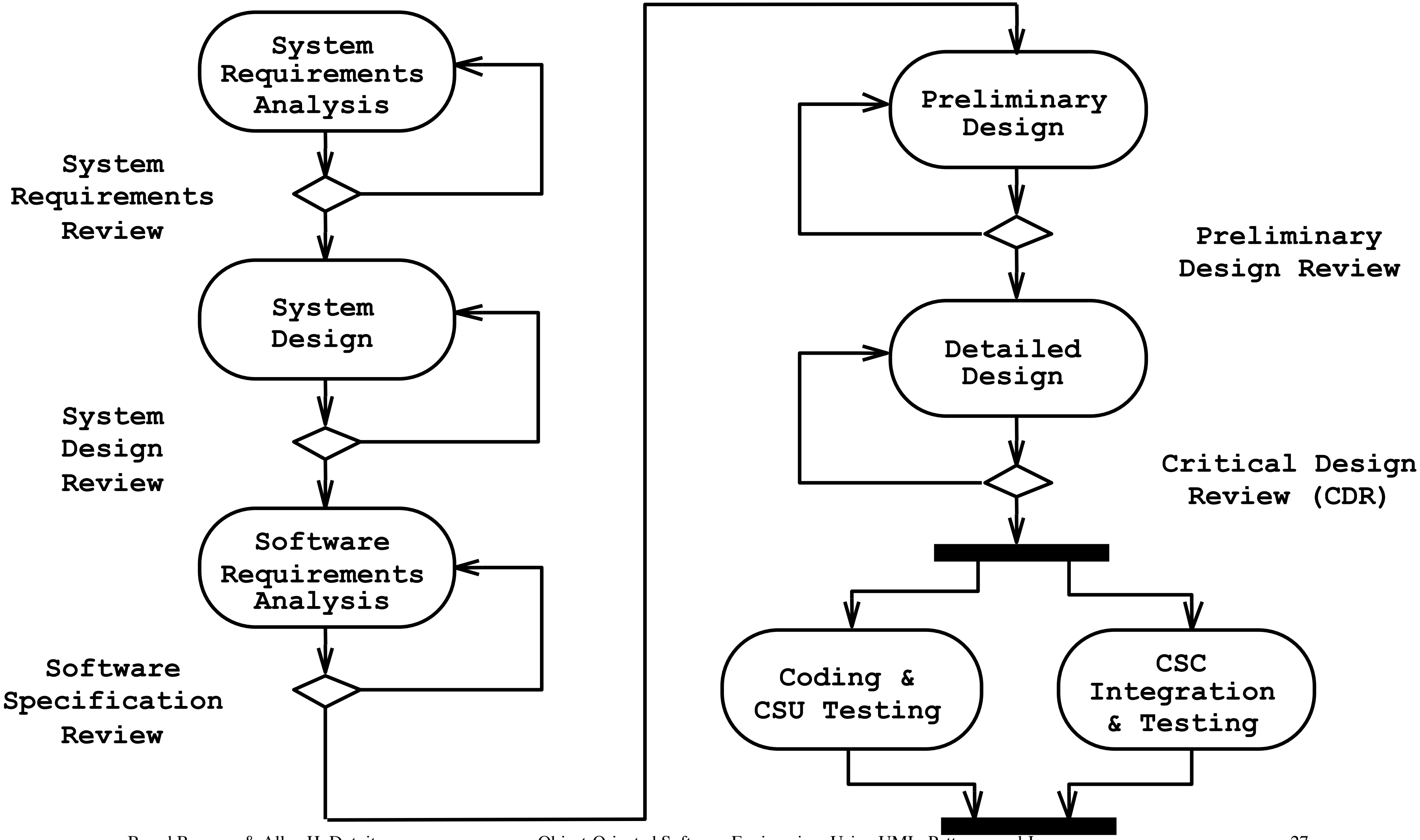

Concept Exploration Process
System Allocation Process
Requirements Process
Design Process
Implementation Process
Verification & Validation Process
Installation Process
Operation & Support Process

adapted from [Royce 1970]

Example of a waterfall model : DOD Standard 2167A

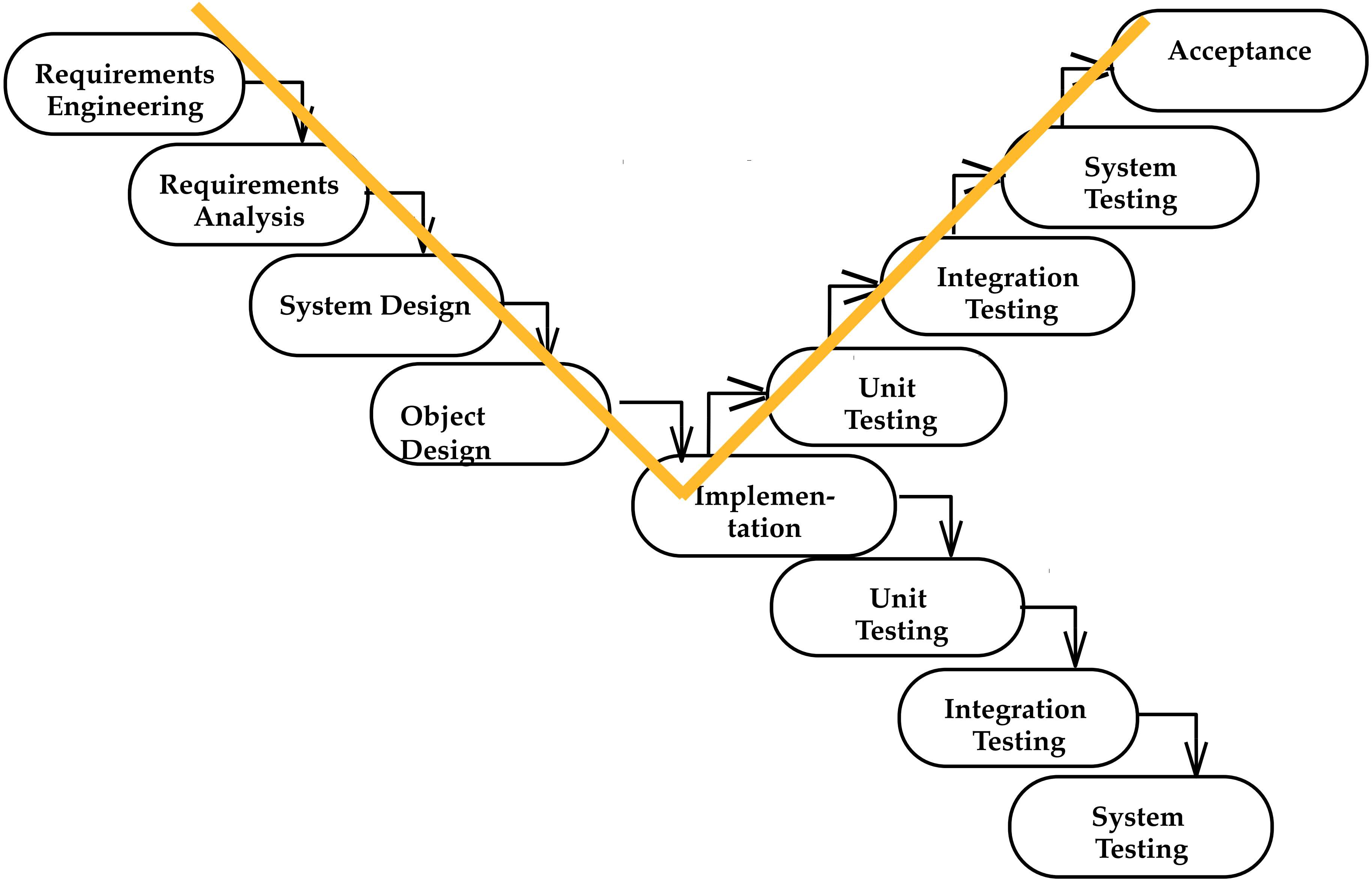
- Software development activities:
  - System Requirements Analysis/Design
  - Software Requirements Analysis
  - Preliminary Design and Detailed Design
  - Coding and CSU testing
  - CSC Integration and Testing
  - CSCI Testing
  - System integration and Testing
- Required by the U.S. Department of Defense for all software contractors in the 1980-90’s.

Activity Diagram of MIL DOD-STD-2167A


System Requirements Analysis
System Requirements Review
System Design
System Design Review
Software Requirements Analysis
Software Specification Review
Preliminary Design
Preliminary Design Review
Detailed Design
Critical Design Review (CDR)
Coding & CSU Testing
CSC Integration & Testing

...

