Introduction to Software Life Cycles

CSCI 5828: Foundations of Software Engineering
Lecture 06 — 09/08/2016

Goals

- Present an introduction to the topic of software life cycles
  - concepts and terminology
  - benefits and limitations
  - examples

Background (I)

- In software engineering, "process is king"
  - That is, the process by which we do things is of utmost importance
- We want our activities to be coordinated and planned
  - that is, "engineered"
- Why?
  - **A high quality process increases our ability to create a high quality product**

Background (II)

- **process**
  - a series of steps that **people** follow involving **activities** and **resources** that produce an intended **output** of some kind
- Activities are arranged into a **workflow** with
  - **sequences of steps** (supports basic work practice)
  - **branches** (supports conditional behavior)
  - **loops** (supports iteration)
- Each **activity**
  - has a **set of inputs** and/or entry criteria
  - and may produce an output that is used in a subsequent step

Background (III)

- A process typically has a set of guiding principles about why you should follow its particular approach
  - it should be able to articulate the goals of each of its activities
- A process uses resources, subject to a set of constraints
  - two primary constraints: **schedule** (time) & **budget** (money)
- Designers of software life cycles created their particular life cycle to help software engineers achieve their goals while meeting their constraints
  - Unfortunately, few life cycles offer guidance on what to do when a limit has been reached
    - i.e. you’ve run out of time or you’ve run out of money
  - Agile is different, as we shall see

Background (IV)

- Why bother with defining and following a life cycle for software development?
  - Impose **consistency** and **structure** on the work practice of an organization
    - especially across project teams in a single organization
    - or across two or more projects performed by the same team
  - provide a vehicle for **capturing/measuring performance** to
    - improve future performance by a particular team
    - to provide evidence needed to change/improve the process
  - To answer the question: **What do I do today?**☺️

Background (V)

- Similarities and differences with manufacturing processes
  - Software life cycles are similar to manufacturing processes
    - You need to **design the process** to produce a **high quality product**
    - You need to **monitor** the process and look for ways to **improve** it
    - The process organizes the steps to ensure the product can be produced within budgetary and scheduling constraints
  - BUT
    - in manufacturing, design is “short”, production is “long” and most of your costs are tied up in production; use varies from instant to long lived
    - in software, design is “long” (and difficult), production is instantaneous (it’s trivial to create a new copy of the final system) and use can be “forever”

Typical Steps in a Software Life Cycle

- Feasibility; Development of a Business Plan
- Requirements Analysis and Specification
- Design
- Implementation and Integration
- Operation and Maintenance

- **Pervasive Concerns**
  - Testing
  - Change Management
  - Configuration Management
  - Build Management and Continuous Integration

Heads-Up

- In the following slides (10-29), I adopt a traditional perspective of SE
  - one that is consistent with the “waterfall” model of development
  - one that assumes a development context with many large stakeholders
  - one that assumes “requirements and design up front”
- We will revisit and unpack this material as we present/investigate agile life cycles more deeply
  - A lot of this material is “musty” from a modern software engineering perspective but it is important to understand the changes that Agile life cycles made to the more traditional perspective of SE

Feasibility and Business Plan

- In some (most?) development contexts
  - an idea for a new software system does NOT lead straight to requirements
  - instead, just enough of the proposed system is defined/discussed to assess
    - whether it is technically feasible to develop
    - whether there are enough resources to develop it
    - whether it will produce enough revenue to justify the costs of development
- Many proposed systems fail to get past this stage

Requirements Analysis and Specification

- **Problem Definition ⇒ Requirements Specification**
  - determine exactly what client wants and identify constraints
  - develop a contract with client
  - Specify the product's task explicitly
- **Difficulties**
  - client asks for wrong product
  - client is computer/software illiterate
  - specifications may be ambiguous, inconsistent, incomplete
- **Validation**
  - extensive reviews to check that requirements satisfy client needs
  - look for ambiguity, consistency, incompleteness
  - develop system/acceptance test plan

