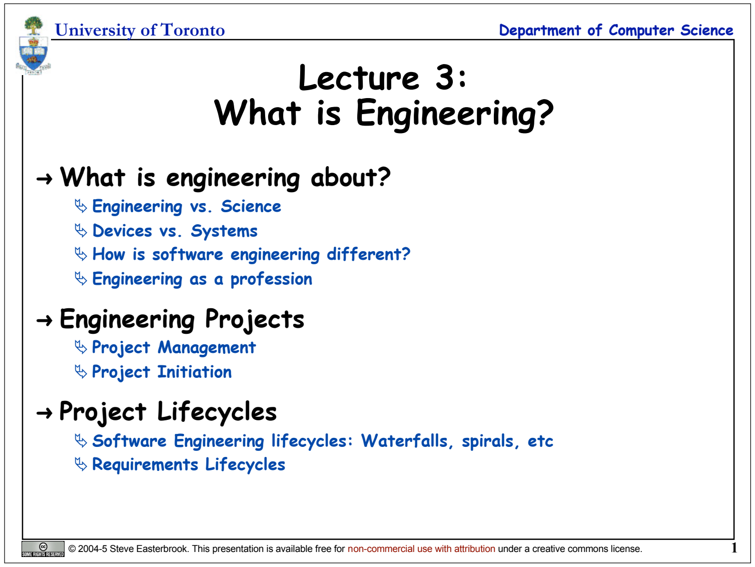
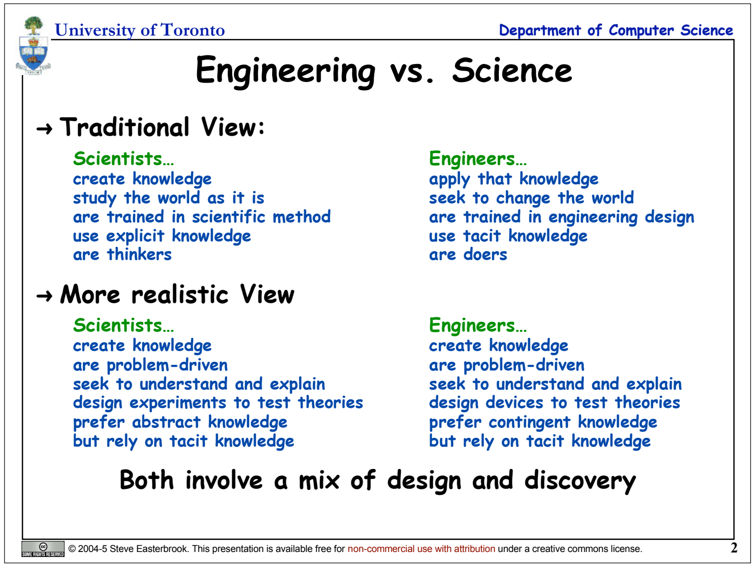


Lecture 3: What is Engineering?

- **What is engineering about?**
  - Engineering vs. Science
  - Devices vs. Systems
  - How is software engineering different?
  - Engineering as a profession
- **Engineering Projects**
  - Project Management
  - Project Initiation
- **Project Lifecycles**
  - Software Engineering lifecycles: Waterfalls, spirals, etc
  - Requirements Lifecycles



Engineering vs. Science

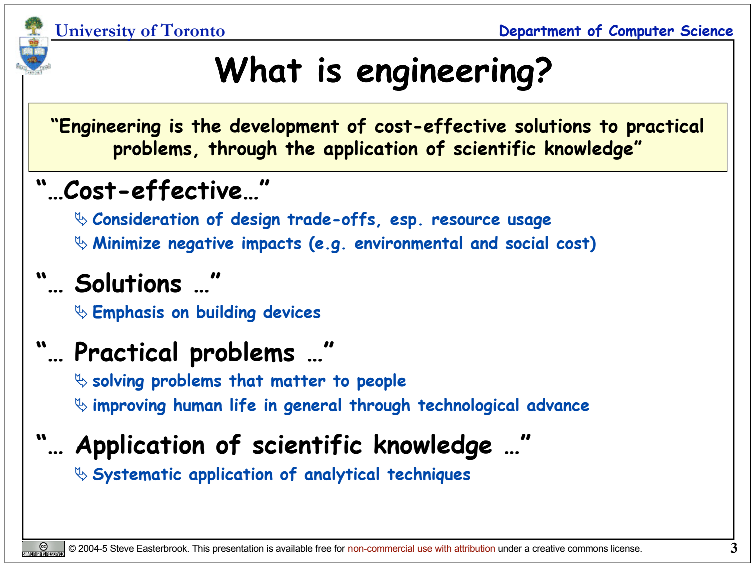
Traditional View:

Scientists…	Engineers…
create knowledge	apply that knowledge
study the world as it is	seek to change the world
are trained in scientific method	are trained in engineering design
use explicit knowledge	use tacit knowledge
are thinkers	are doers

More realistic View

Scientists…	Engineers…
create knowledge	create knowledge
are problem-driven	are problem-driven
seek to understand and explain	seek to understand and explain
design experiments to test theories	design devices to test theories
prefer abstract knowledge	prefer contingent knowledge
but rely on tacit knowledge	but rely on tacit knowledge

Both involve a mix of design and discovery



What is engineering?

> "Engineering is the development of cost-effective solutions to practical problems, through the application of scientific knowledge"

"…Cost-effective…"

- Consideration of design trade-offs, esp. resource usage
- Minimize negative impacts (e.g. environmental and social cost)

"… Solutions …"

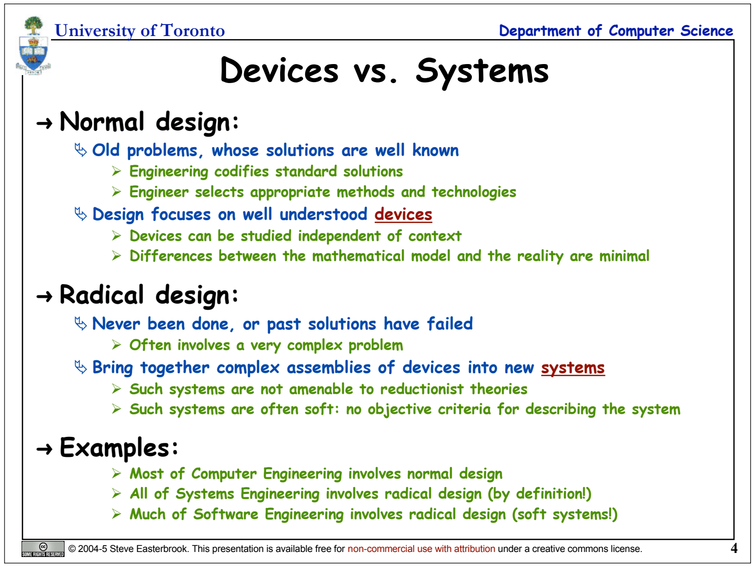
- Emphasis on building devices

"… Practical problems …"

- solving problems that matter to people
- improving human life in general through technological advance

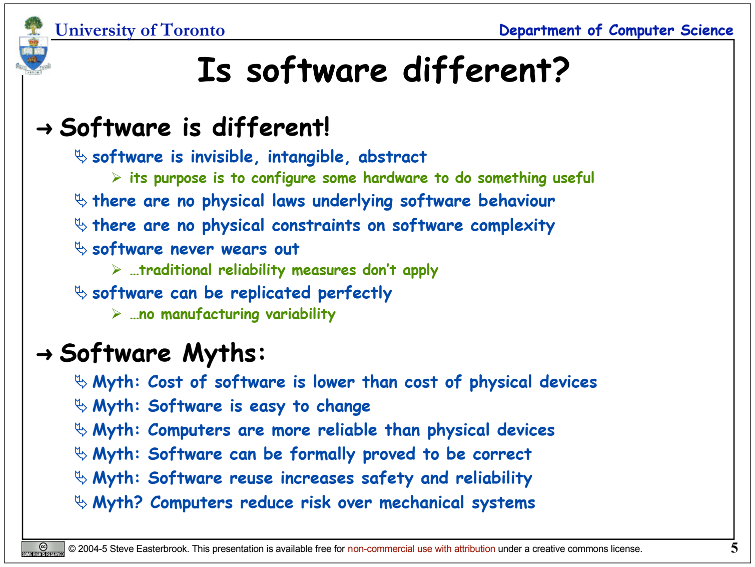
"… Application of scientific knowledge …"

