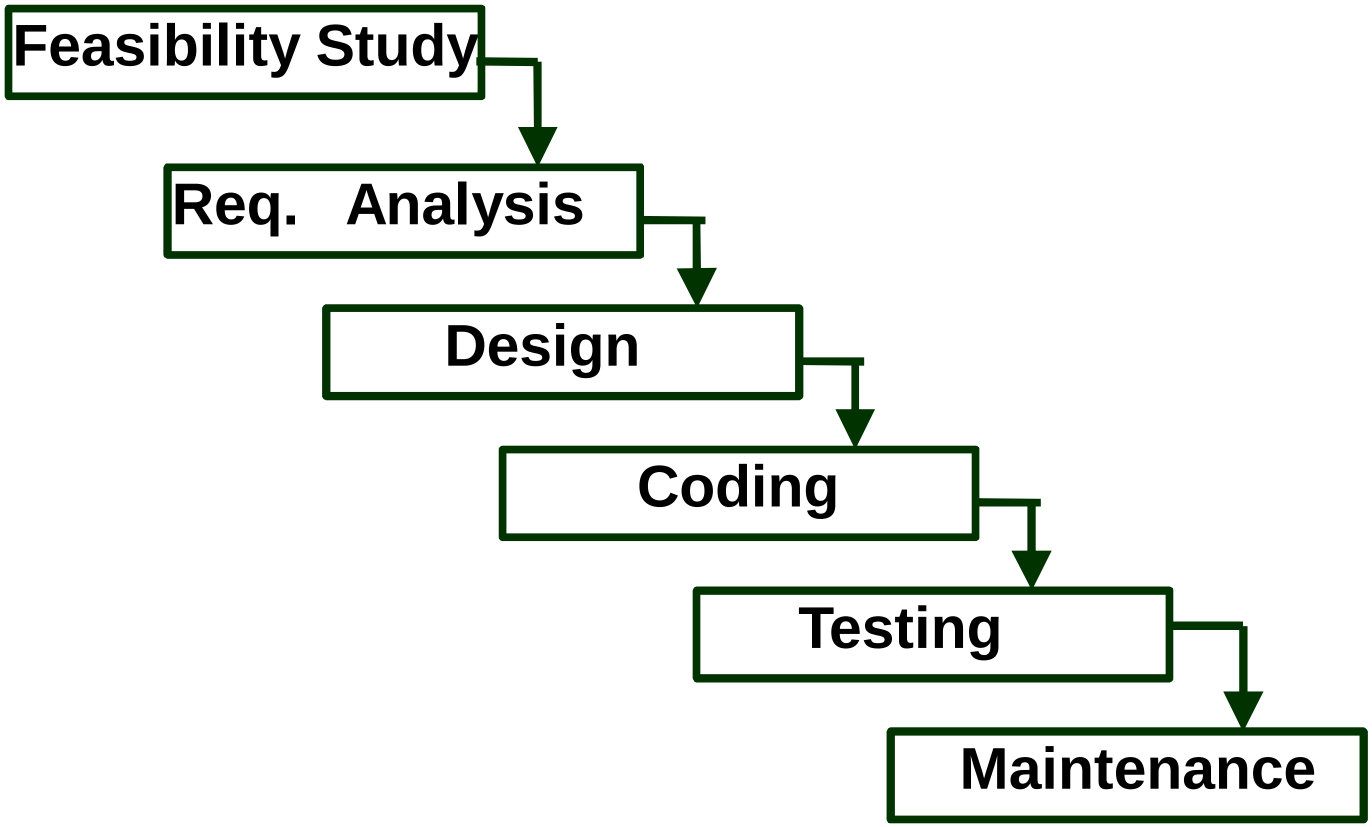
Life Cycle Models

Classical Waterfall Model

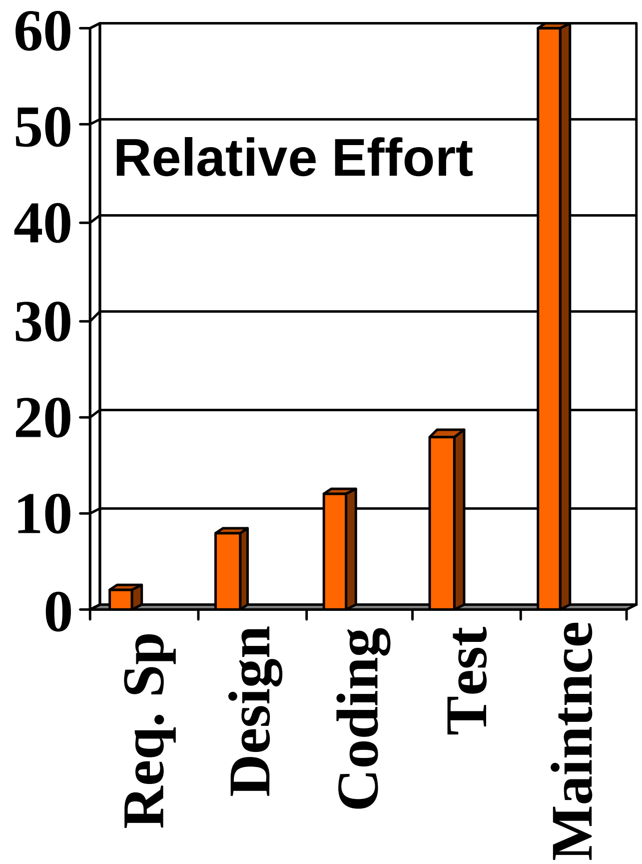
- Classical waterfall model divides life cycle into phases:
  - feasibility study,
  - requirements analysis and specification,
  - design,
  - coding and unit testing,
  - integration and system testing,
  - maintenance.