From the Waterfall Model to the V Model



Requirements Engineering

Requirements Analysis

System Design

Object Design

Implementation

Unit Testing

Integration Testing

System Testing

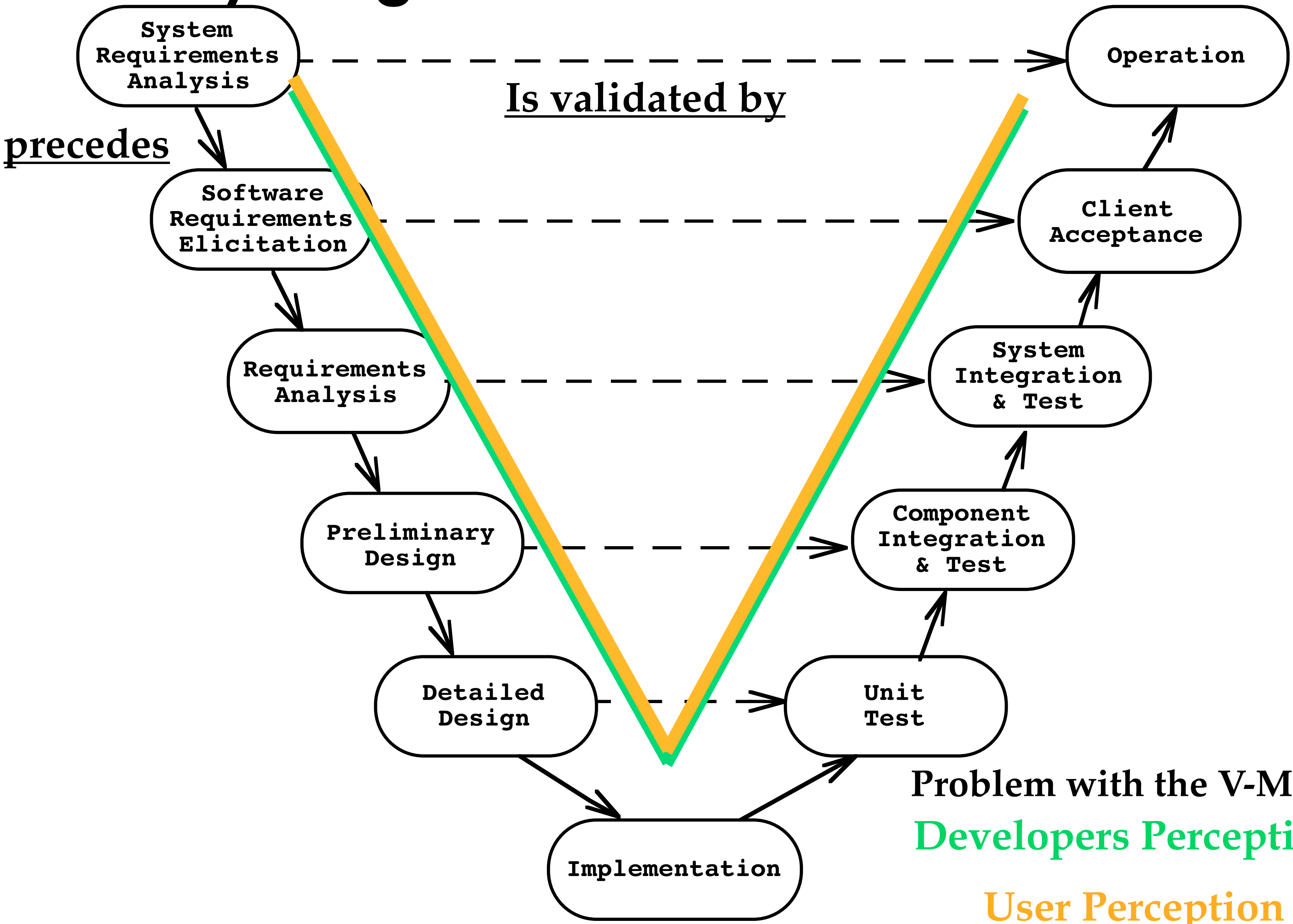
Unit Testing

Integration Testing

System Testing

Acceptance

Activity Diagram of the V Model



Problem with the V-Model:

Developers Perception =

User Perception

Properties of Waterfall-based Models

- Managers love waterfall models
  - Nice milestones
  - No need to look back (linear system)
  - Always one activity at a time
  - Easy to check progress during development: 90% coded, 20% tested
- However, software development is non-linear
  - While a design is being developed, problems with requirements are identified
  - While a program is being coded, design and requirement problems are found
  - While a program is tested, coding errors, design errors and requirement errors are found.

The Alternative: Allow Iteration

http://en.wikipedia.org/wiki/File:Escher_Waterfall.jpg

Note: The image is copyrighted

Escher was the first:-)

Construction of Escher's Waterfall Model

http://www.cs.technion.ac.il/~gershon/EscherForReal/EscherWaterfall2Penrose.gif

Note: The image is copyrighted

Spiral Model

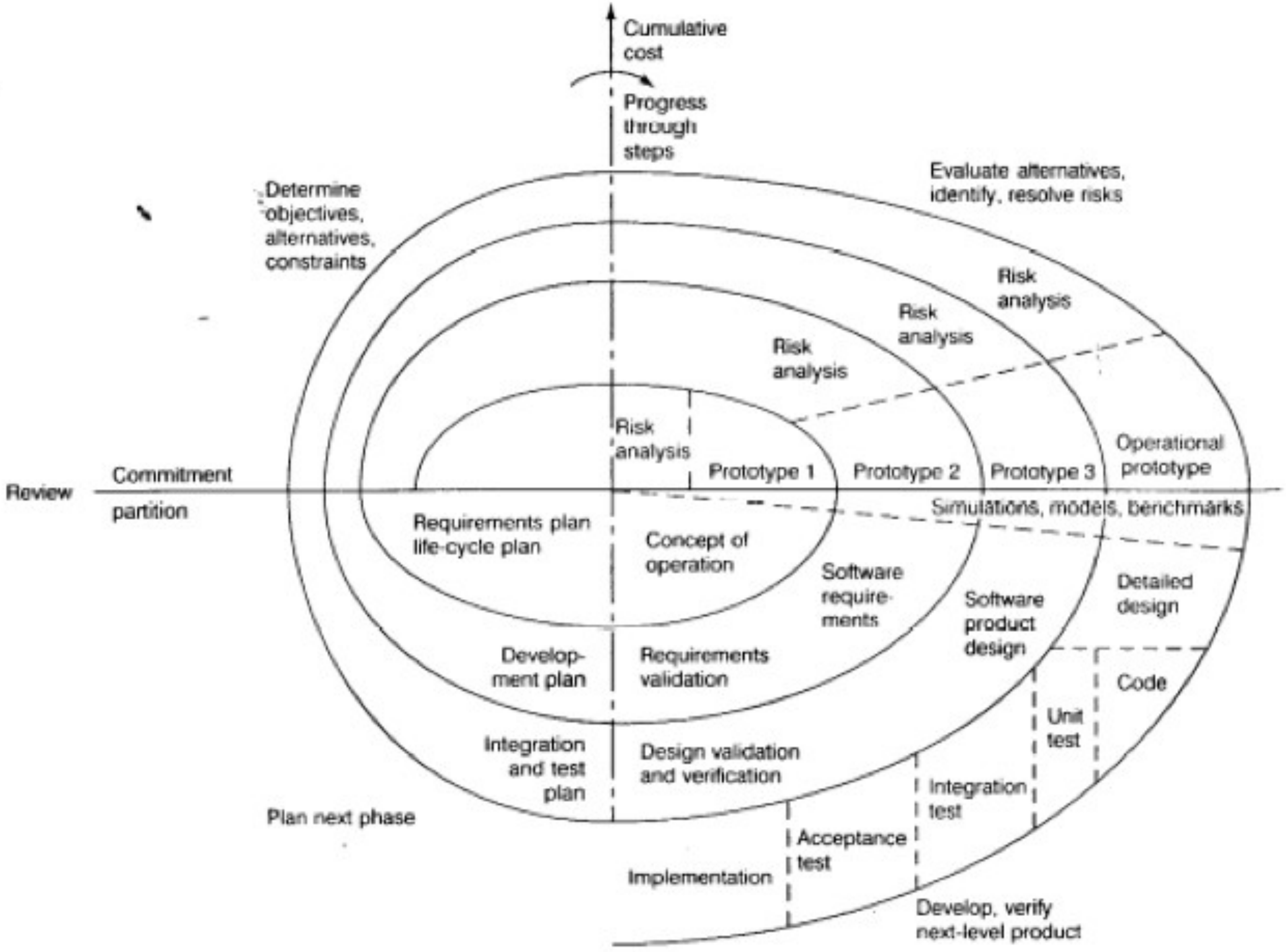
- The spiral model proposed by Boehm has the following set of activities
    - Determine objectives and constraints
    - Evaluate alternatives
    - Identify risks
    - Resolve risks by assigning priorities to risks
    - Develop a series of prototypes for the identified risks starting with the highest risk
    - Use a waterfall model for each prototype development
    - If a risk has successfully been resolved, evaluate the results of the round and plan the next round
    - If a certain risk cannot be resolved, terminate the project immediately
- This set of activities is applied to a couple of so-called rounds.

