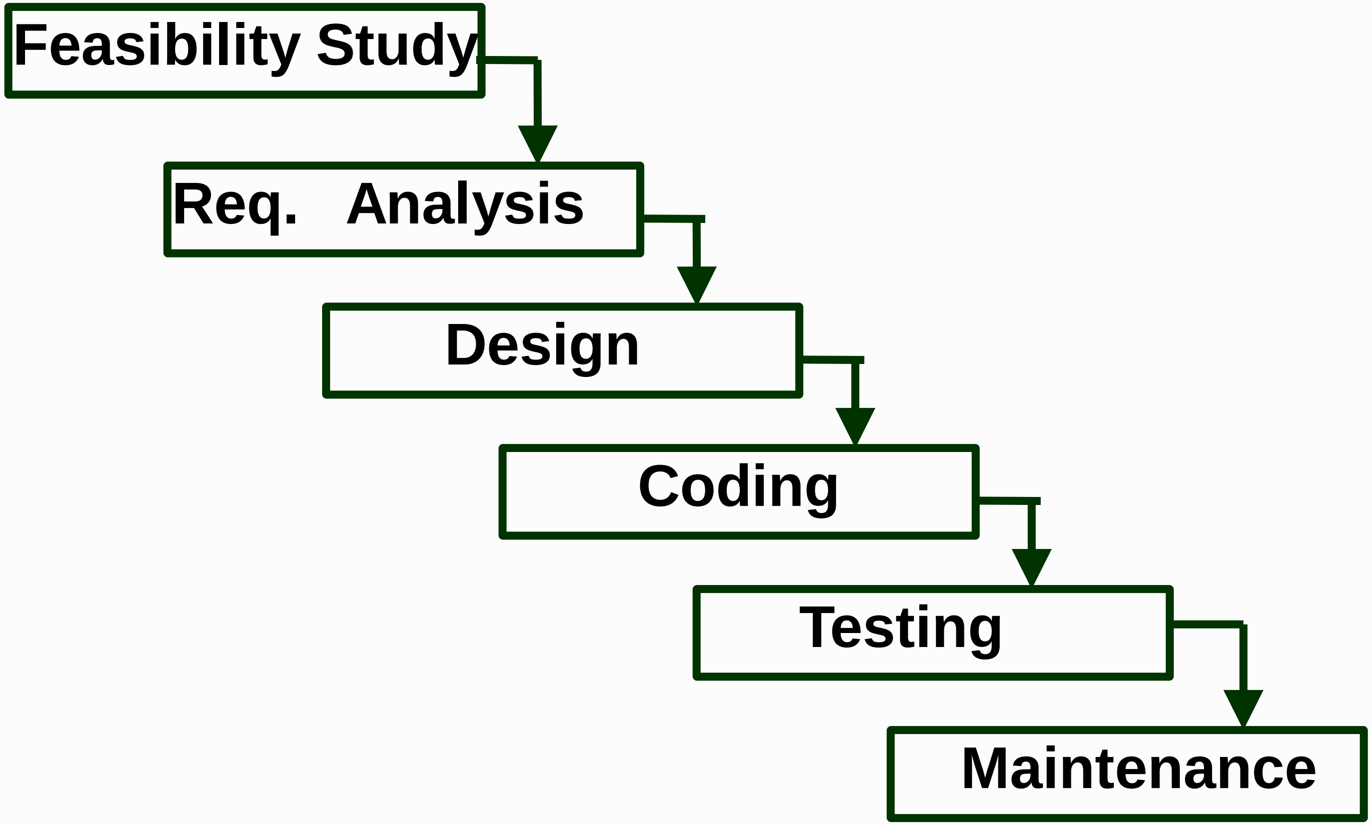
Life Cycle Models

Software Engineering

Classical Waterfall Model

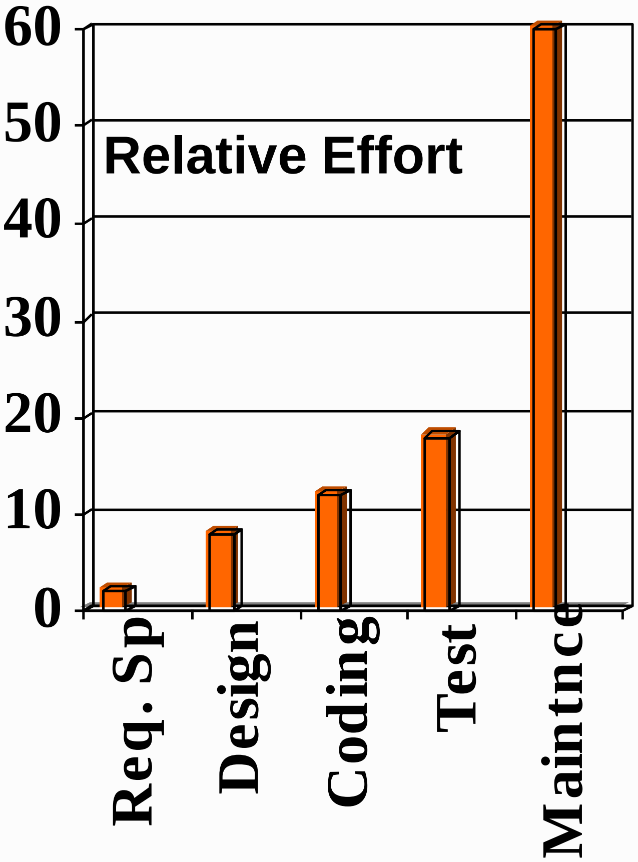
- Classical waterfall model divides life cycle into phases:
  - feasibility study,
  - requirements analysis and specification,
  - design,
  - coding and unit testing,
  - integration and system testing,
  - maintenance.

Classical Waterfall Model



Relative Effort for Phases

- Phases between feasibility study and testing
  - known as development phases.
- Among all life cycle phases
  - maintenance phase consumes maximum effort.
- Among development phases,
  - testing phase consumes the maximum effort.



Classical Waterfall Model (CONT.)

- Most organizations usually define:
  - standards on the outputs (deliverables) produced at the end of every phase
  - entry and exit criteria for every phase.
- They also prescribe specific methodologies for:
  - specification,
  - design,
  - testing,
  - project management, etc.

Classical Waterfall Model (CONT.)

- The guidelines and methodologies of an organization:
  - called the organization's software development methodology.
- Software development organizations:
  - expect fresh engineers to master the organization's software development methodology.

Feasibility Study

- Main aim of feasibility study:determine whether developing the product
  - financially worthwhile
  - technically feasible.
- First roughly understand what the customer wants:
  - different data which would be input to the system,
  - processing needed on these data,
  - output data to be produced by the system,
  - various constraints on the behavior of the system.

Activities during Feasibility Study

- Work out an overall understanding of the problem.
- Formulate different solution strategies.
- Examine alternate solution strategies in terms of:
    - resources required,
    - cost of development, and
    - development time.

Activities during Feasibility Study

- Perform a cost/benefit analysis:
  - to determine which solution is the best.
  - you may determine that none of the solutions is feasible due to:
    - high cost,
