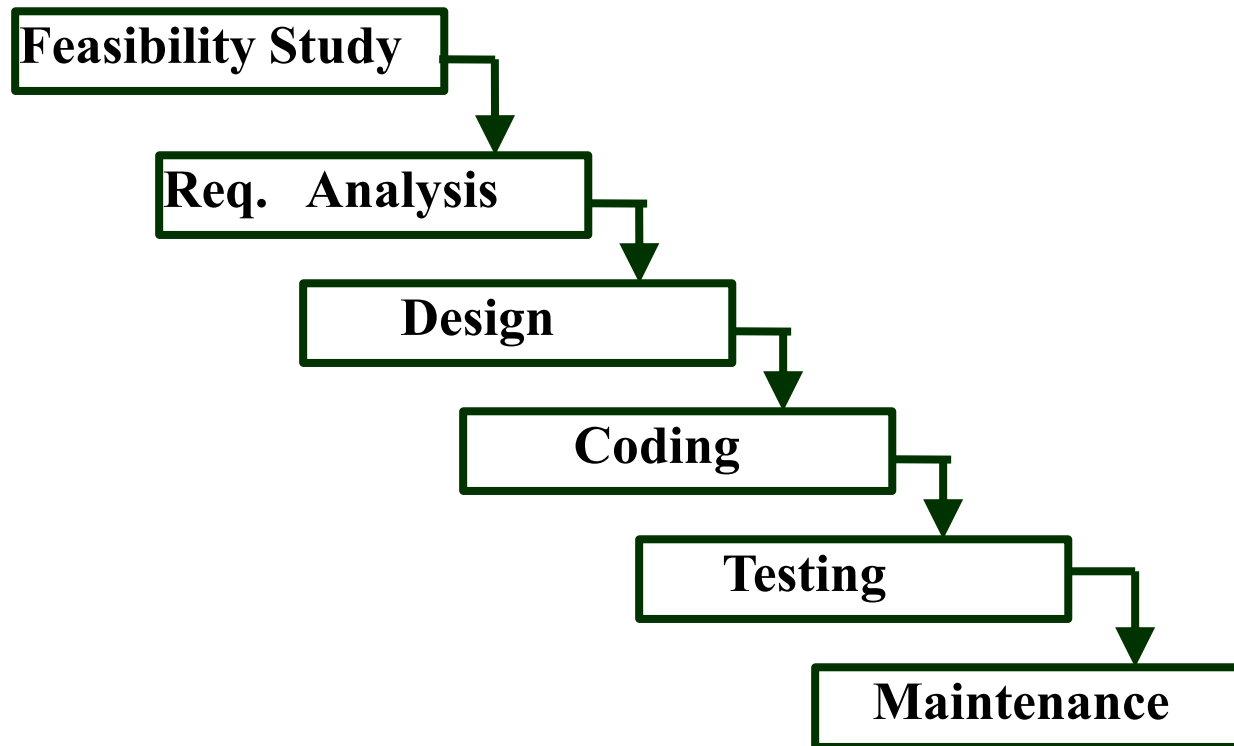


Life Cycle Models

Classical Waterfall Model

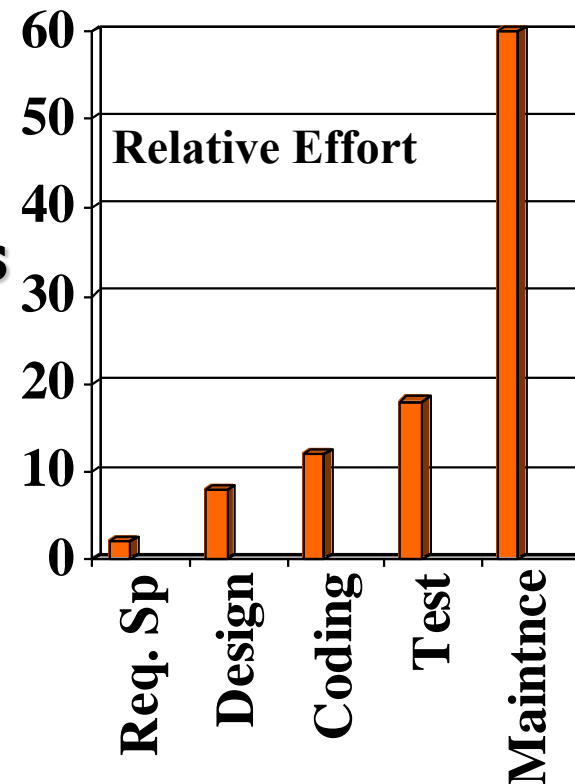
- **Classical waterfall model divides life cycle into phases:**
 - **feasibility study,**
 - **requirements analysis and specification,**
 - **design,**
 - **coding and unit testing,**
 - **integration and system testing,**
 - **maintenance.**