Rounds in Boehm's Spiral Model

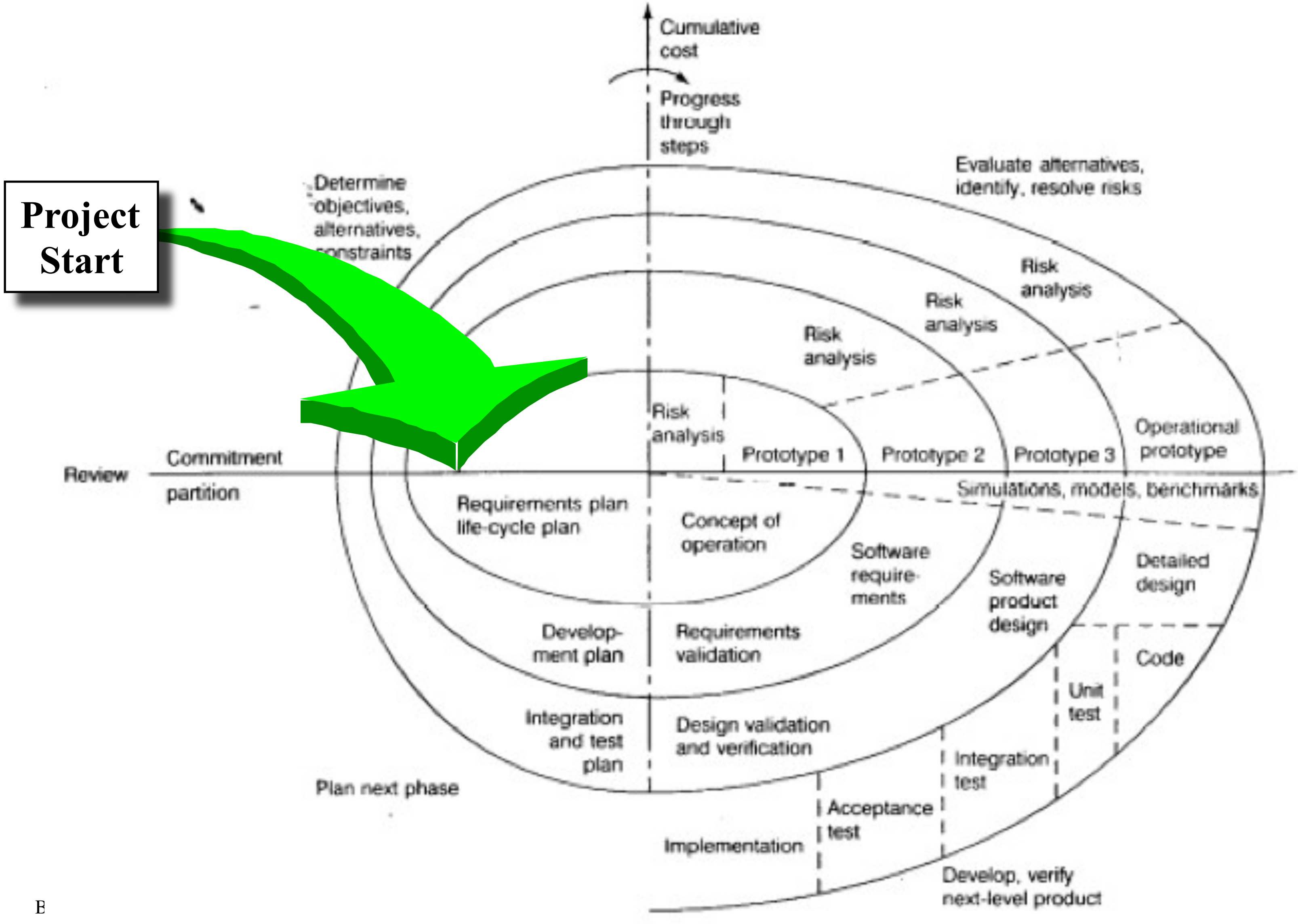
- Concept of Operations
- Software Requirements
- Software Product Design
- Detailed Design
- Code
- Unit Test
- Integration and Test
- Acceptance Test
- Implementation

- For each round go through these activities:
  - Define objectives, alternatives, constraints
  - Evaluate alternatives, identify and resolve risks
  - Develop and verify a prototype ▷
  - Plan the next round.

Diagram of Boehm's Spiral Model



Round 1, Concept of Operations, Quadrant IV: Determine Objectives,Alternatives & Constraints



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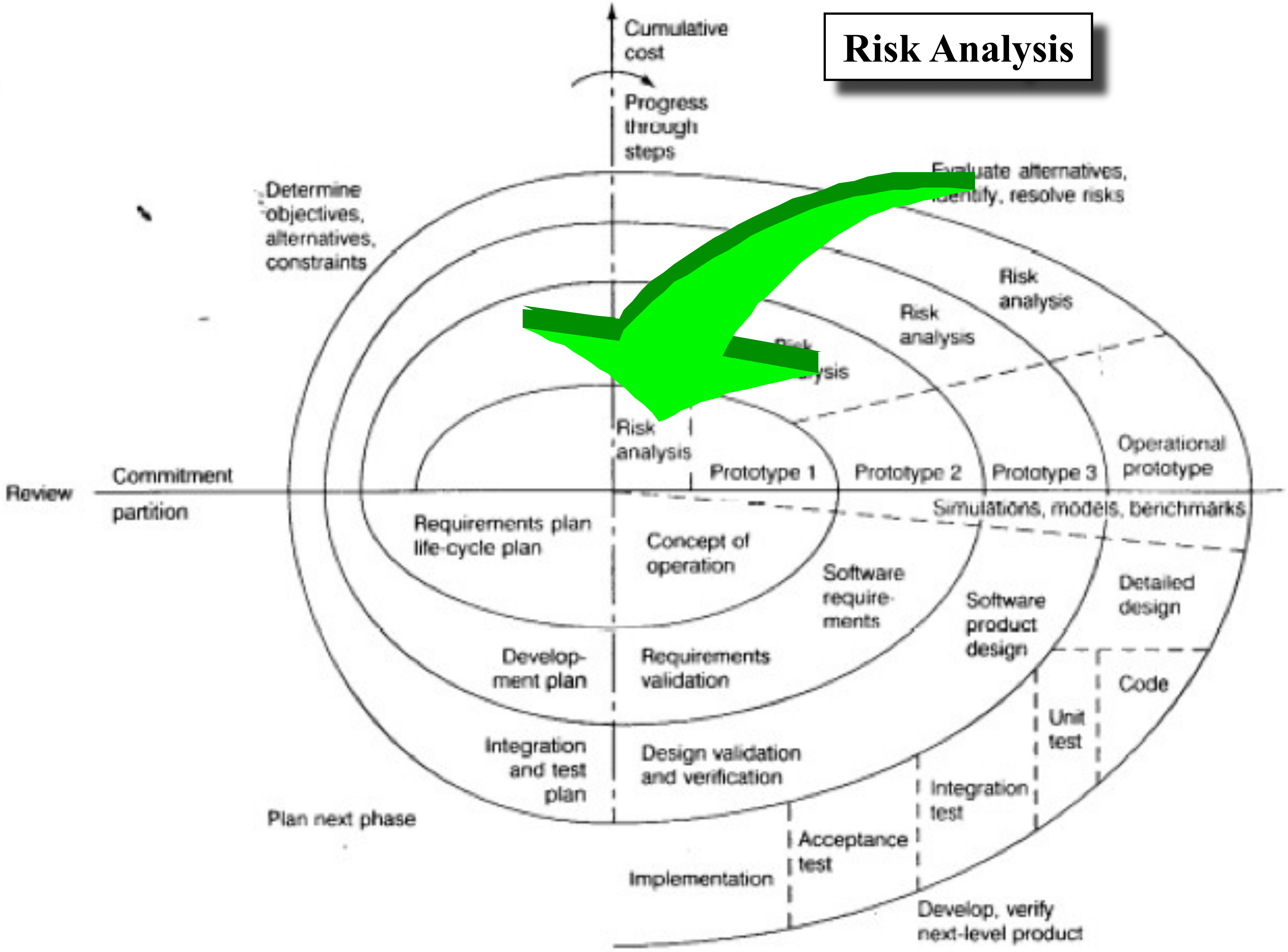
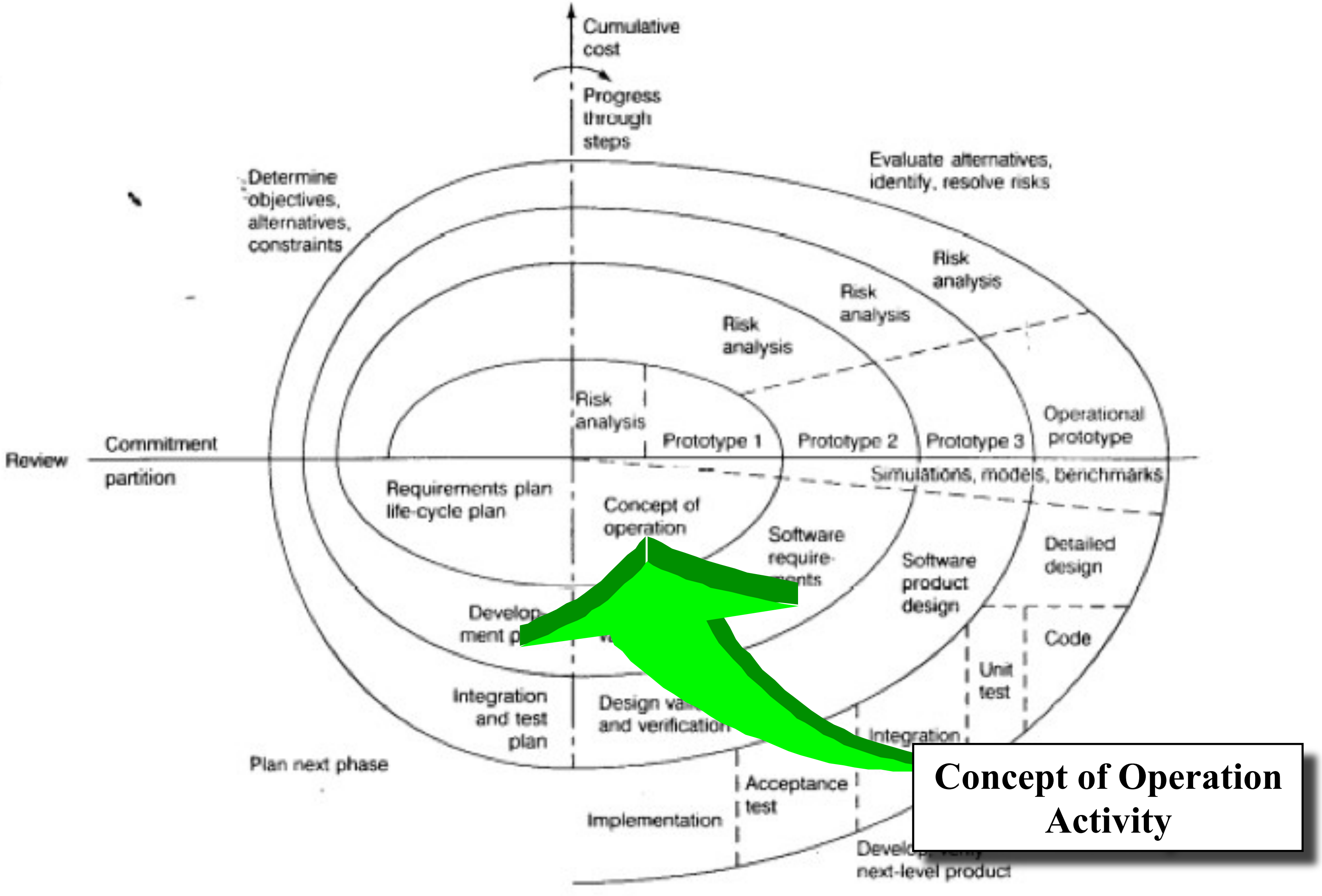
Round 1, Concept of Operations, Quadrant I: Evaluate Alternatives, identify & resolve Risks