Design

- **Requirements Specification ⇒ Design**
  - develop architectural design (system structure)
    - decompose software into modules with module interfaces
  - develop detailed design (module specifications)
    - select algorithms and data structures
  - maintain record of design decisions
- **Difficulties**
  - miscommunication between module designers
  - design may be inconsistent, incomplete, ambiguous
- **Verification**
  - extensive design reviews (inspections) to determine that design conforms to requirements
  - check module interactions
  - develop integration test plan

Implementation and Integration

- **Design ⇒ Implementation**
  - implement modules and verify they meet their specifications
  - combine modules according to architectural design
- **Difficulties**
  - module interaction errors
  - order of integration has a critical influence on product quality
- **Verification and Testing**
  - code reviews to determine that implementation conforms to requirements and design
  - develop unit/module test plan: focus on individual module functionality
  - develop integration test plan: focus on module interfaces
  - develop system test plan: focus on requirements and determine whether product as a whole functions correctly

Operation and Maintenance

- **Operation ⇒ Change**
  - maintain software after (and during) user operation
  - determine whether product as a whole still functions correctly
- **Difficulties**
  - design not extensible
  - lack of up-to-date documentation
  - personnel turnover
- **Verification and Testing**
  - review to determine that change is made correctly and all documentation updated
  - test to determine that change is correctly implemented
  - test to determine that no inadvertent changes were made to compromise system functionality