    - resource constraints,
    - technical reasons.

Requirements Analysis and Specification

- Aim of this phase:
  - understand the exact requirements of the customer,
  - document them properly.
- Consists of two distinct activities:
  - requirements gathering and analysis
  - requirements specification.

Goals of Requirements Analysis

- Collect all related data from the customer:
  - analyze the collected data to clearly understand what the customer wants,
  - find out any inconsistencies and incompleteness in the requirements,
  - resolve all inconsistencies and incompleteness.

Requirements Gathering

- Gathering relevant data:
  - usually collected from the end-users through interviews and discussions.
  - For example, for a business accounting software:
    - interview all the accountants of the organization to find out their requirements.

Requirements Analysis (CONT.)

- The data you initially collect from the users:
  - would usually contain several contradictions and ambiguities:
  - each user typically has only a partial and incomplete view of the system.

Requirements Analysis (CONT.)

- Ambiguities and contradictions:
  - must be identified
  - resolved by discussions with the customers.
- Next, requirements are organized:
  - into a Software Requirements Specification (SRS) document.

Requirements Analysis (CONT.)

- Engineers doing requirements analysis and specification:
  - –are designated as analysts.

Design

- Design phase transforms requirements specification:
  - into a form suitable for implementation in some programming language.

Design

- In technical terms:
  - during design phase, software architecture is derived from the SRS document.
- Two design approaches:
  - traditional approach,
  - object oriented approach.

Traditional Design Approach

- Consists of two activities:
  - Structured analysis
  - Structured design

Structured Analysis Activity

- Identify all the functions to be performed.
- Identify data flow among the functions.
- Decompose each function recursively into sub-functions.
  - Identify data flow among the subfunctions as well.

Structured Analysis (CONT.)