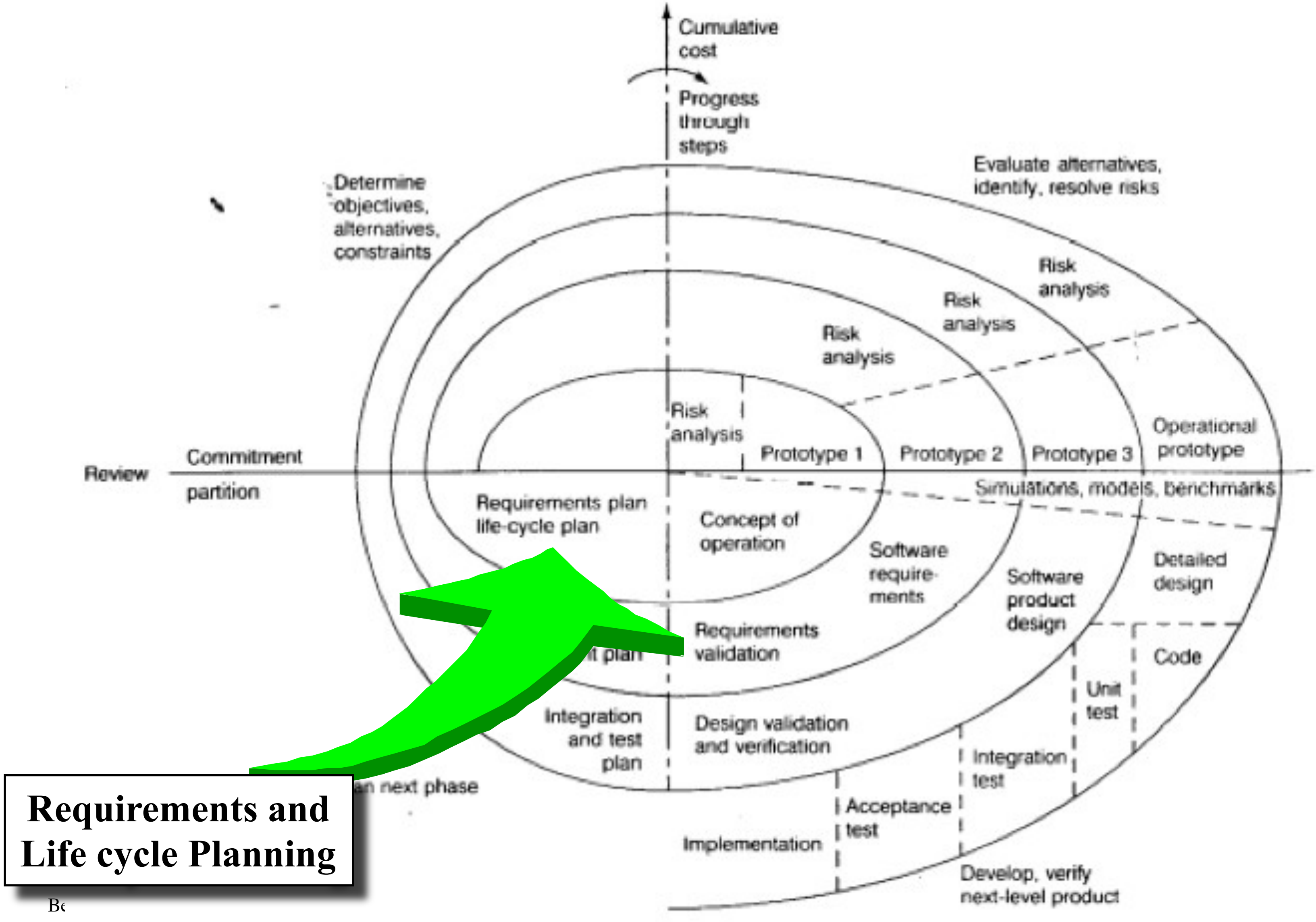

Risk Analysis

Round 1, Concept of Operations, Quadrant II: Develop and Verify



Concept of Operation Activity

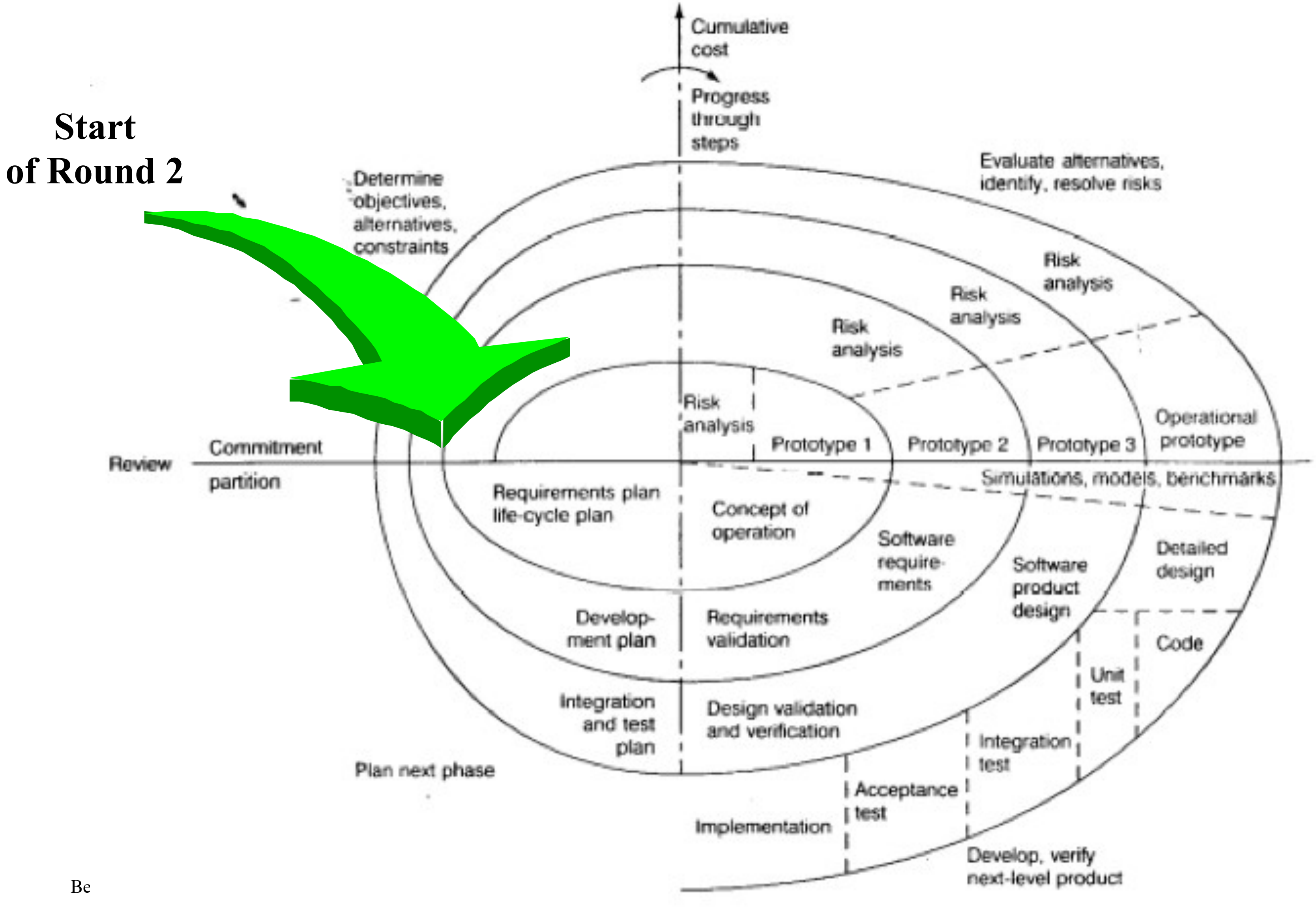
Round 1, Concept of Operations, Quadrant III: Prepare for Next Activity



Requirements and Life cycle Planning

Be

Round 2, Software Requirements, Quadrant IV: Determine Objectives,Alternatives & Constraints