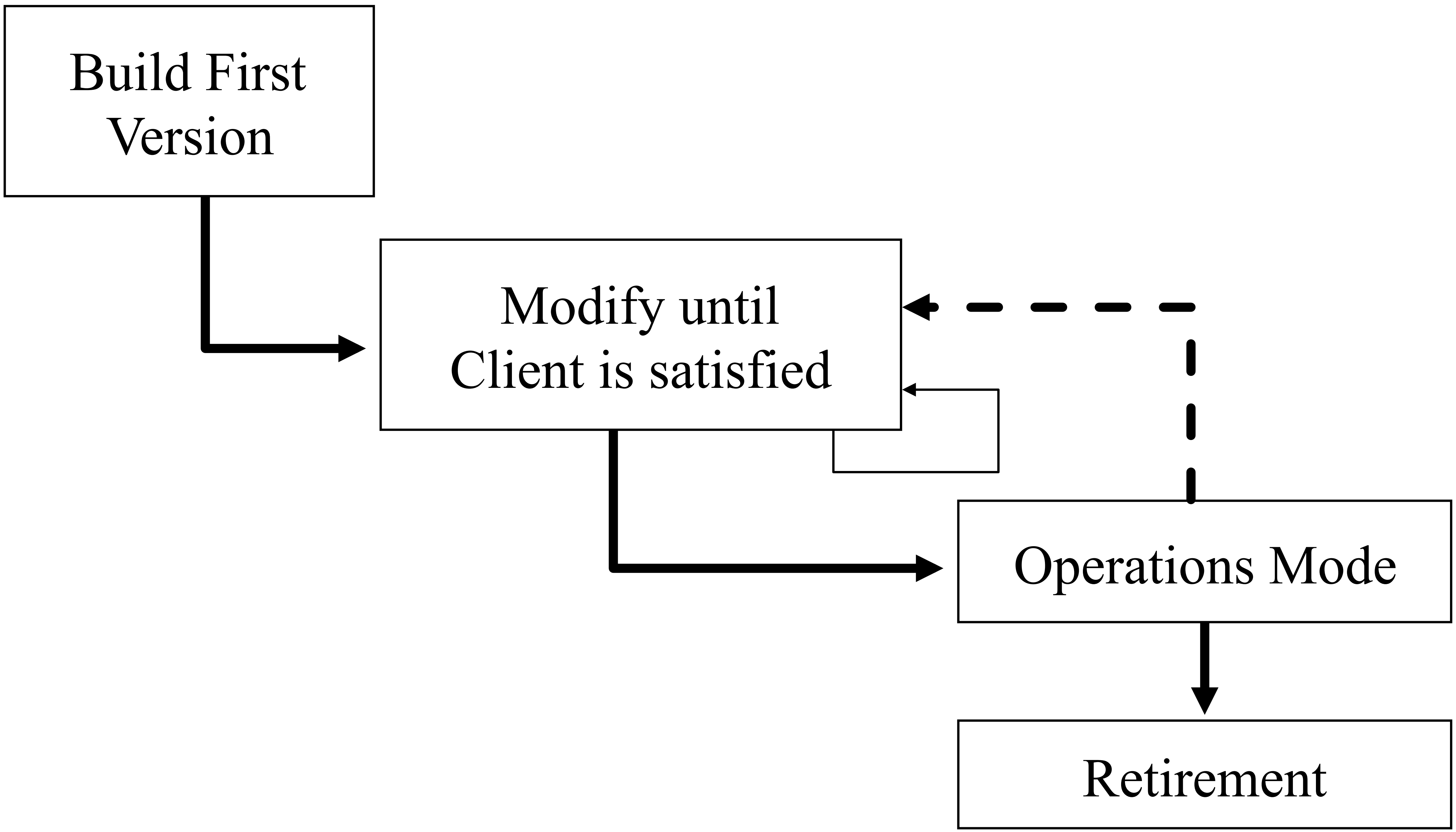
Discussion

- You will see the previous five activities appear in almost every software life cycle
- Within each of these major types of development activities, there will be
  - lots of different sub-activities
    - UI design, code reviews, refactoring, build management, configuration management, deployment, testing, profiling, debugging, etc.
    - meetings, e-mail, texting, IM, phone calls, etc. (i.e. **coordination**)
    - change requests, identification of problems, resolution of ambiguities, problem solving, etc.
  - “controlled chaos”

Example Life Cycles

- One Anti Life Cycle
  - “Code & Fix”
- Exemplars
  - Waterfall
  - Rapid Prototyping
  - Incremental
  - Spiral Model
  - Rational Unified Process