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.**

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

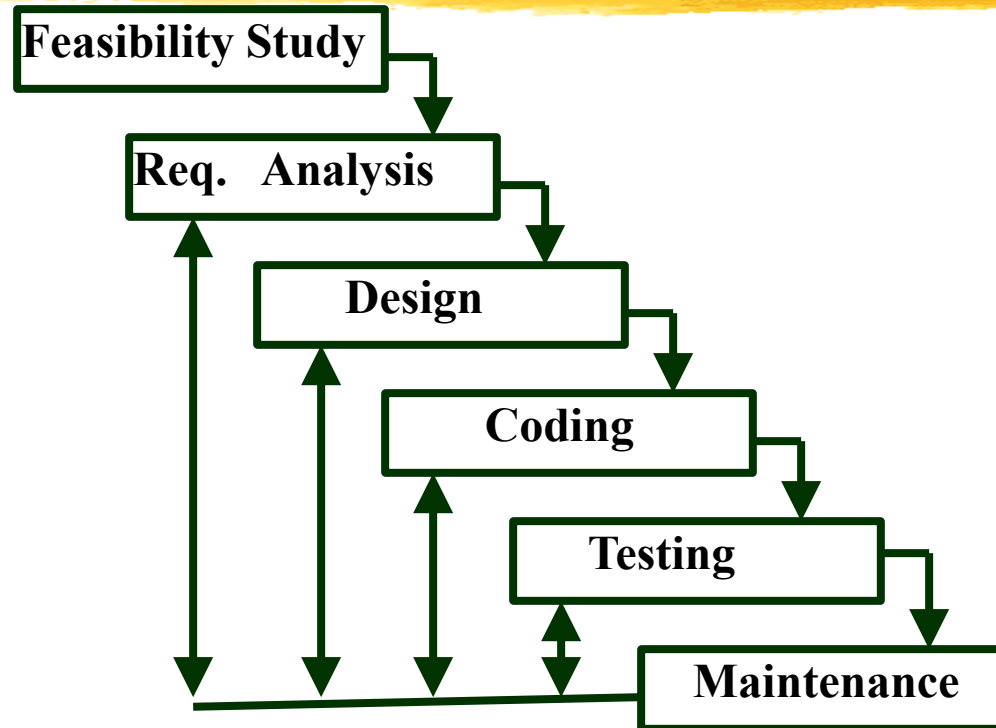
(CONT.)



- **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.
- **For example:**
 - **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.

Shortcomings of Iterative Waterfall Model



- Does not consider risks
 - Does not consider uncertainties concerning the requirements
 - Cannot be used by customer's having rough or unclear idea of her requirements
- Rigid Phase Sequence
 - May lead to blocking states
 - May lead to some efficient engineers sitting idly

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.)