- Carried out using Data flow diagrams (DFDs).
- After structured analysis, carry out structured design:
  - architectural design (or high-level design)
  - detailed design (or low-level design).

Structured Design

- High-level design:
  - decompose the system into *modules*,
  - represent invocation relationships among the modules.
- Detailed design:
  - different modules designed in greater detail:
    - data structures and algorithms for each module are designed.

Object Oriented Design

- First identify various objects (real world entities) occurring in the problem:
  - identify the relationships among the objects.
  - For example, the objects in a pay-roll software may be:
    - employees,
    - managers,
    - pay-roll register,
    - Departments, etc.

Object Oriented Design (CONT.)

- Object structure
  - further refined to obtain the detailed design.
- OOD has several advantages:
  - lower development effort,
  - lower development time,
  - better maintainability.

Implementation

- Purpose of implementation phase (aka coding and unit testing phase):
  - translate software design into source code.

Implementation

- During the implementation phase:
  - each module of the design is coded,
  - each module is unit tested
    - tested independently as a stand alone unit, and debugged,
  - each module is documented.

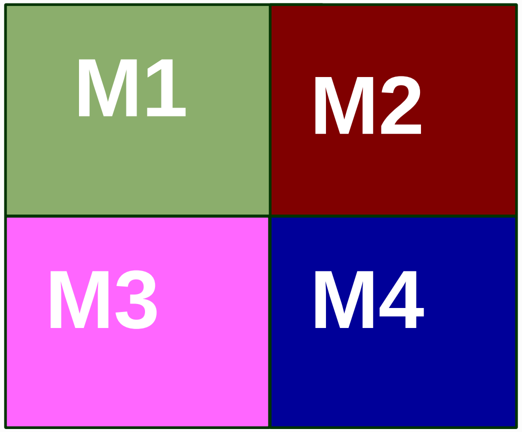
Implementation (CONT.)

- The purpose of unit testing:
  - test if individual modules work correctly.
- The end product of implementation phase:
  - a set of program modules that have been tested individually.

Integration and System Testing

- Different modules are integrated in a planned manner:
  - modules are almost never integrated in one shot.
  - Normally integration is carried out through a number of steps.
- During each integration step,
  - the partially integrated system is tested.

Integration and System Testing



M1

M2

M3

M4

System Testing

- After all the modules have been successfully integrated and tested:
  - system testing is carried out.
- Goal of system testing:
  - ensure that the developed system functions according to its requirements as specified in the SRS document.

Maintenance

- Maintenance of any software product:
  - requires much more effort than the effort to develop the product itself.
  - development effort to maintenance effort is typically 40:60.

Maintenance (CONT.)

- Corrective maintenance:
  - Correct errors which were not discovered during the product development phases.
- Perfective maintenance:
  - Improve implementation of the system
  - enhance functionalities of the system.
- Adaptive maintenance:
  - Port software to a new environment,
    - e.g. to a new computer or to a new operating system.

Iterative Waterfall Model

- Classical waterfall model is idealistic:
  - assumes that no defect is introduced during any development activity.
  - in practice:
    - defects do get introduced in almost every phase of the life cycle.