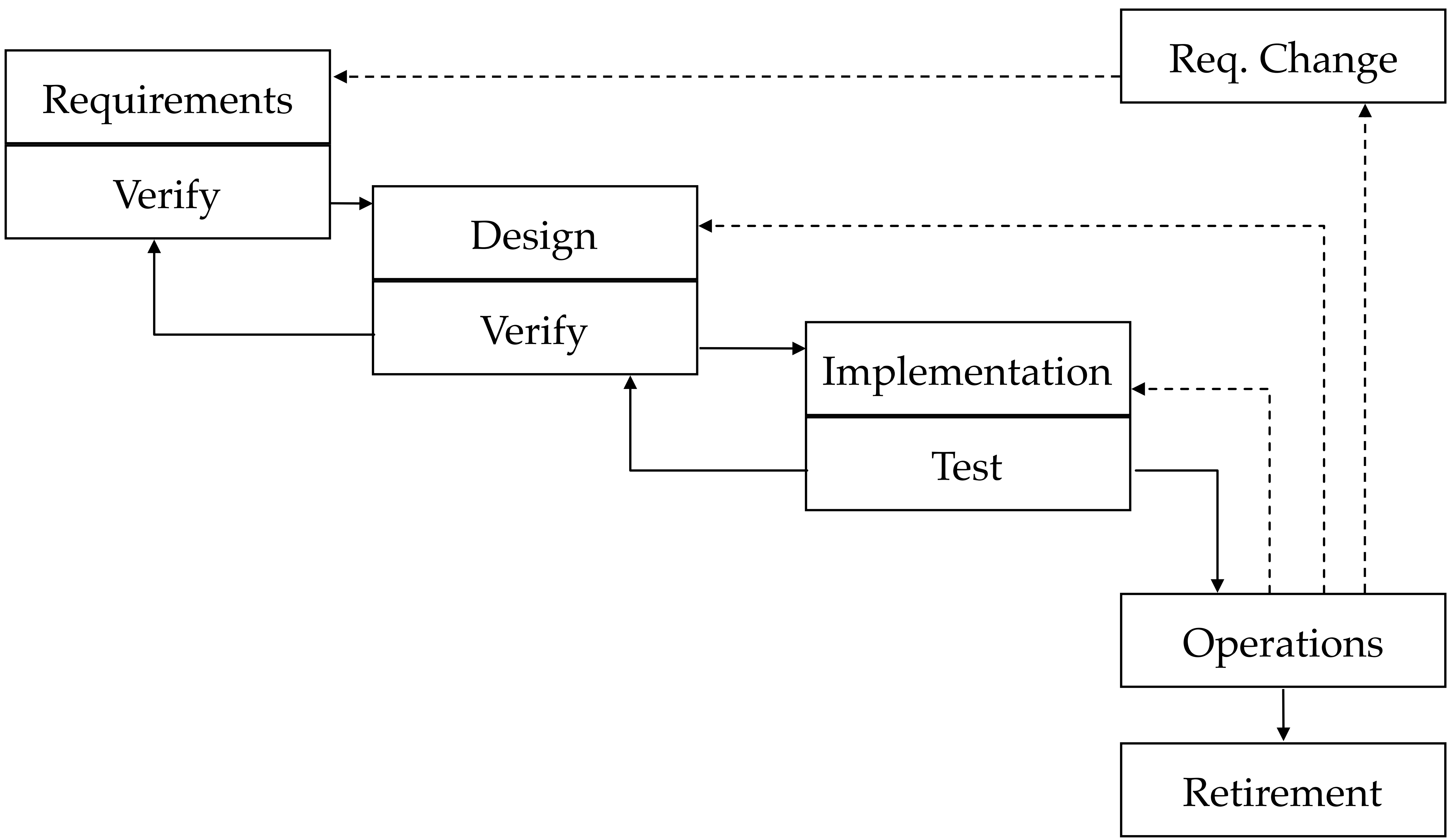
Code & Fix


Build First Version
Modify until Client is satisfied
Operations Mode
Retirement

Discussion

- Useful for small-scale, personal development
- Problems become apparent in any serious coding effort
  - No process for things like versioning, testing, change management, etc.
    - If you do any of these things, you are no longer doing “code and fix”
  - Difficult to coordinate activities of multiple programmers
  - Non-technical users cannot explain how the program should work
  - Programmers do not know or understand user needs

Waterfall


Requirements
Verify
Design
Verify
Implementation
Test
Req. Change
Operations
Retirement