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.

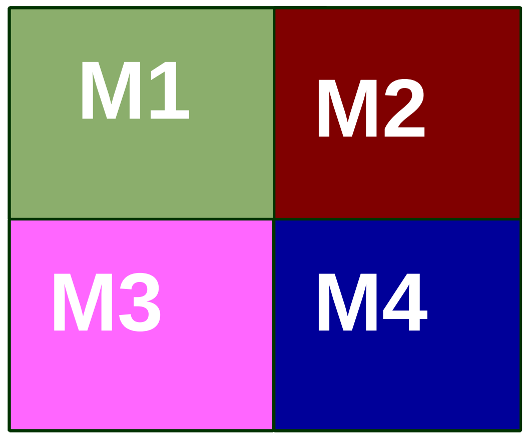
Implementation (CONT.)

- 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.

Integration and System Testing



System Testing

- After all the modules have been successfully integrated and tested:
  - system testing is carried out.
- <u>Goal of system testing:</u>
  - 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.)

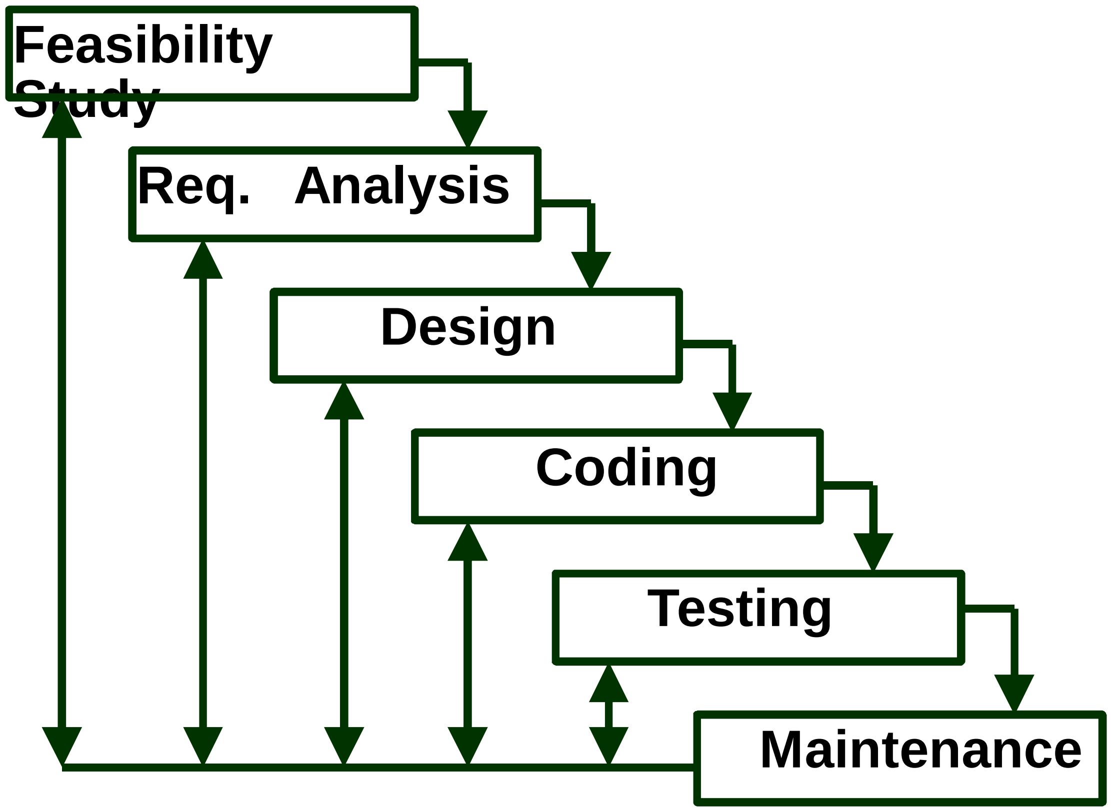
- Defects usually get detected much later in the life cycle:
  - **For example, a design defect might go unnoticed till the coding or testing phase.**

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.