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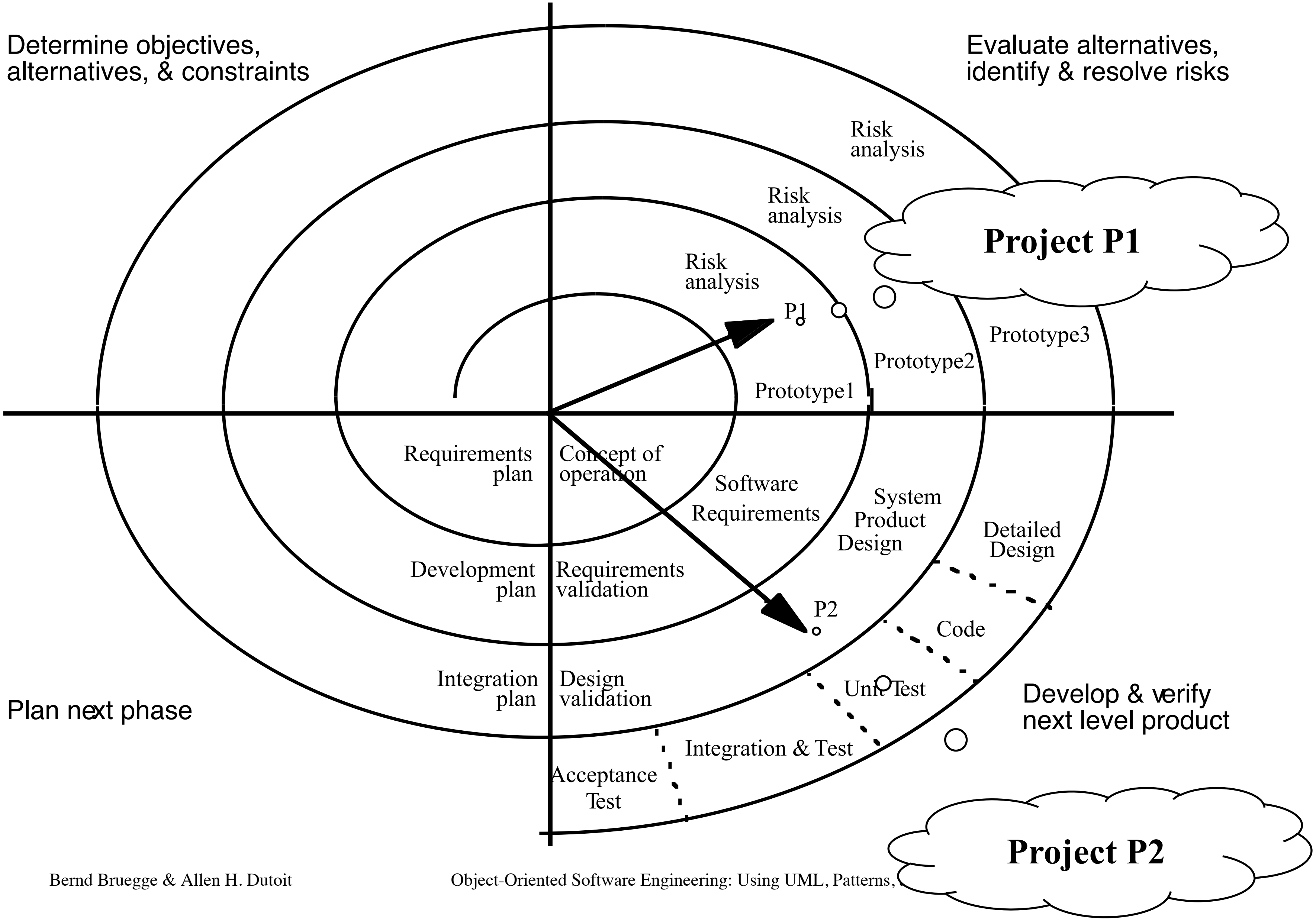
Comparison of Projects

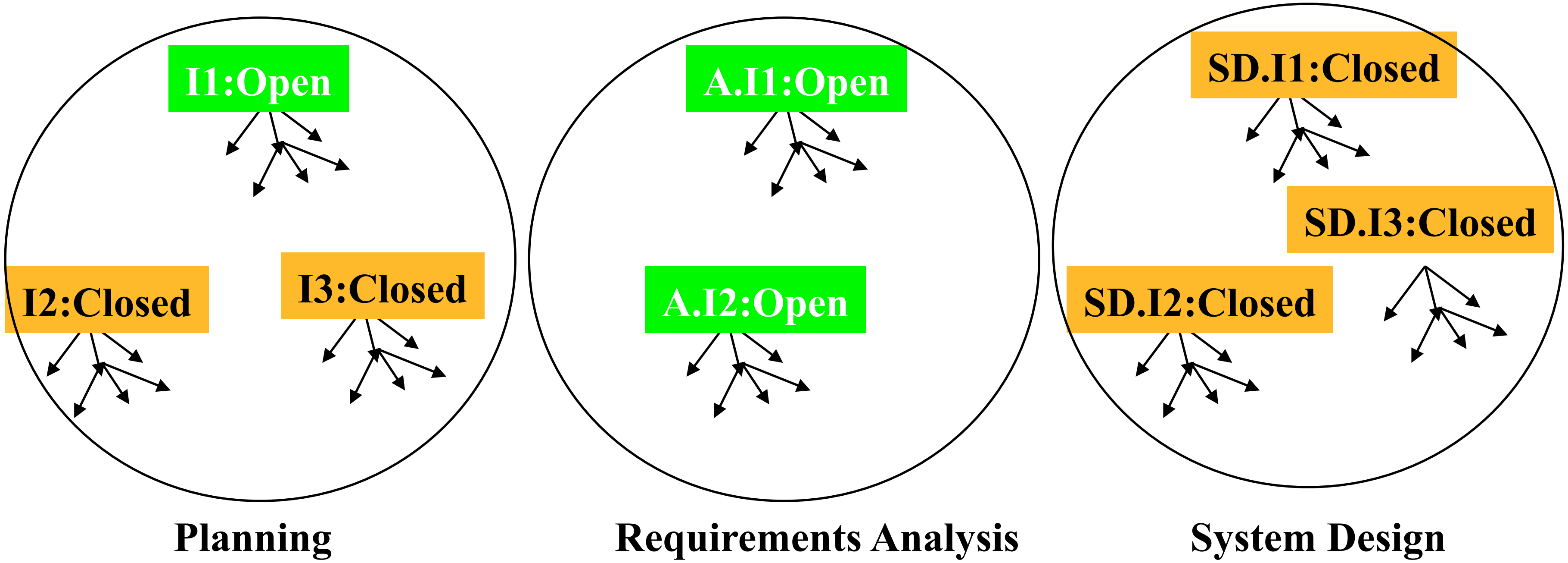


Limitations of Waterfall and Spiral Models

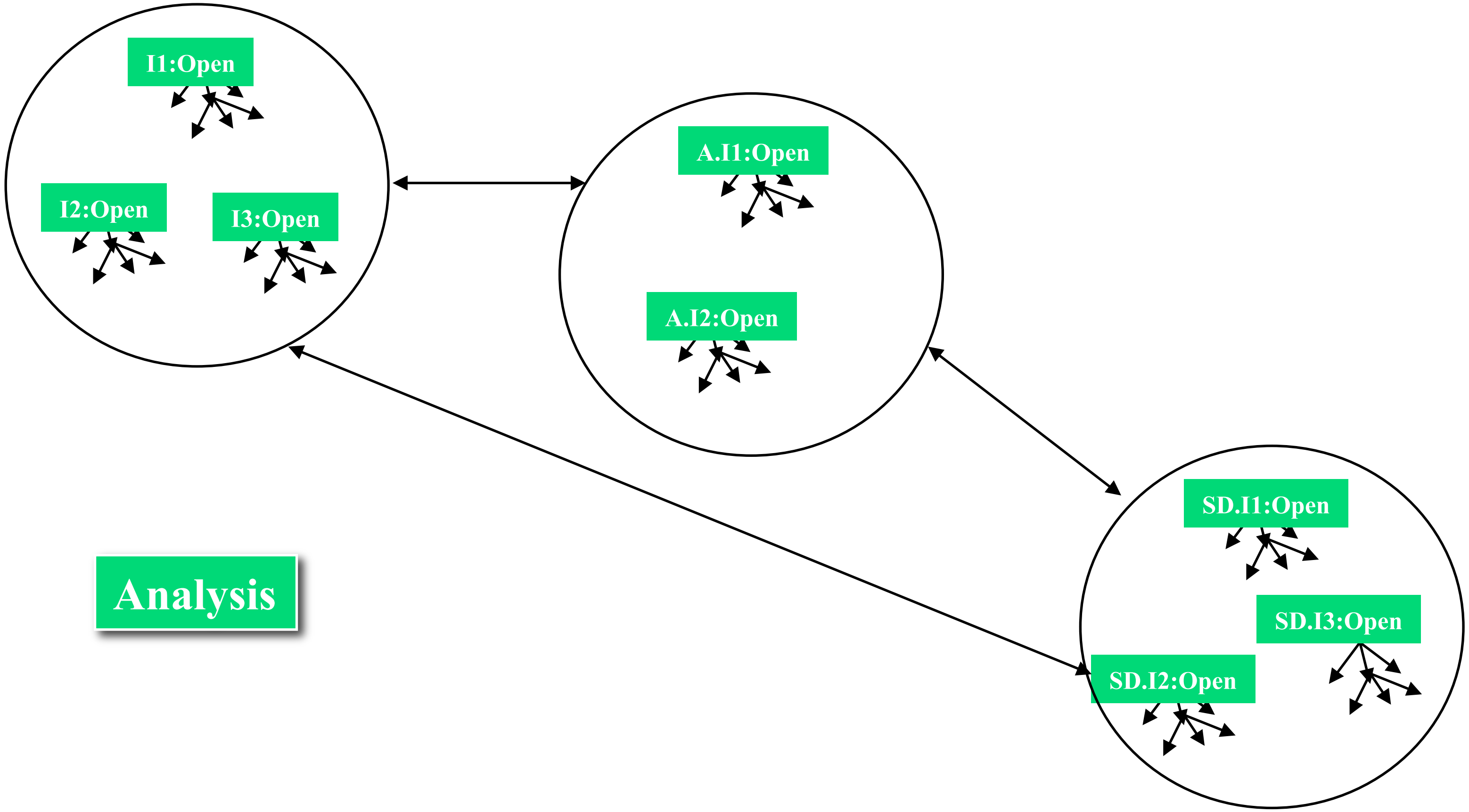
- Neither of these models deal well with frequent change
  - The Waterfall model assumes that once you are done with a phase, all issues covered in that phase are closed and cannot be reopened
  - The Spiral model can deal with change between phases, but does not allow change within a phase
- What do you do if change is happening more frequently?
  - "The only constant is the change"