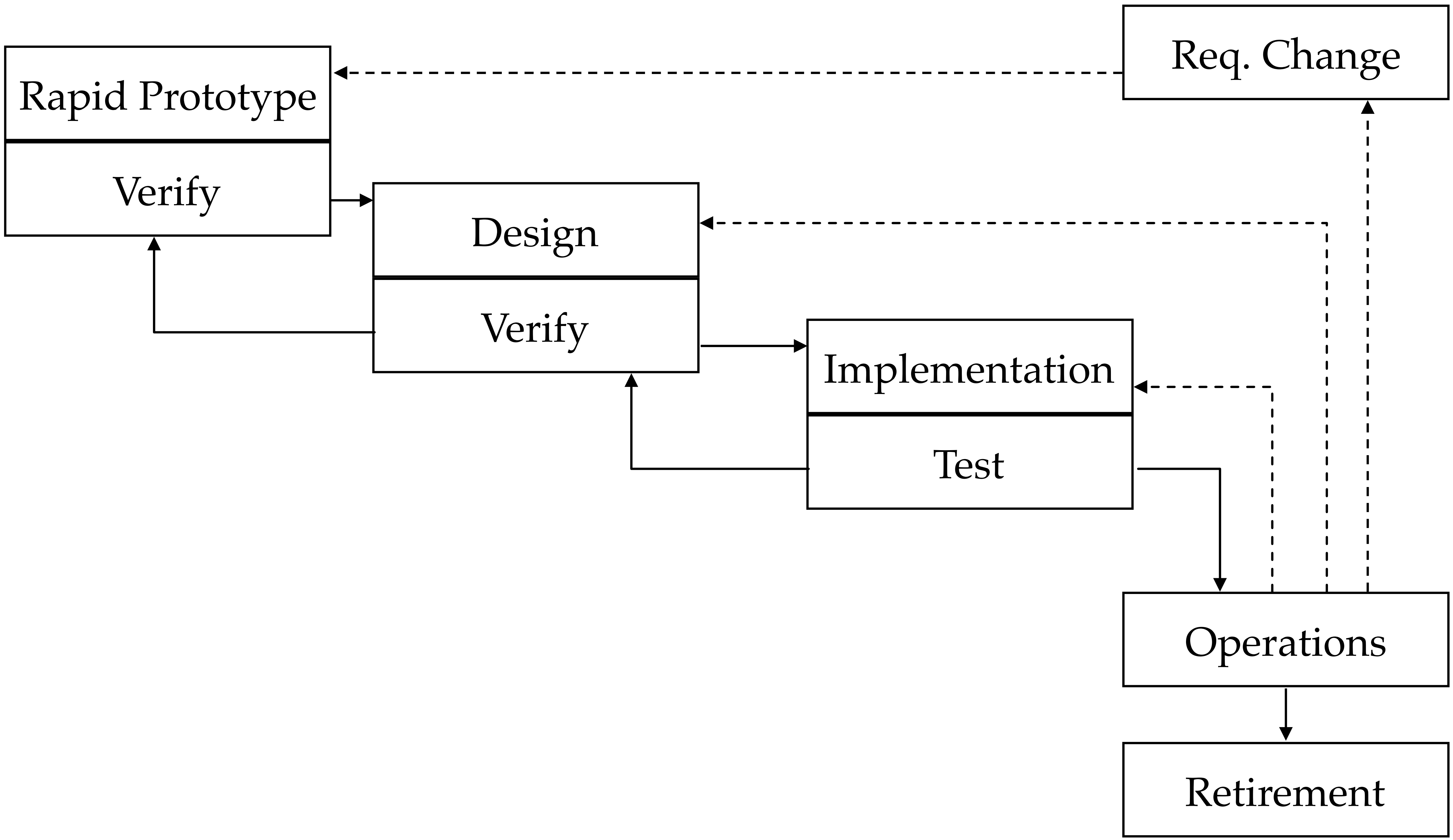
Discussion

- Proposed in early 70s by Winston Royce
  - as how **NOT** to run a software development project (!!!)
- Widely used (even today)
- Advantages
  - Straightforward to Measure
  - Possible to move between stages when the need occurs
  - Experience applying steps in past projects can be used in estimating duration of steps in future projects
  - Produces software artifacts that can be re-used in other projects

Discussion

- The original waterfall model had disadvantages because it disallowed iteration
  - This made the process inflexible and monolithic
  - Making estimates about how long the process would take was difficult
  - Did not deal well with changing requirements
  - Maintenance phase not handled well
- However, these are challenges that all life cycle models face
- The “waterfall with feedback” model was created in response
  - Slide 19 shows the “with feedback” version