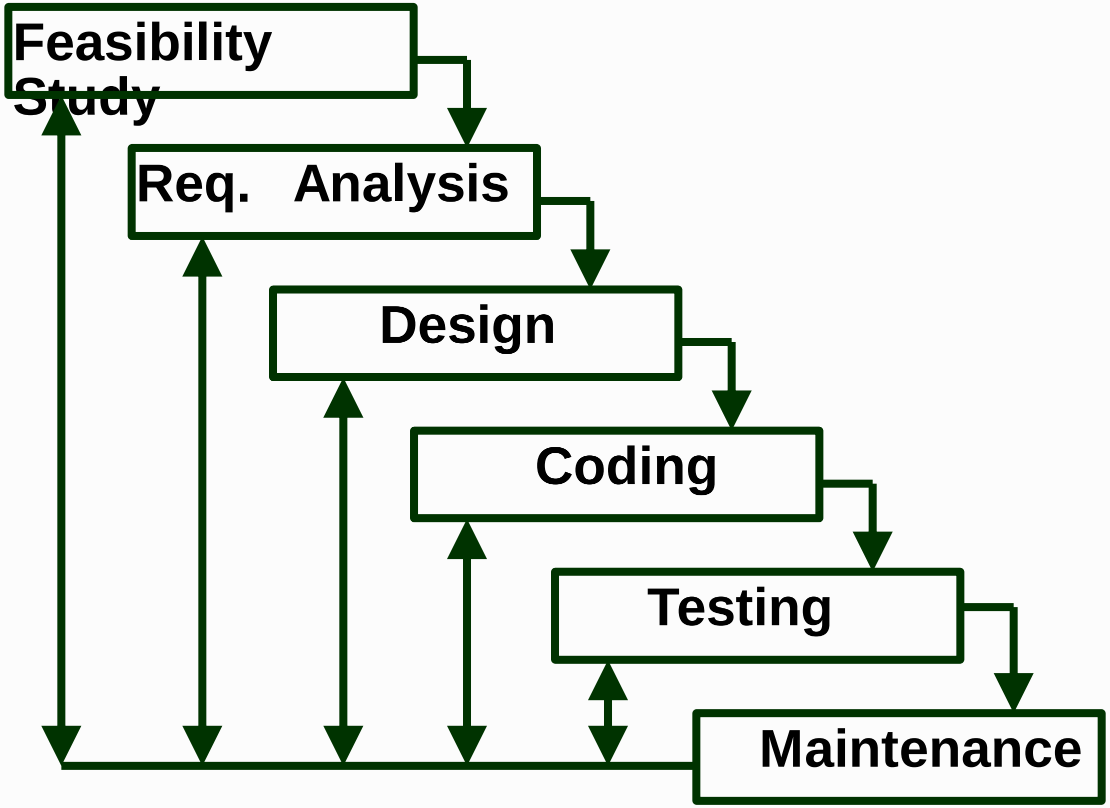
Iterative Waterfall Model (CONT.)

- Defects usually get detected much later in the life cycle:
  - For example, a design defect might go unnoticed till the coding or testing phase.

Iterative Waterfall Model (CONT.)

- Once a defect is detected:
  - we need to go back to the phase where it was introduced
  - redo some of the work done during that and all subsequent phases.
- Therefore we need feedback paths in the classical waterfall model.

Iterative Waterfall Model (CONT.)



Iterative Waterfall Model (CONT.)

- Errors should be detected
  - in the same phase in which they are introduced.
- <u>For example:</u>
  - if a design problem is detected in the design phase itself,
    - the problem can be taken care of much more easily
    - than say if it is identified at the end of the integration and system testing phase.

Phase containment of errors

- Reason: rework must be carried out not only to the design but also to code and test phases.
- The principle of detecting errors as close to its point of introduction as possible:
  - is known as **phase containment of errors.**
- Iterative waterfall model is by far the most widely used model.
  - Almost every other model is derived from the waterfall model.

Classical Waterfall Model (CONT.)

- Irrespective of the life cycle model actually followed:
  - the documents should reflect a classical waterfall model of development,
  - comprehension of the documents is facilitated.

Classical Waterfall Model (CONT.)

- Metaphor of mathematical theorem proving:
  - A mathematician presents a proof as a single chain of deductions,
    - even though the proof might have come from a convoluted set of partial attempts, blind alleys and backtracks.

Prototyping Model

- Before starting actual development,
  - a working prototype of the system should first be built.
- A prototype is a toy implementation of a system:
  - limited functional capabilities,
  - low reliability,
  - inefficient performance.

Reasons for developing a prototype

- Illustrate to the customer:
  - input data formats, messages, reports, or interactive dialogs.
- Examine technical issues associated with product development:
  - Often major design decisions depend on issues like:
    - response time of a hardware controller,
    - efficiency of a sorting algorithm, etc.

Prototyping Model (CONT.)

- The third reason for developing a prototype is:
  - – it is impossible to ``get it right'' the first time,
  - – we must plan to throw away the first product
    - if we want to develop a good product.