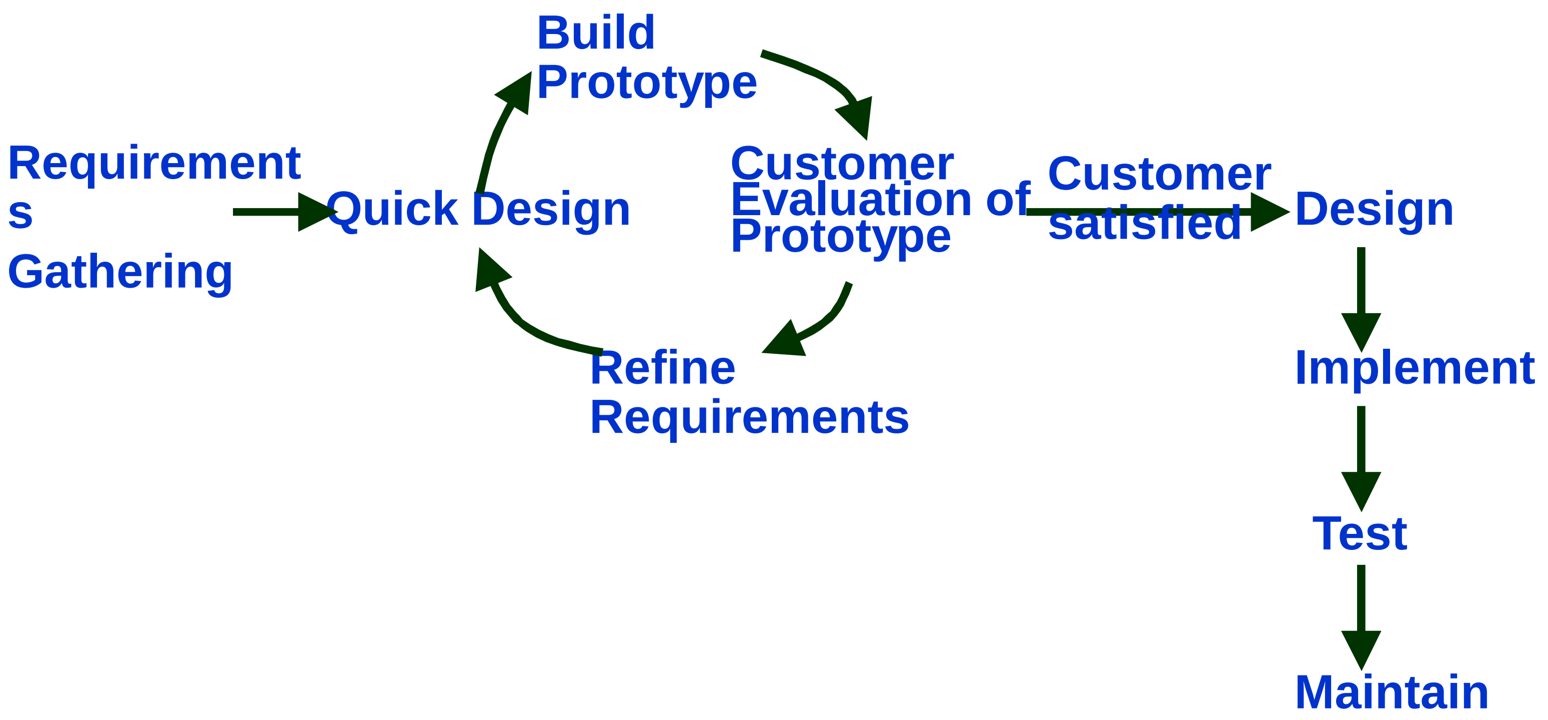
Prototyping Model (CONT.)