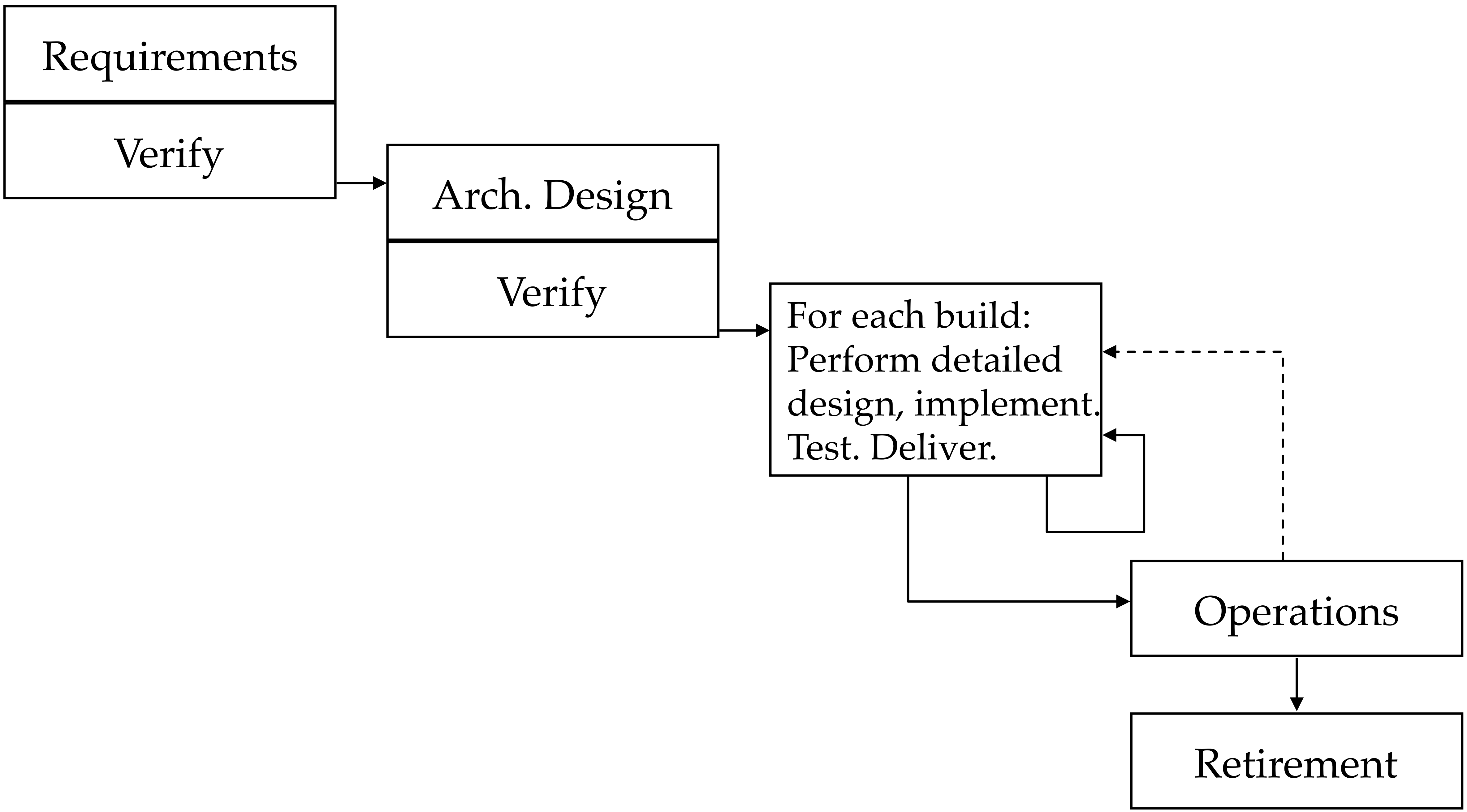
Rapid Prototyping



Discussion

- Prototypes are used to develop requirements specifications
  - Once reqs. are known, waterfall is used
- Prototypes are discarded once design begins
  - Prototypes should not be used as a basis for implementation. Prototyping tools do not create production quality code
- In addition, customer needs to be "educated" about prototypes
  - they need to know that prototypes are used just to answer requirements-related questions
  - otherwise, they get impatient!