An Alternative: Issue-Based Development

- A system is described as a collection of issues
  - Issues are either closed or open
  - Closed issues have a resolution
  - Closed issues can be reopened (Iteration!)
- The set of closed issues is the basis of the system model

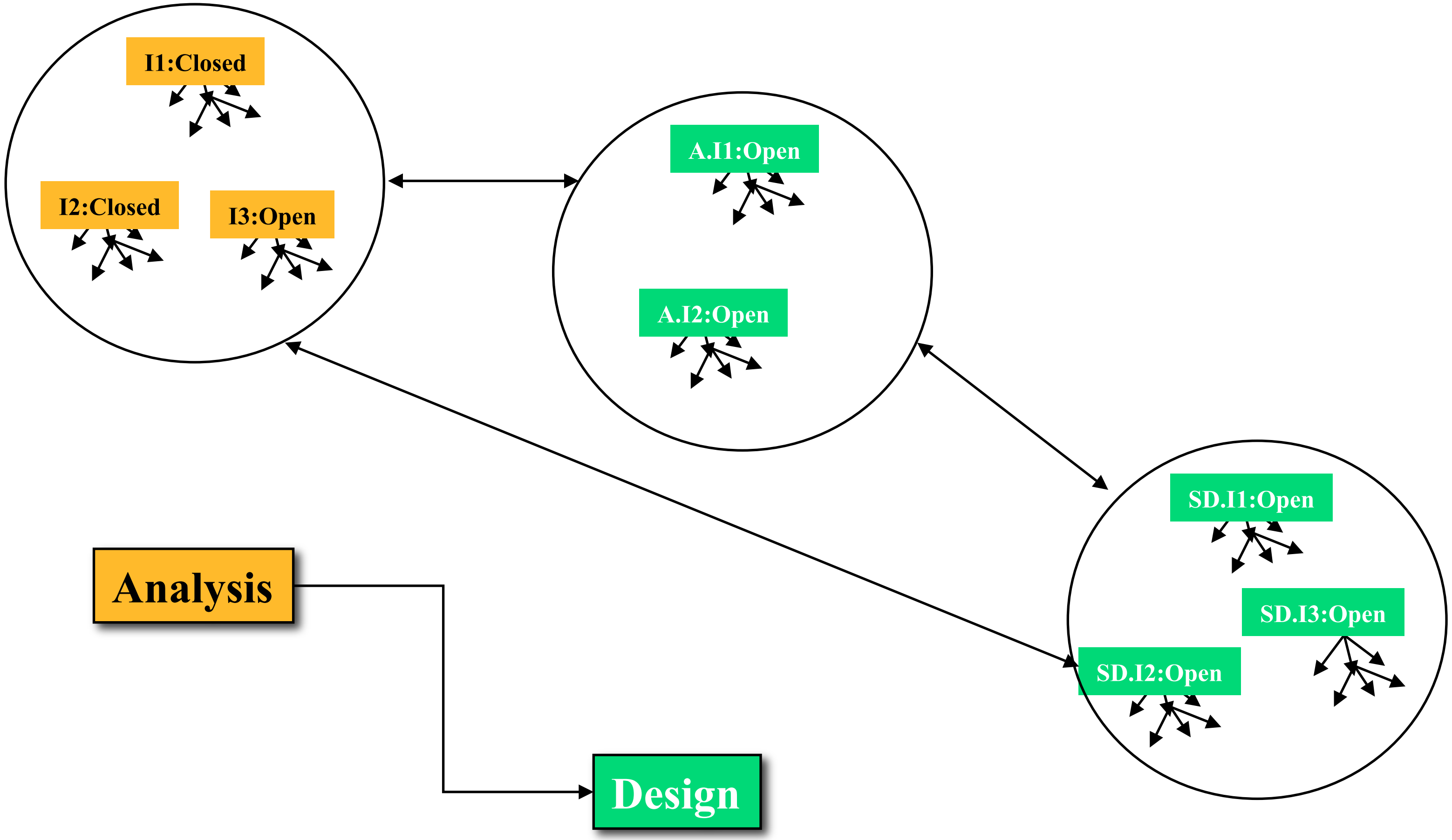


Waterfall Model: Analysis Phase

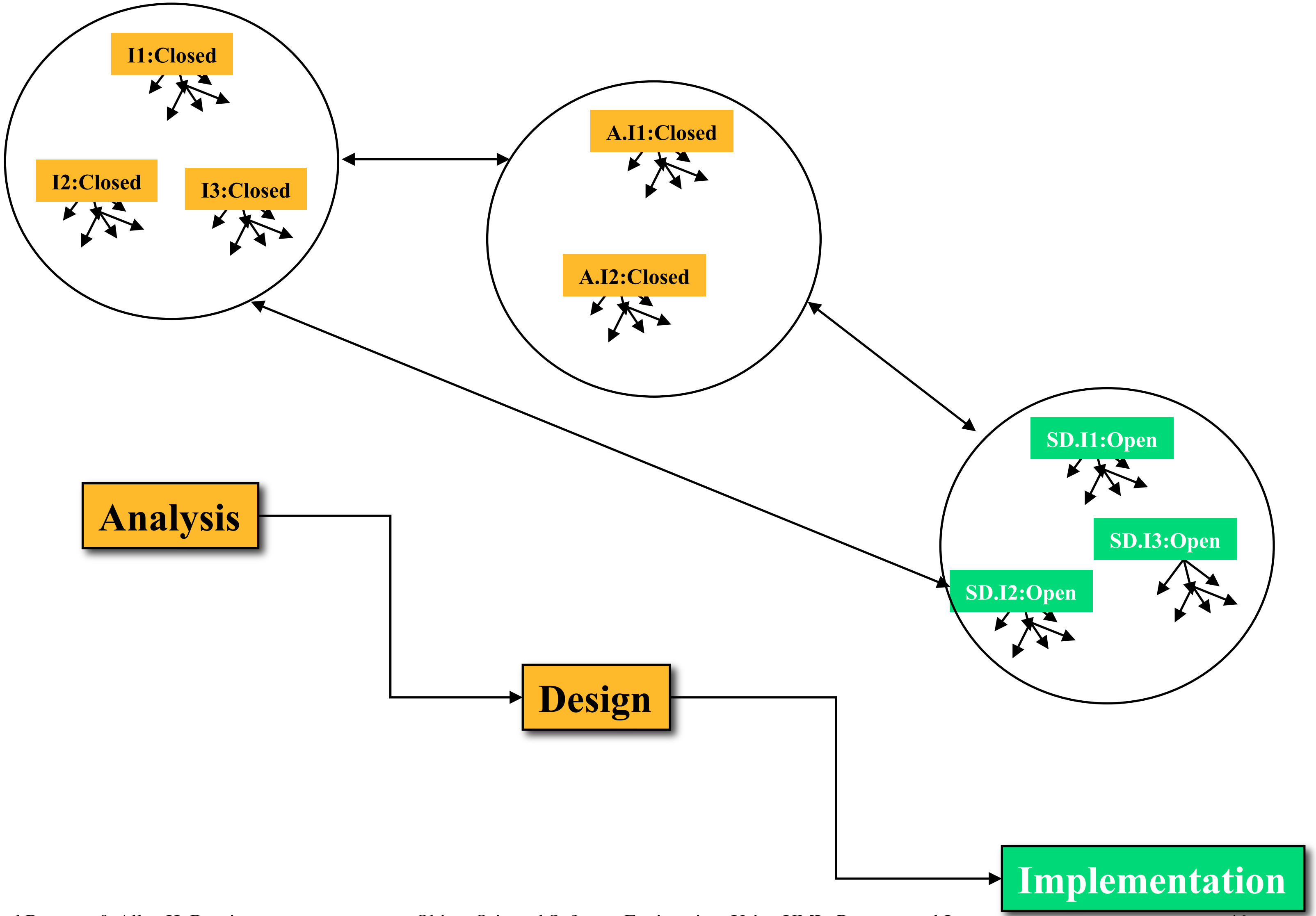


Analysis

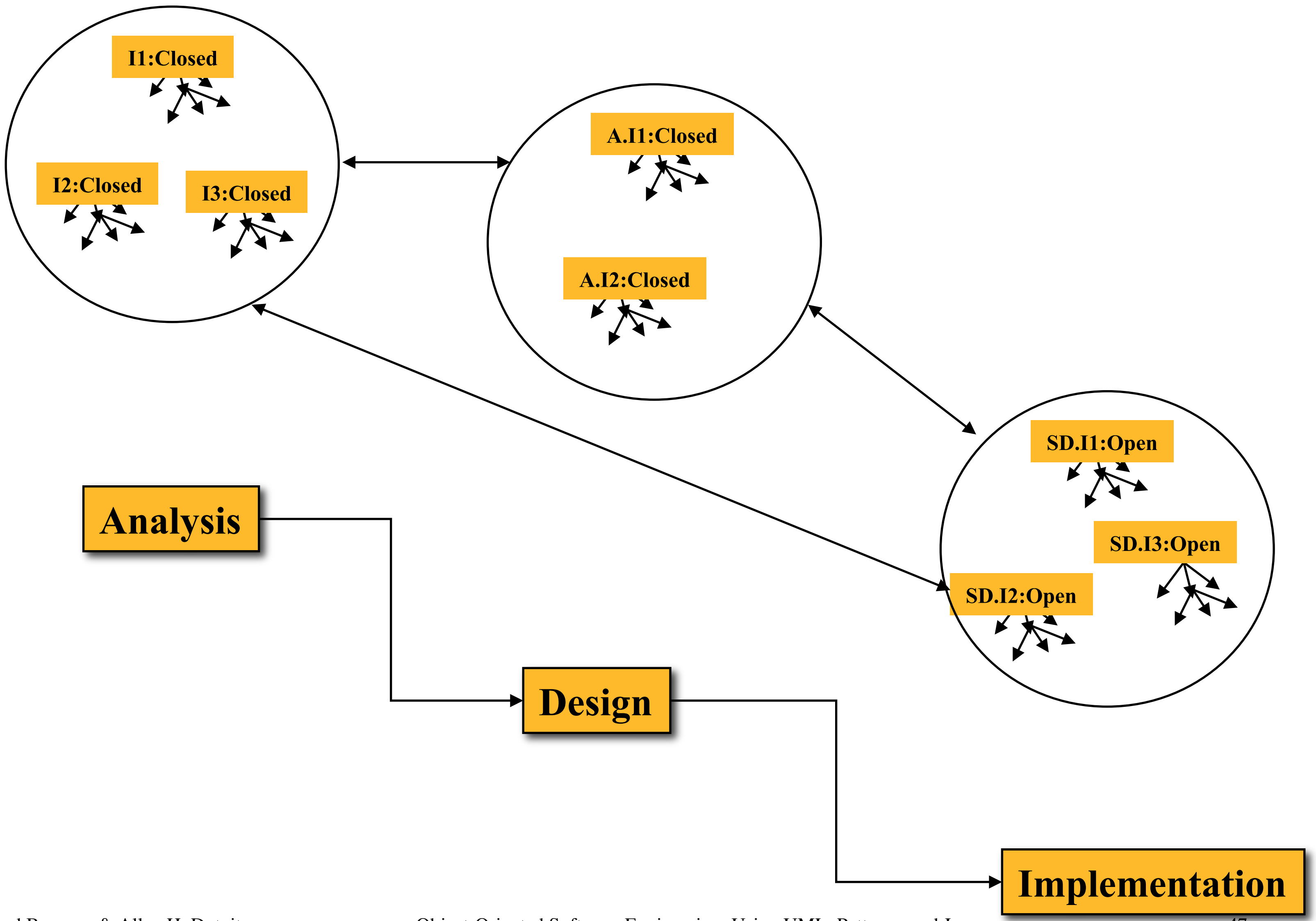
Waterfall Model: Design Phase



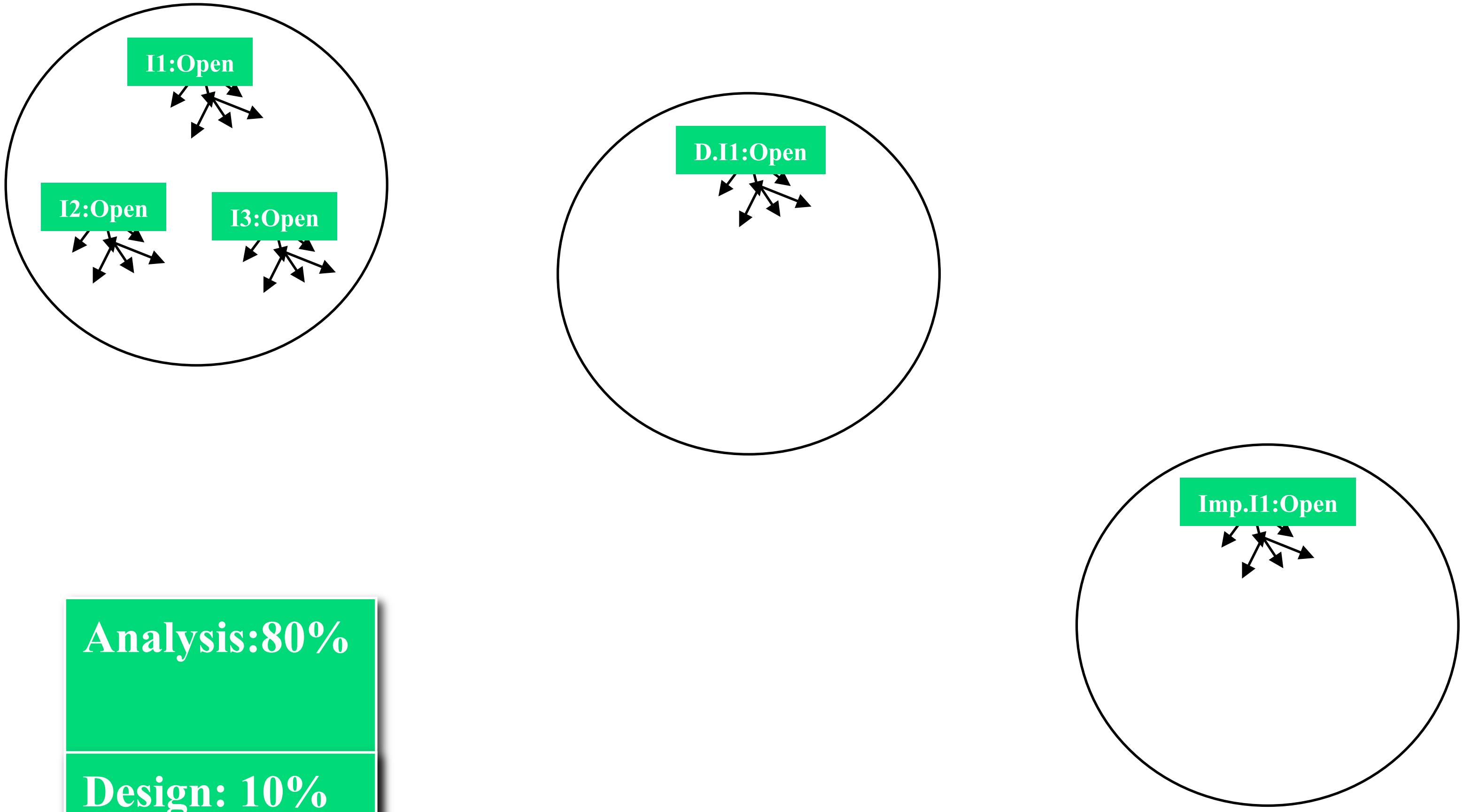
Waterfall Model: Implementation Phase



Waterfall Model: Project is Done



Issue-Based Model: Analysis Phase

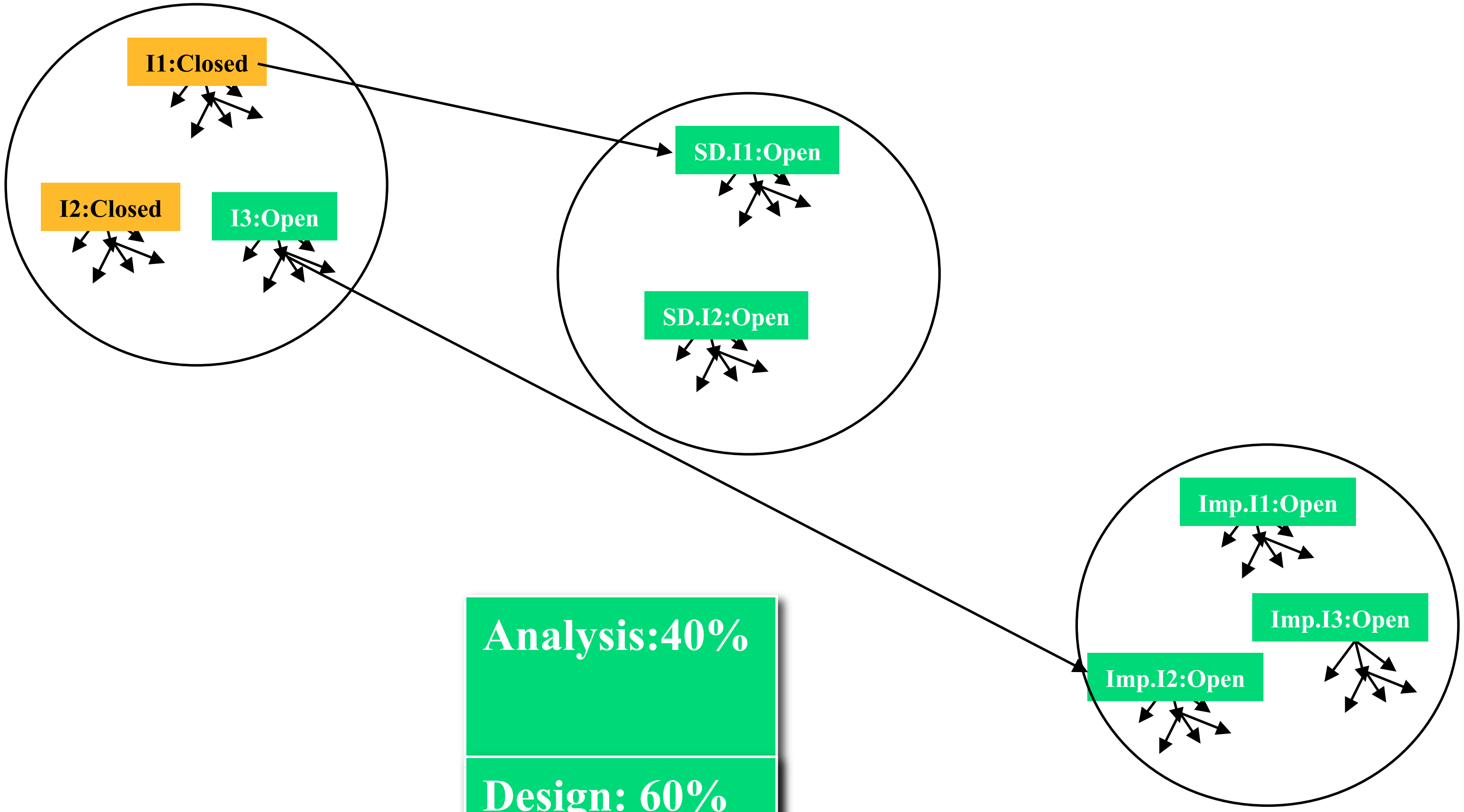


Analysis:80%