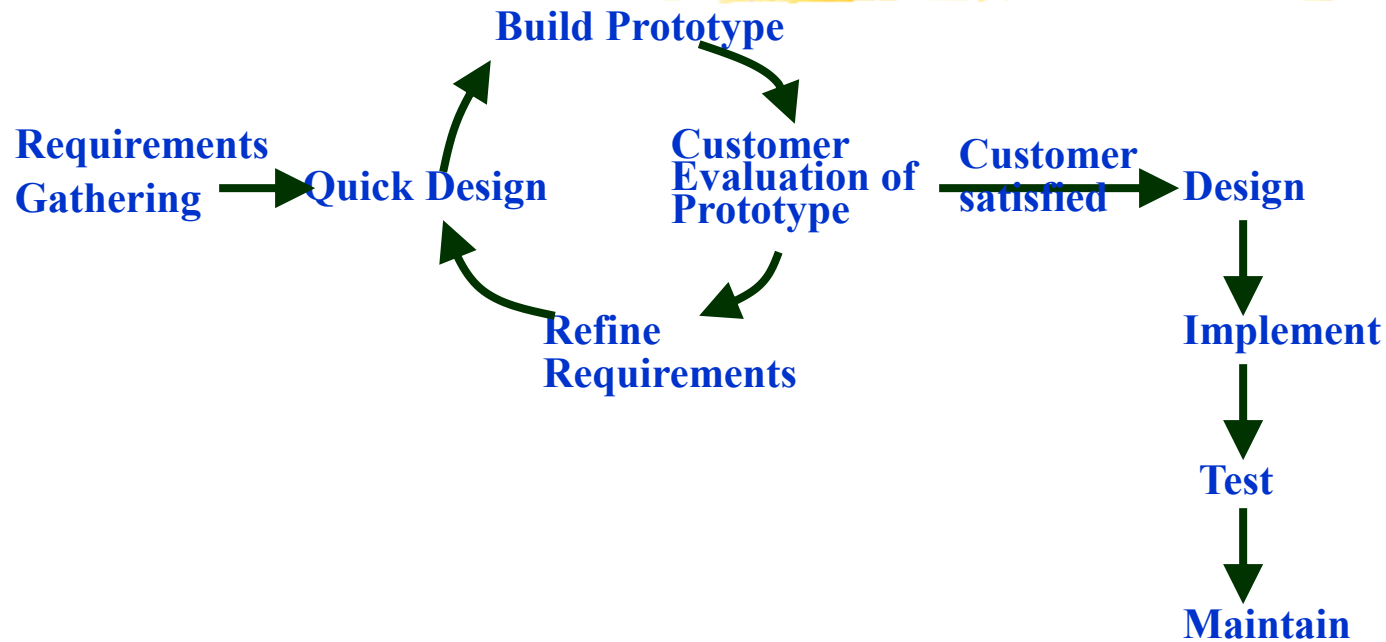


- **Start with approximate requirements.**
- **Carry out a quick design.**
- **Prototype model is built using several short-cuts:**
 - Short-cuts might involve using inefficient, inaccurate, or dummy functions.
 - * A function may use a table look-up rather than performing the actual computations.

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.