- Systematic application of analytical techniques



Devices vs. Systems

- **Normal design:**
  - Old problems, whose solutions are well known
    - Engineering codifies standard solutions
    - Engineer selects appropriate methods and technologies
  - Design focuses on well understood devices
    - Devices can be studied independent of context
    - Differences between the mathematical model and the reality are minimal
- **Radical design:**
  - Never been done, or past solutions have failed
    - Often involves a very complex problem
  - Bring together complex assemblies of devices into new systems
    - Such systems are not amenable to reductionist theories
    - Such systems are often soft: no objective criteria for describing the system
- **Examples:**
    - Most of Computer Engineering involves normal design
    - All of Systems Engineering involves radical design (by definition!)
    - Much of Software Engineering involves radical design (soft systems!)



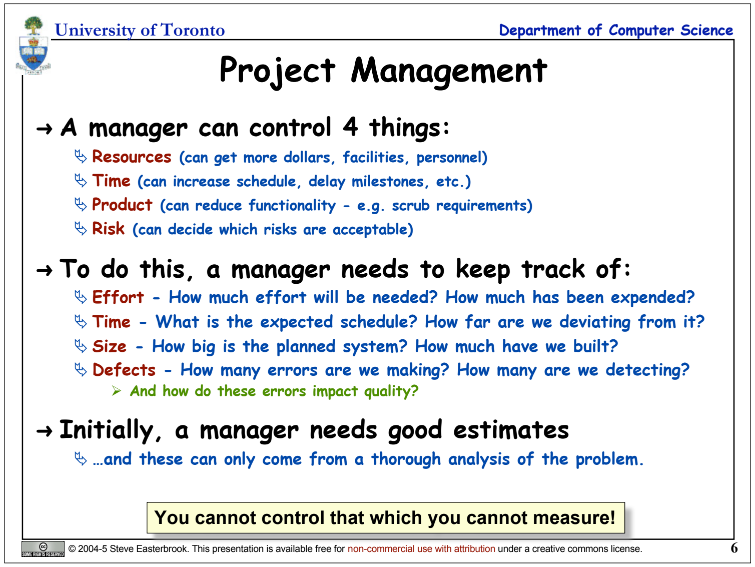
Is software different?

Software is different!

- software is invisible, intangible, abstract
  - its purpose is to configure some hardware to do something useful
- there are no physical laws underlying software behaviour
- there are no physical constraints on software complexity
- software never wears out
  - …traditional reliability measures don't apply
- software can be replicated perfectly
  - …no manufacturing variability

Software Myths:

- Myth: Cost of software is lower than cost of physical devices
- Myth: Software is easy to change
- Myth: Computers are more reliable than physical devices
- Myth: Software can be formally proved to be correct
- Myth: Software reuse increases safety and reliability
- Myth? Computers reduce risk over mechanical systems



Project Management

A manager can control 4 things:

- Resources (can get more dollars, facilities, personnel)
- Time (can increase schedule, delay milestones, etc.)
- Product (can reduce functionality - e.g. scrub requirements)
- Risk (can decide which risks are acceptable)

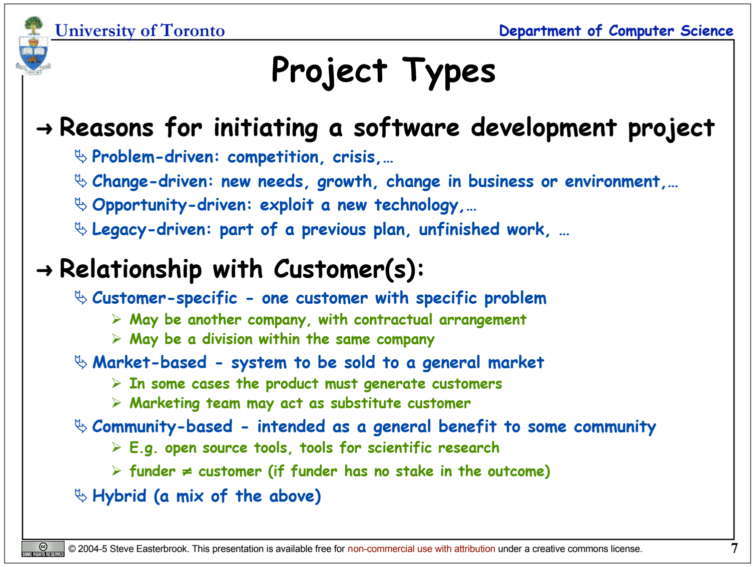
To do this, a manager needs to keep track of:

- Effort - How much effort will be needed? How much has been expended?
- Time - What is the expected schedule? How far are we deviating from it?
- Size - How big is the planned system? How much have we built?
- Defects - How many errors are we making? How many are we detecting?
  - And how do these errors impact quality?

Initially, a manager needs good estimates

- …and these can only come from a thorough analysis of the problem.

You cannot control that which you cannot measure!



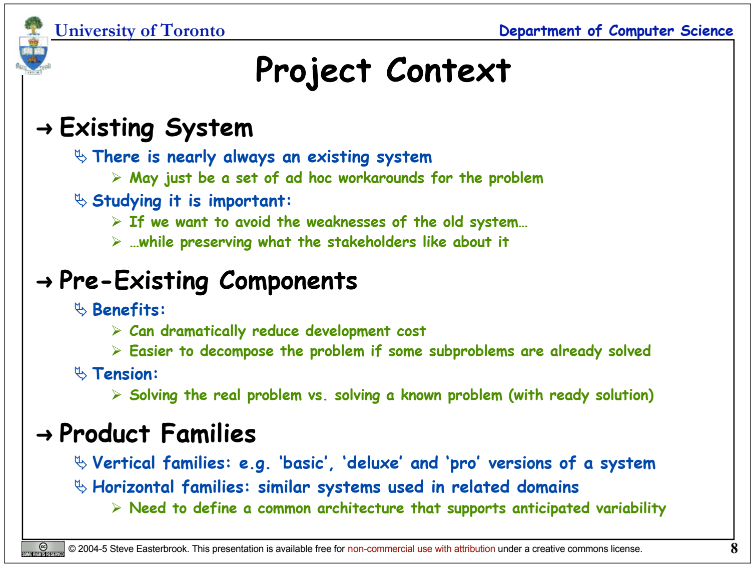
Project Types

Reasons for initiating a software development project

- Problem-driven: competition, crisis,…
- Change-driven: new needs, growth, change in business or environment,…
- Opportunity-driven: exploit a new technology,…
- Legacy-driven: part of a previous plan, unfinished work, …

Relationship with Customer(s):

- Customer-specific - one customer with specific problem
  - May be another company, with contractual arrangement
  - May be a division within the same company
- Market-based - system to be sold to a general market
  - In some cases the product must generate customers
  - Marketing team may act as substitute customer
- Community-based - intended as a general benefit to some community
  - E.g. open source tools, tools for scientific research
  - funder ≠ customer (if funder has no stake in the outcome)
- Hybrid (a mix of the above)



Project Context

Existing System

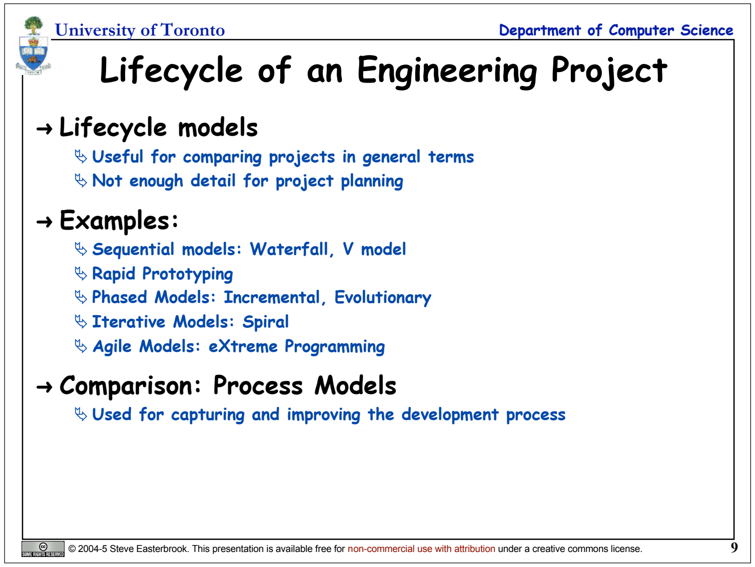
- There is nearly always an existing system
  - May just be a set of ad hoc workarounds for the problem
- Studying it is important:
  - If we want to avoid the weaknesses of the old system…
  - …while preserving what the stakeholders like about it