Design: 10%

Implementation: 10%

Issue-Based Model: Design Phase

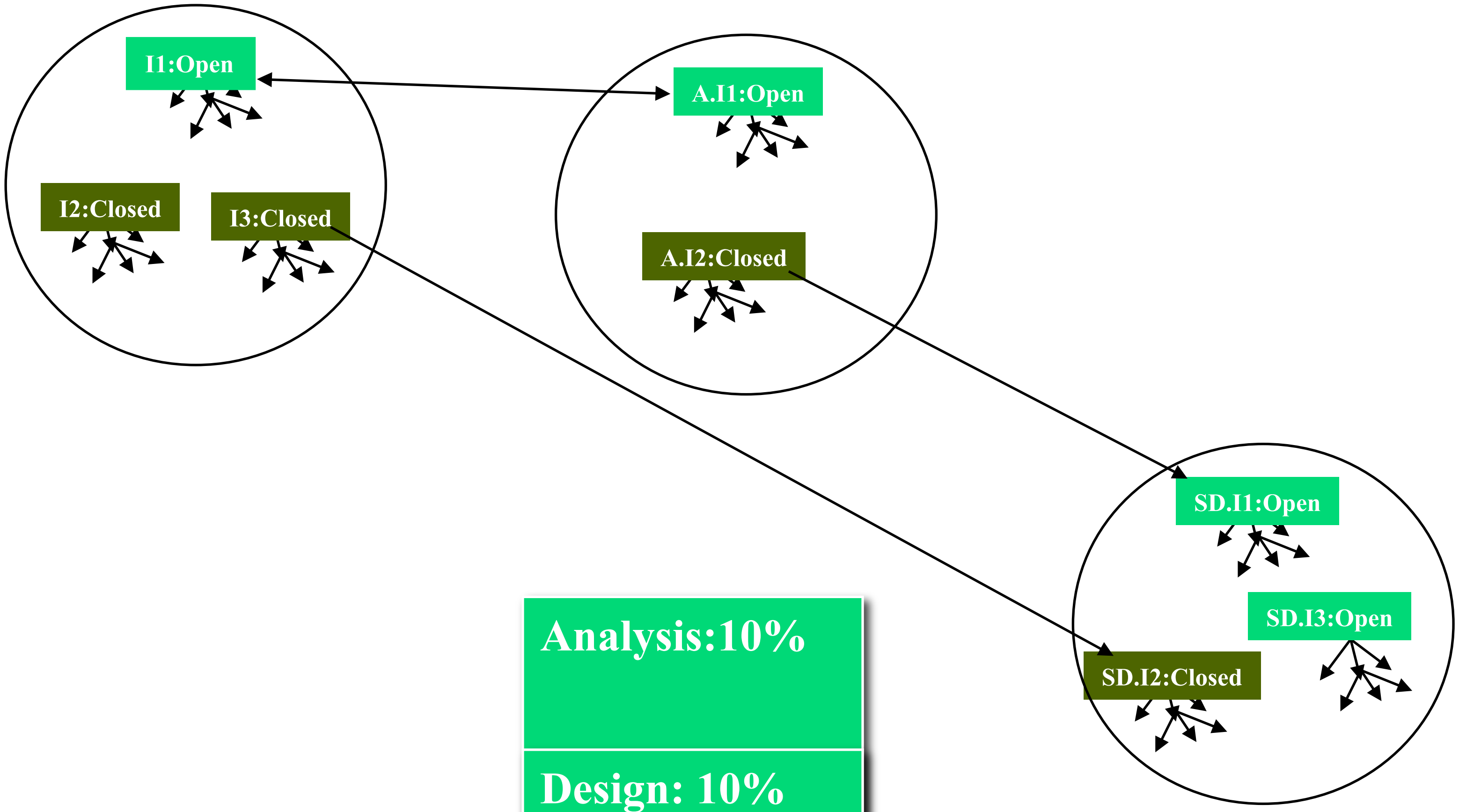


Analysis:40%

Design: 60%

Implementation: 0%

Issue-Based Model: Implementation Phase

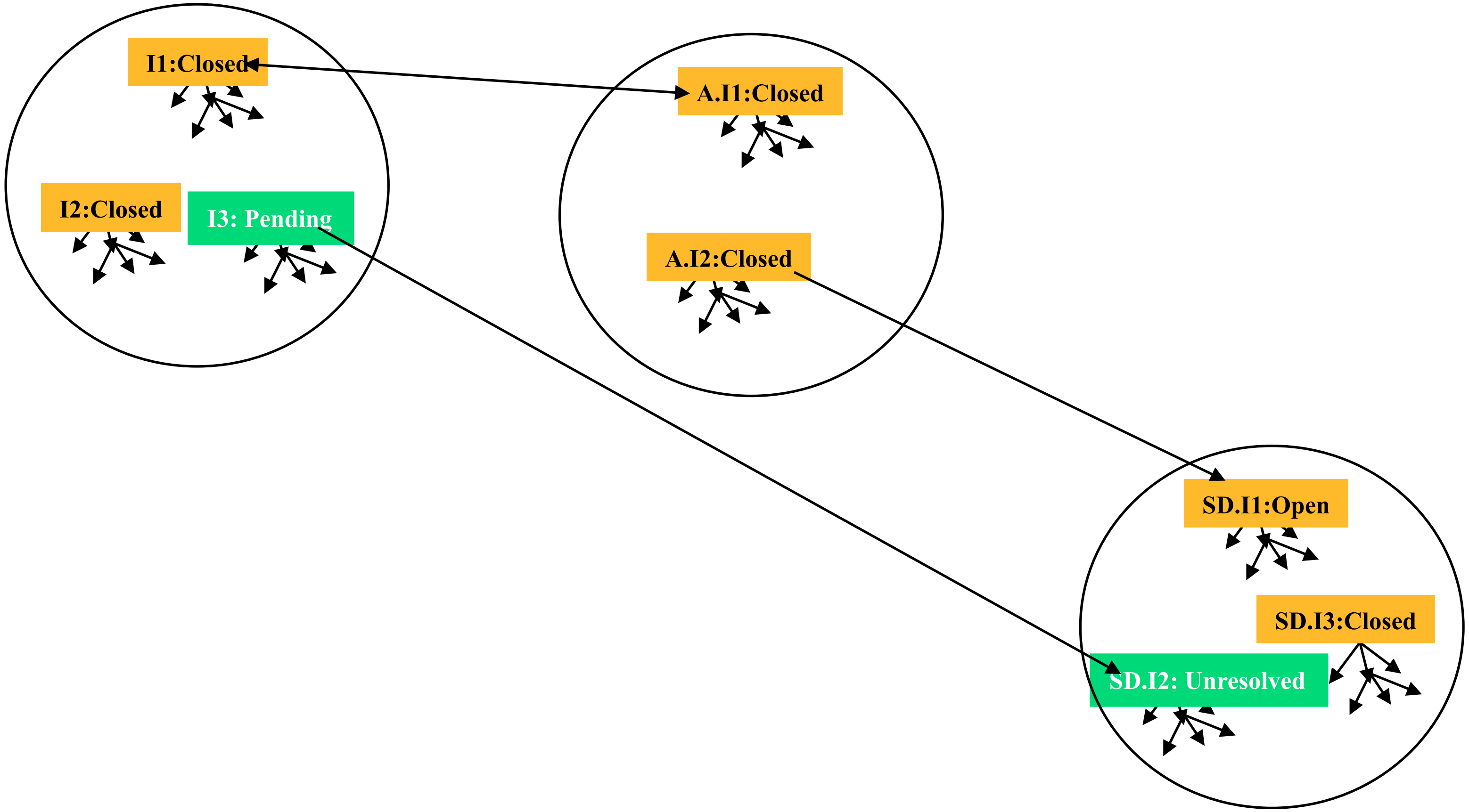


Analysis:10%

Design: 10%

Implementation: 60%

Issue-Based Model: Prototype is Done



Frequency of Change and Choice of Software Lifecycle Model

PT = Project Time, MTBC = Mean Time Between Change

- Change rarely occurs (MTBC » PT)
  - Linear Model (Waterfall, V-Model)
  - Open issues are closed before moving to next phase
- Change occurs sometimes (MTBC ≈ PT)
  - Iterative model (Spiral Model, Unified Process)
  - Change occurring during phase may lead to iteration of a previous phase or cancellation of the project
- Change is frequent (MTBC « PT)
  - Issue-based Model (Concurrent Development, Scrum)
  - Phases are never finished, they all run in parallel.

Summary

- Software life cycle models
  - Sequential models
    - Pure waterfall model and V-model
    - Sawtooth model
  - Iterative model
    - Boehm's spiral model
      - Rounds
      - Comparison of projects
  - Prototyping
    - Revolutionary and evolutionary prototyping
    - Time-boxed prototyping instead of rapid prototyping
  - Entity-oriented models
    - Issue-based model
    - Sequential models can be modeled as special cases of the issue-based model.