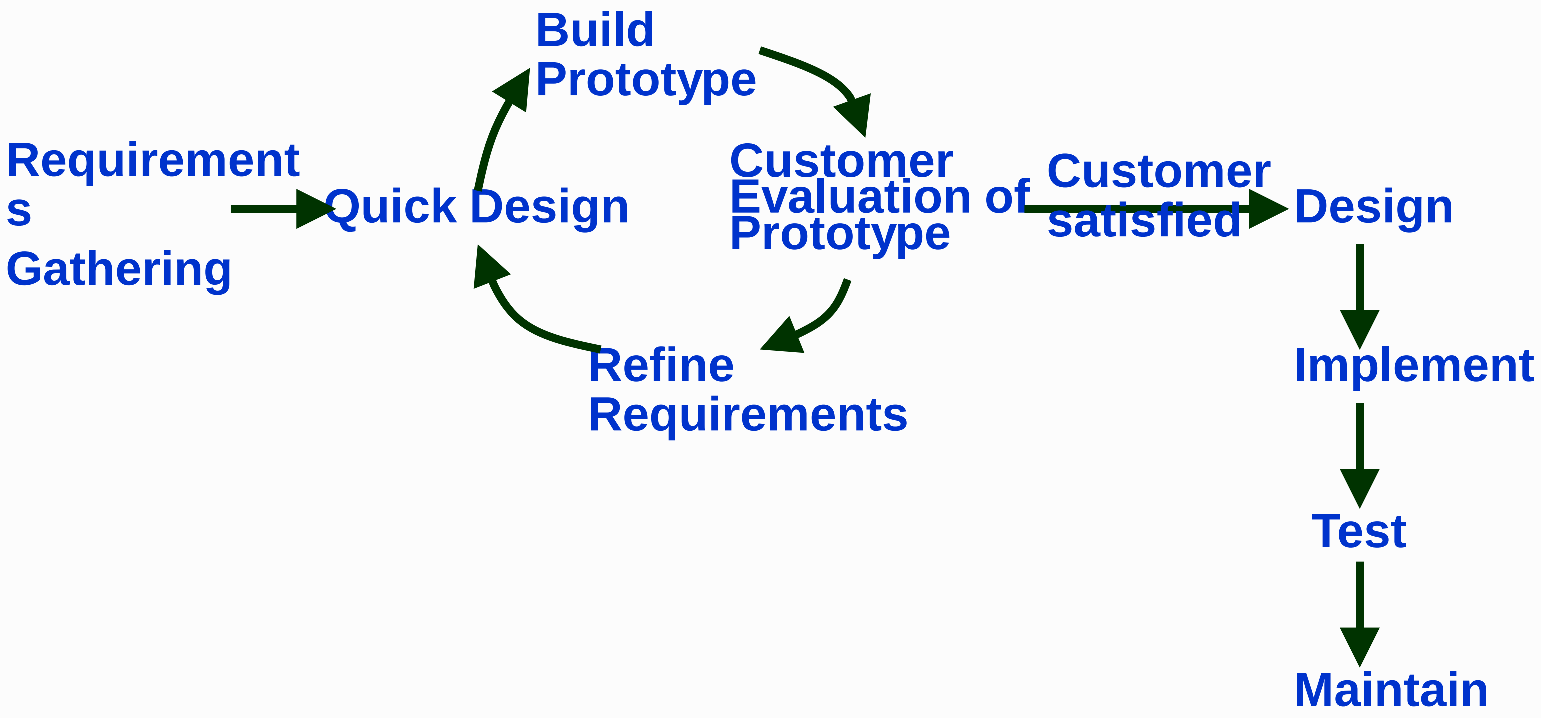
Prototyping Model (CONT.)

- Start with approximate requirements.
- Carry out a quick design.
- Prototype model is built using several short-cuts:
  - Short-cuts might involve using inefficient, inaccurate, or dummy functions.
    - A function may use a table look-up rather than performing the actual computations.

Prototyping Model (CONT.)

- The developed prototype is submitted to the customer for his evaluation:
  - Based on the user feedback, requirements are refined.
  - This cycle continues until the user approves the prototype.
- The actual system is developed using the classical waterfall approach.

Prototyping Model (CONT.)



Prototyping Model (CONT.)

- Requirements analysis and specification phase becomes redundant:
  - final working prototype (with all user feedbacks incorporated) serves as an animated requirements specification.
- Design and code for the prototype is usually thrown away:
  - However, the experience gathered from developing the prototype helps a great deal while developing the actual product.

Prototyping Model (CONT.)

- Even though construction of a working prototype model involves additional cost --- overall development cost might be lower for:
  - systems with unclear user requirements,
  - systems with unresolved technical issues.
- Many user requirements get properly defined and technical issues get resolved:
  - these would have appeared later as change requests and resulted in incurring massive redesign costs.