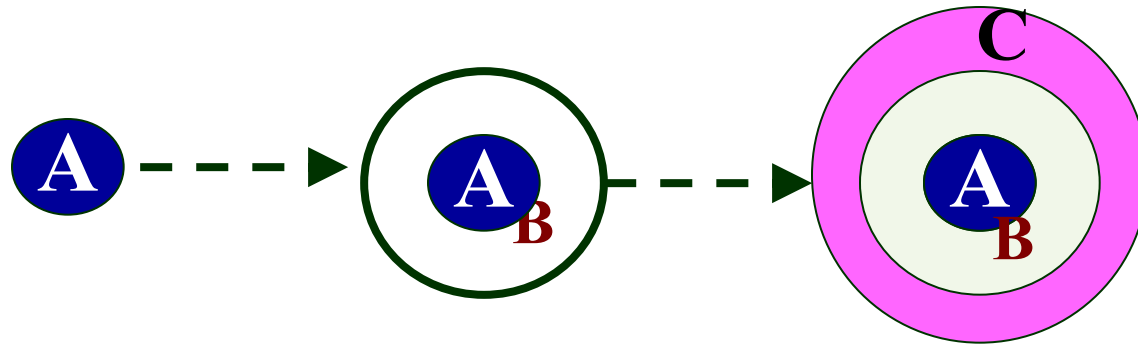
Evolutionary Model

- **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

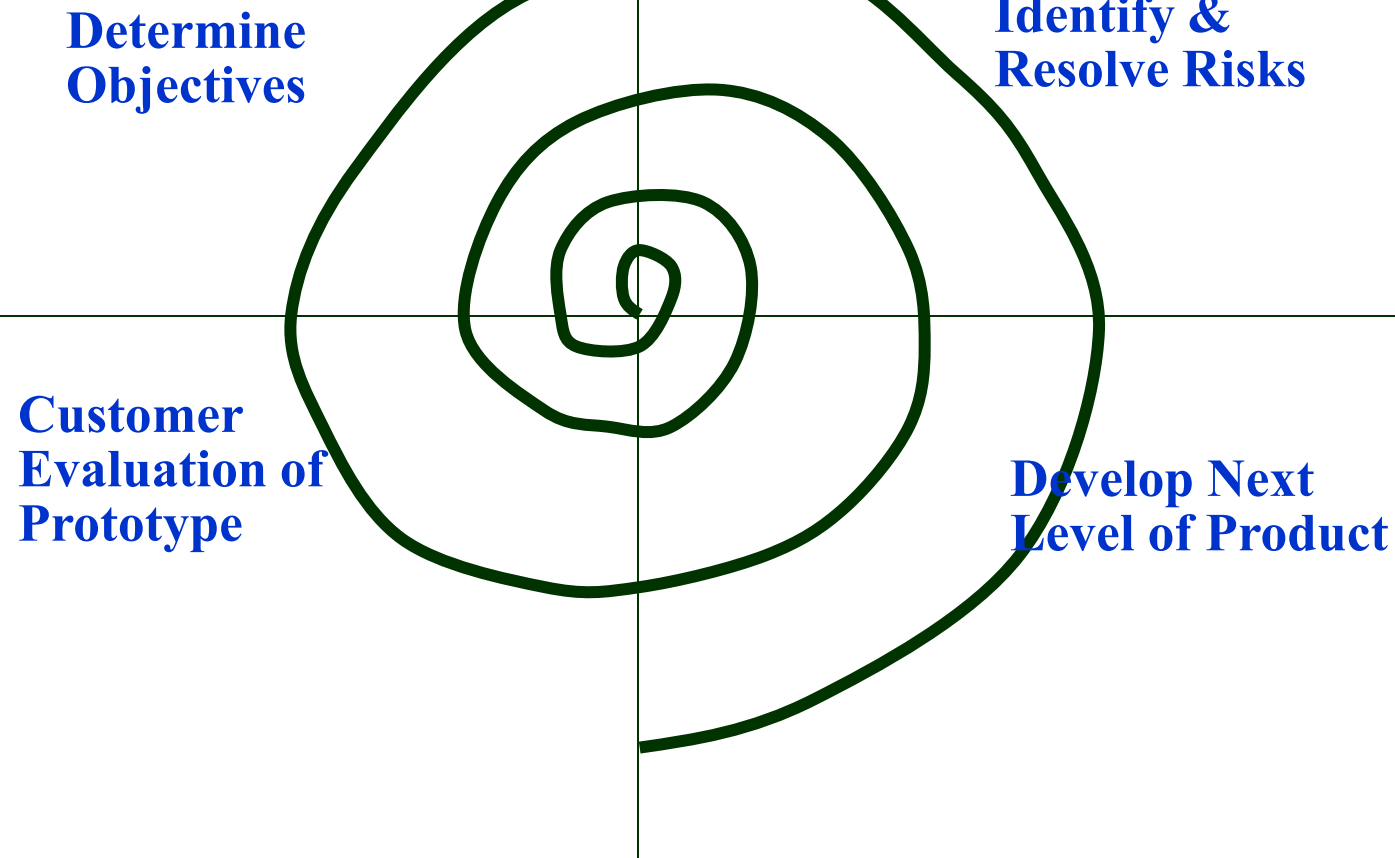
- **Proposed by Boehm in 1988.**
- **Each loop of the spiral represents a phase of the software process:**
 - the innermost loop might be concerned with system feasibility,
 - the next loop with system requirements definition,
 - the next one with system design, and so on.
- **There are no fixed phases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



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.