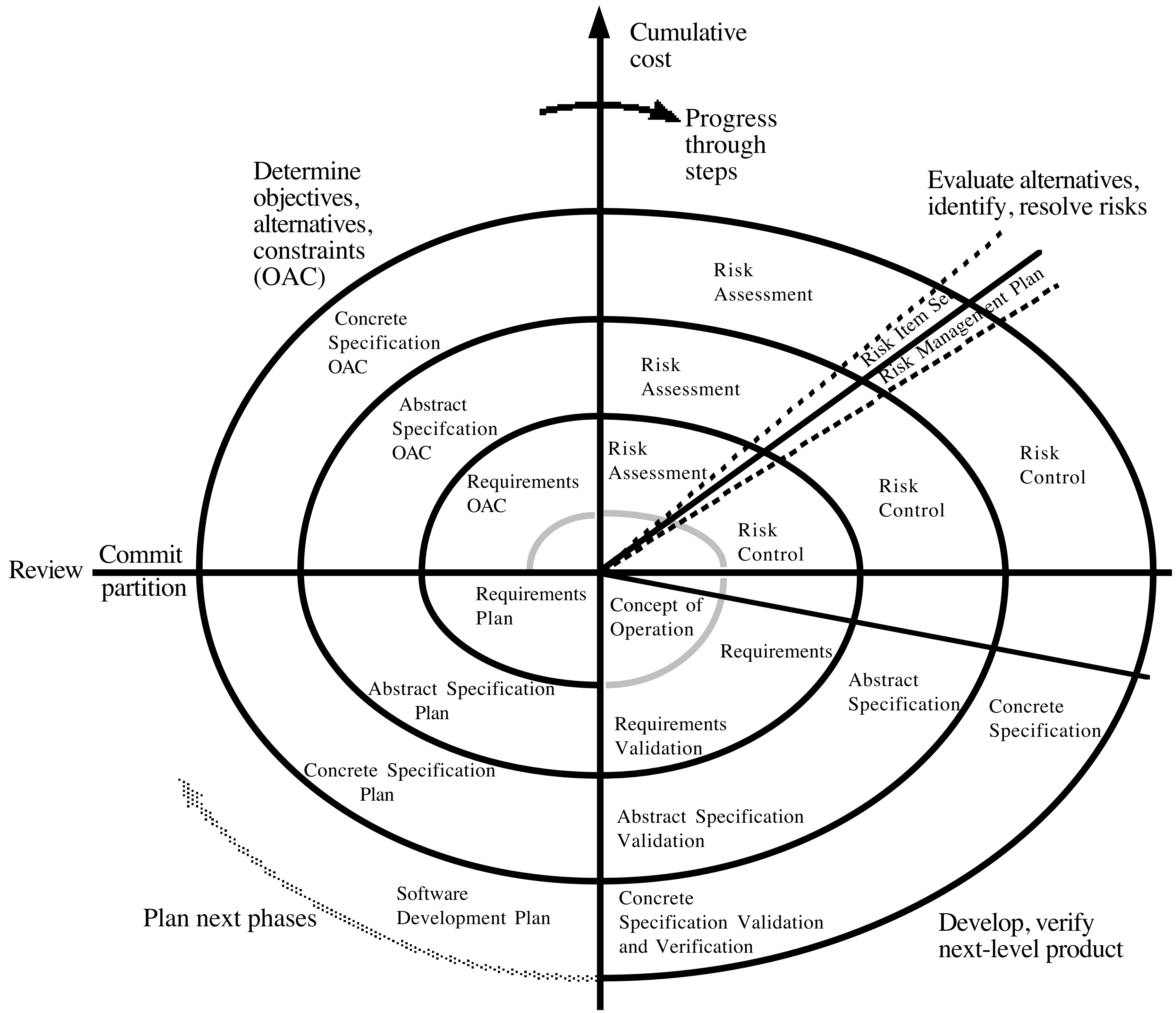
Incremental



Discussion

- Used by Microsoft (at least when building Windows XP)
  - Programs are built everyday by the build manager
    - If a programmer checks in code that "breaks the build" they become the new build manager!
- Iterations are planned according to features
  - e.g. features 1 and 2 are being worked on in iteration 1
    - features 3 and 4 are in iteration 2, etc.
- This life cycle also specifies two critical roles
  - product manager and program manager
  - Note: the original link is no longer active; fortunately I saved a copy