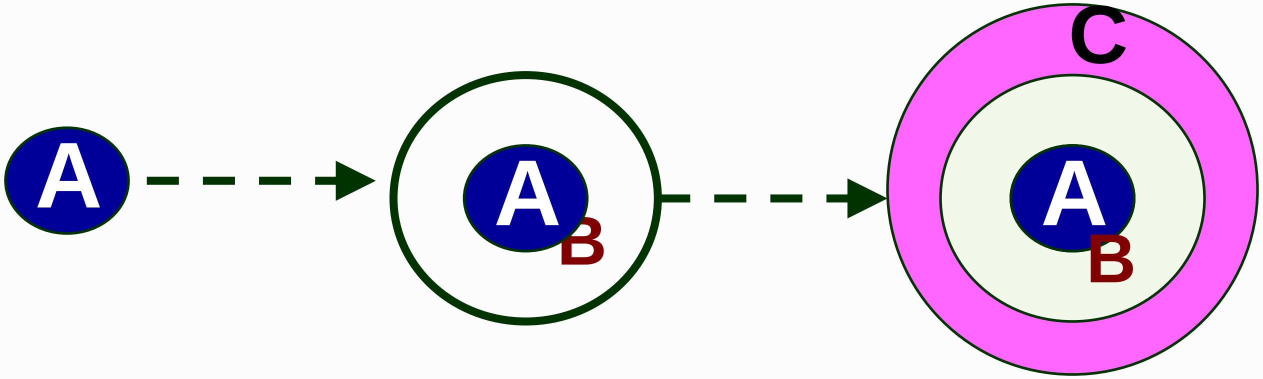
Evolutionary Model

- Evolutionary model (aka successive versions or incremental model):
  - The system is broken down into several modules which can be incrementally implemented and delivered.
- First develop the core modules of the system.
- The initial product skeleton is refined into increasing levels of capability:
  - by adding new functionalities in successive versions.

Evolutionary Model (CONT.)

- Successive version of the product:
  - functioning systems capable of performing some useful work.
  - A new release may include new functionality:
    - also existing functionality in the current release might have been enhanced.

Evolutionary Model (CONT.)



Advantages of Evolutionary Model

- Users get a chance to experiment with a partially developed system:
  - much before the full working version is released,
- Helps finding exact user requirements:
  - much before fully working system is developed.
- Core modules get tested thoroughly:
  - reduces chances of errors in final product.

Disadvantages of Evolutionary Model

- Often, difficult to subdivide problems into functional units:
  - which can be incrementally implemented and delivered.
  - evolutionary model is useful for very large problems,
    - where it is easier to find modules for incremental implementation.

Evolutionary Model with Iteration

- Many organizations use a combination of iterative and incremental development:
  - a new release may include new functionality
  - existing functionality from the current release may also have been modified.

Evolutionary Model with iteration

- Several advantages:
  - Training can start on an earlier release
    - customer feedback taken into account
  - Markets can be created:
    - for functionality that has never been offered.
  - Frequent releases allow developers to fix unanticipated problems quickly.