- 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.**

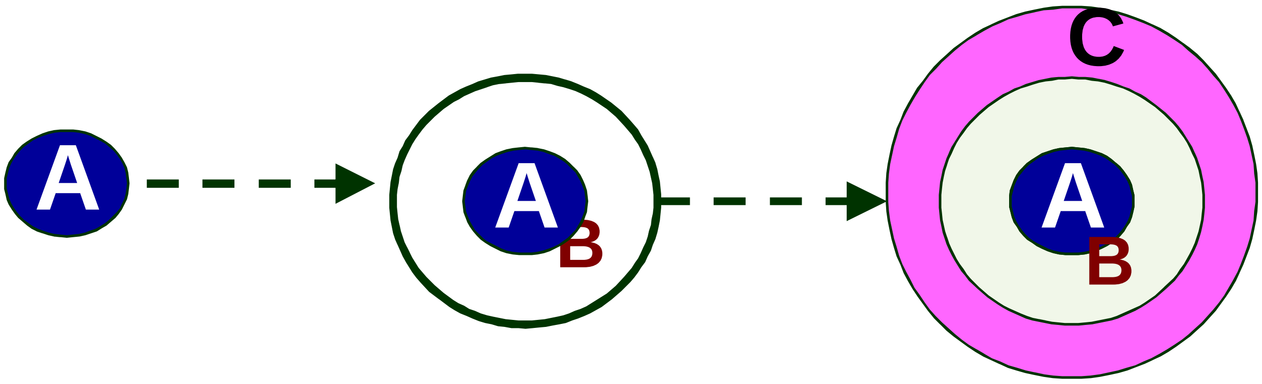
Evolutionary Model

- 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.

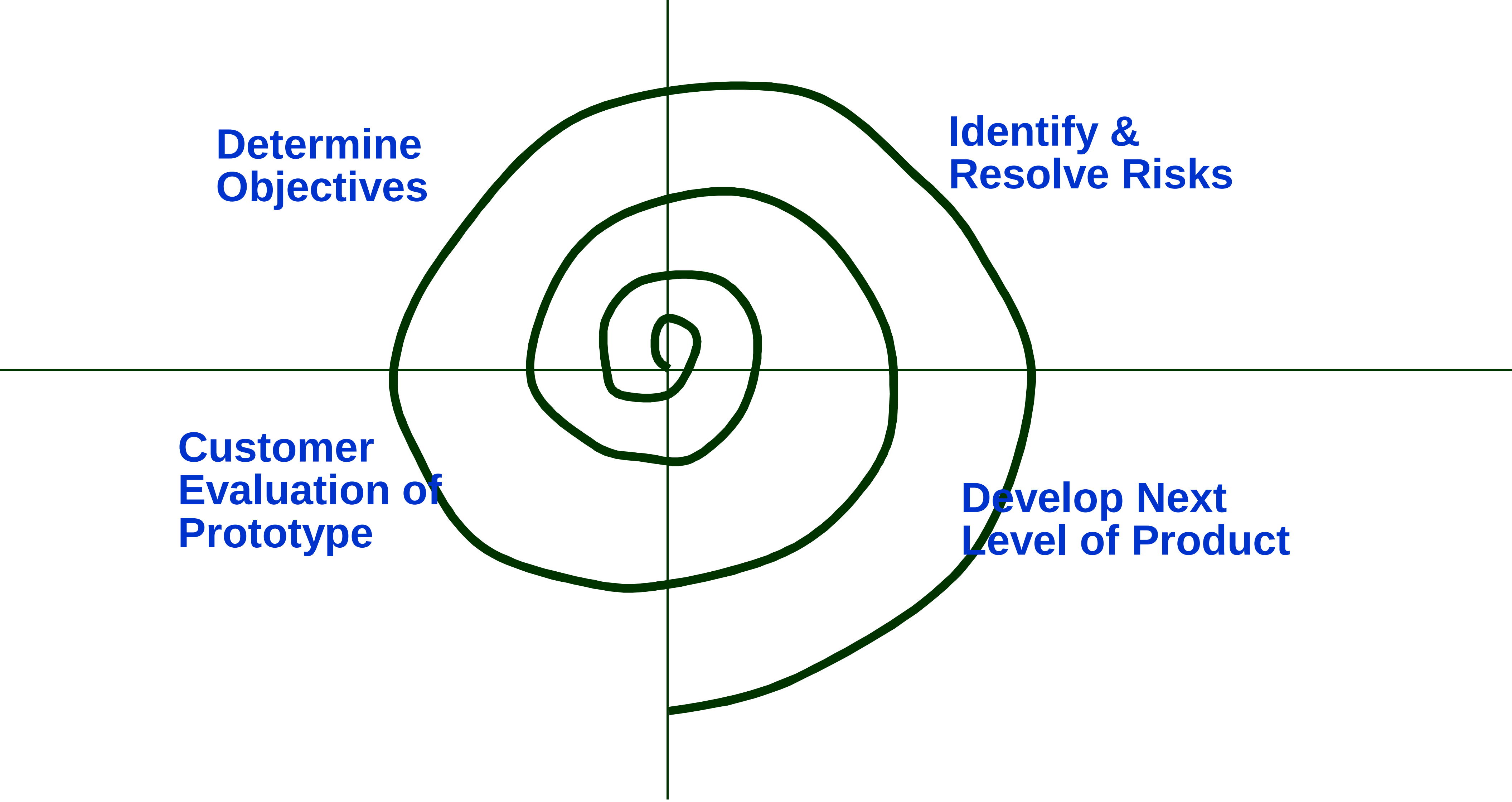
Spiral Model

- 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.)



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.**