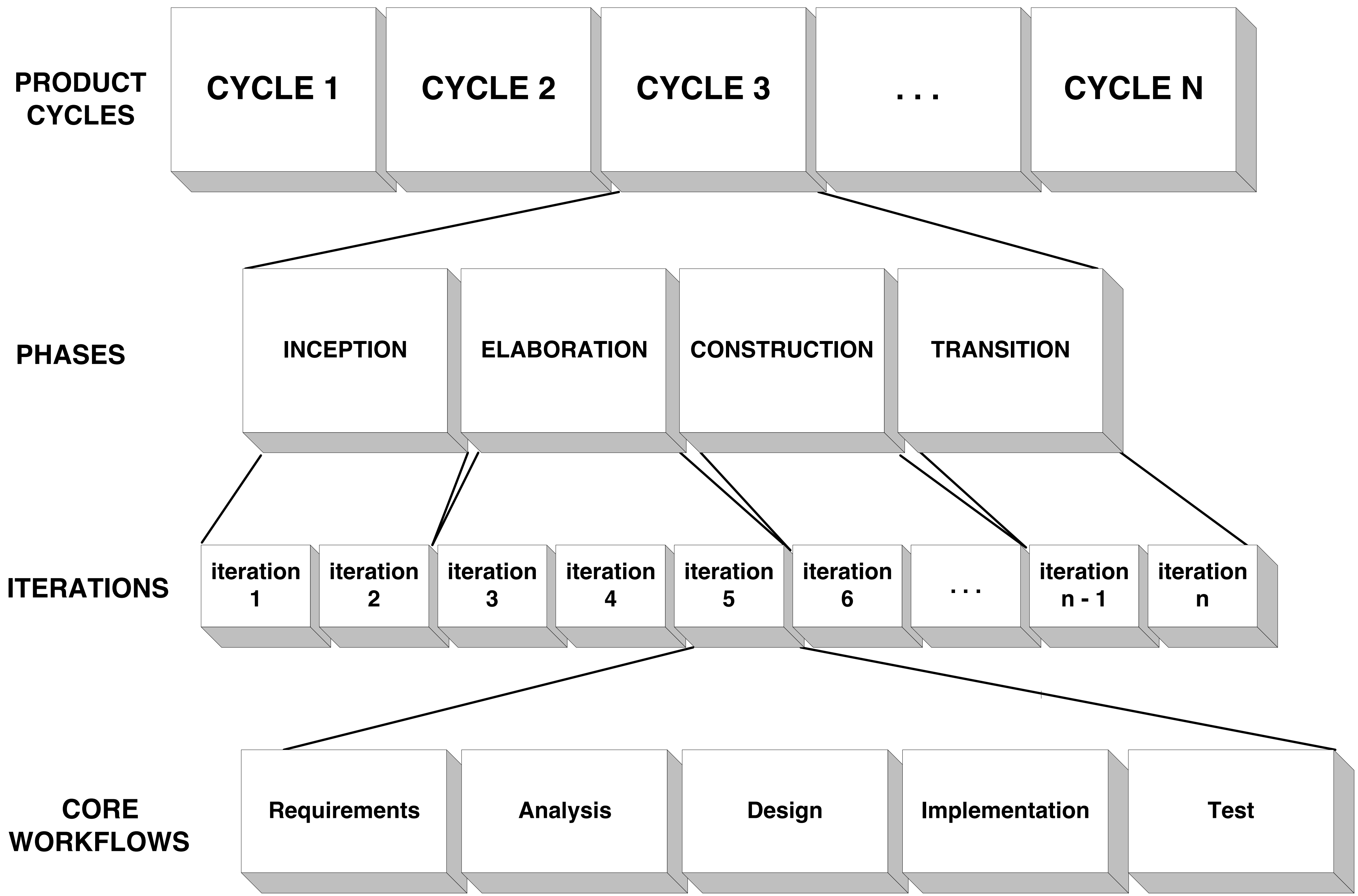
Spiral Model [Boehm, 1988]



Discussion

- Similar to Iterative Model, but:
  - each iteration is driven by “risk management”
    - Determine objectives and current status
    - Identify Risks
    - Develop plan to address highest risk items and proceed through iteration
  - Repeat

Rational Unified Process



Discussion

- A variant of the waterfall model with all of the major steps
  - It advocates the use of object-oriented analysis and design techniques throughout
- Our "big three" concepts from Lecture 1 writ large
  - Specification: objects and classes used in all phases
  - Translation: objects and classes go from high level specs to extremely detailed specs that can be translated directly to code
    - some OO A&D tools will generate source code based on UML designs
  - Iteration: Product Cycles ⇒ Phase ⇒ Iterations ⇒ Major Life Cycle Steps
- A step towards agile in that the activities are "fractal"
  - You may find yourself performing implementation and testing during project inception

Summary

- Life cycles make software development
  - predictable, repeatable, measurable, and efficient
- High-quality processes should lead to high-quality products
  - at least it improves the odds of producing good software
- We've seen
  - Typical stages in software life cycles
  - Examples of traditional software life cycles

Coming Up Next

- Lecture 7: Introduction to Agile Life Cycles