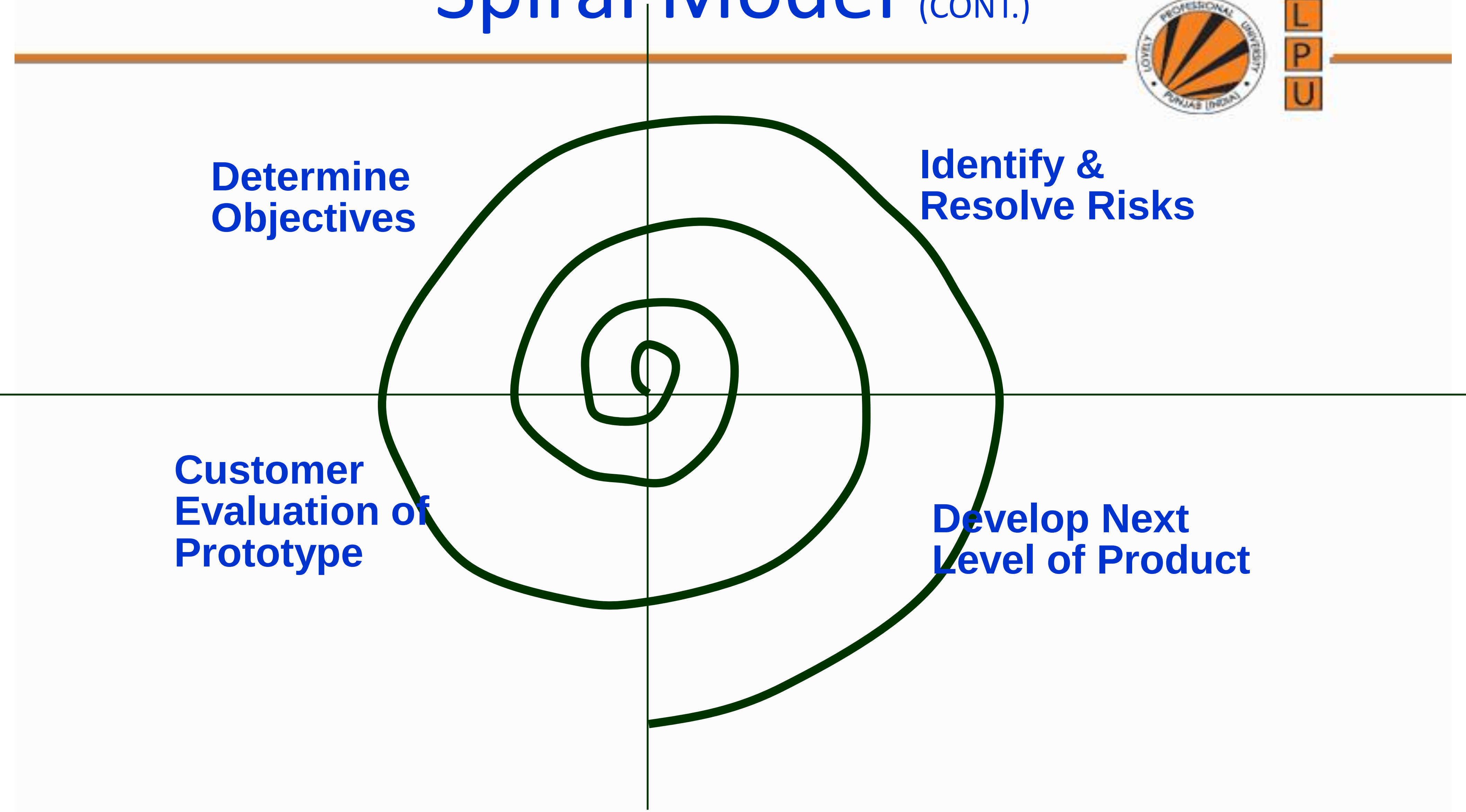
Spiral Model

- Proposed by Boehm in 1988.
- Each loop of the spiral represents a phase of the software process:
  - the innermost loop might be concerned with system feasibility,
  - the next loop with system requirements definition,
  - the next one with system design, and so on.
- There are no fixed phases in this model, the phases shown in the figure are just examples.

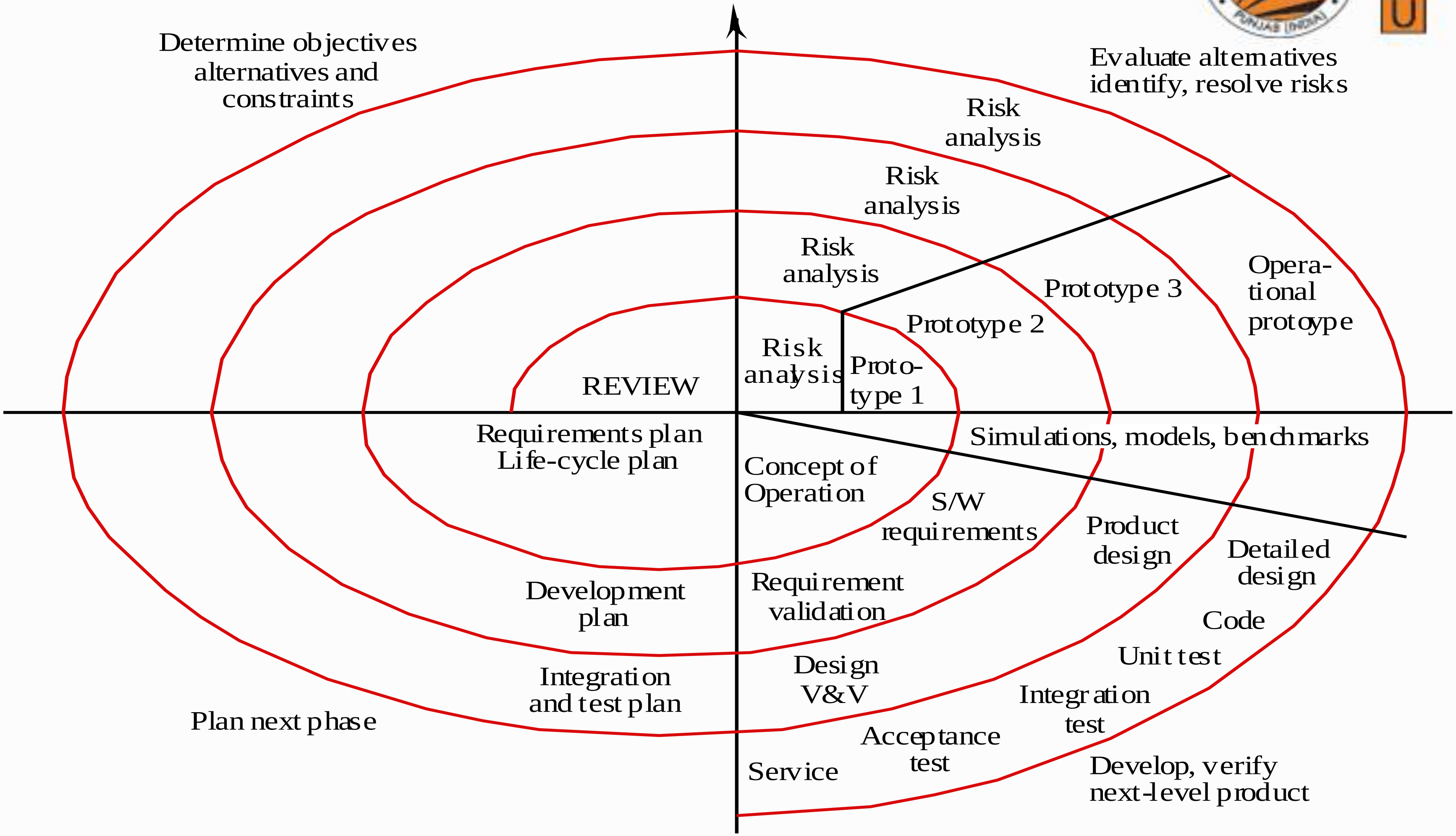
Spiral Model (CONT.)

- The team must decide:
  - how to structure the project into phases.
- Start work using some generic model:
  - add extra phases
    - for specific projects or when problems are identified during a project.
- Each loop in the spiral is split into four sectors (quadrants).

Spiral Model (CONT.)


Determine Objectives
Identify & Resolve Risks
Customer Evaluation of Prototype
Develop Next Level of Product

Spiral Model



Determine objectives alternatives and constraints

Evaluate alternatives identify, resolve risks

Risk analysis

Risk analysis

Risk analysis

Risk analysis

Prototype 3

Prototype 2

Proto-type 1

Opera-tional protoype

REVIEW

Requirements plan Life-cycle plan

Concept of Operation

Simulations, models, benchmarks

S/W requirements

Product design

Detailed design

Development plan

Requirement validation

Code

Unit test

Integration and test plan

Design V&V

Integration test

Plan next phase

Acceptance test

Service

Develop, verify next-level product

Objective Setting (First Quadrant)

- Identify objectives of the phase,
- Examine the risks associated with these objectives.
  - Risk:
    - any adverse circumstance that might hamper successful completion of a software project.
- Find alternate solutions possible.

Risk Assessment and Reduction (Second Quadrant)

- For each identified project risk,
  - a detailed analysis is carried out.
- Steps are taken to reduce the risk.
- For example, if there is a risk that the requirements are inappropriate:
  - a prototype system may be developed.

Spiral Model (CONT.)

- Development and Validation (Third quadrant):
  - develop and validate the next level of the product.
- Review and Planning (Fourth quadrant):
  - review the results achieved so far with the customer and plan the next iteration around the spiral.
- With each iteration around the spiral:
  - progressively more complete version of the software gets built.

Spiral Model as a meta model

- Subsumes all discussed models:
  - a single loop spiral represents waterfall model.
  - uses an evolutionary approach --
    - iterations through the spiral are evolutionary levels.
  - enables understanding and reacting to risks during each iteration along the spiral.
  - uses:
    - prototyping as a risk reduction mechanism
    - retains the step-wise approach of the waterfall model.

Comparison of Different Life Cycle Models

- Iterative waterfall model
  - most widely used model.
  - But, suitable only for well-understood problems.
- Prototype model is suitable for projects not well understood:
  - user requirements
  - technical aspects

Comparison of Different Life Cycle Models (CONT.)

- Evolutionary model is suitable for large problems:
  - can be decomposed into a set of modules that can be incrementally implemented,
  - incremental delivery of the system is acceptable to the customer.
- The spiral model:
  - suitable for development of technically challenging software products that are subject to several kinds of risks.