Pre-Existing Components

- Benefits:
  - Can dramatically reduce development cost
  - Easier to decompose the problem if some subproblems are already solved
- Tension:
  - Solving the real problem vs. solving a known problem (with ready solution)

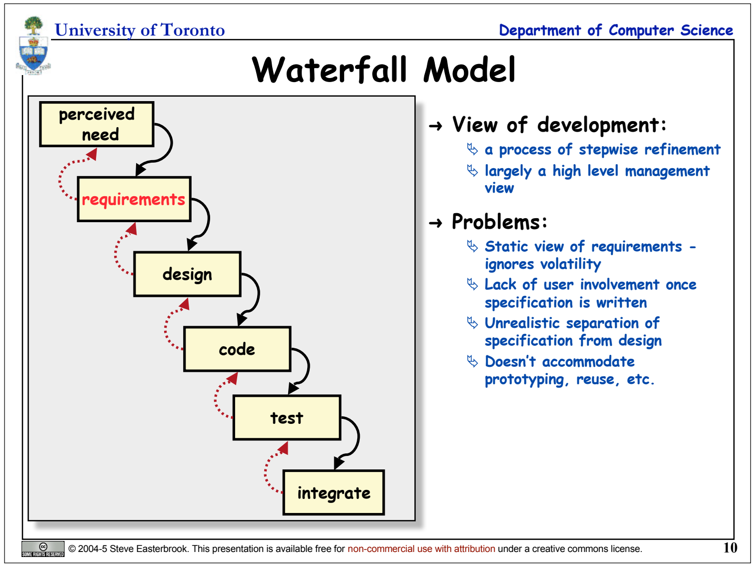
Product Families

- Vertical families: e.g. 'basic', 'deluxe' and 'pro' versions of a system
- Horizontal families: similar systems used in related domains
  - Need to define a common architecture that supports anticipated variability



Lifecycle of an Engineering Project

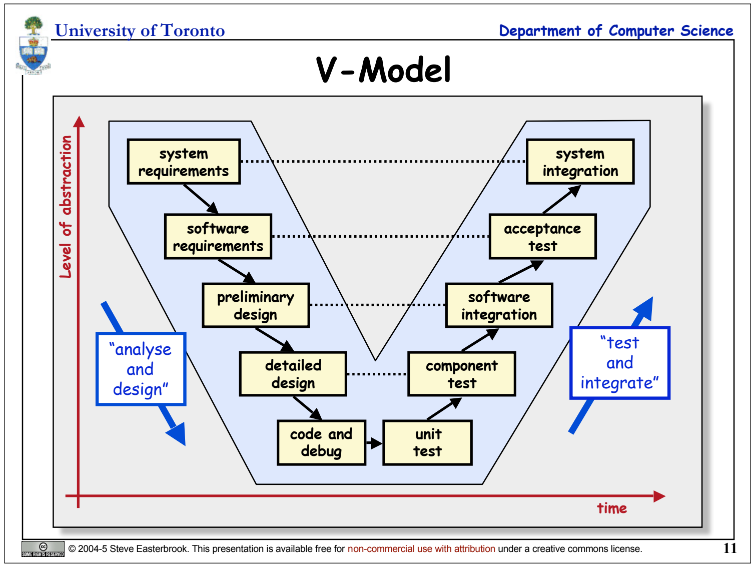
- **Lifecycle models**
  - Useful for comparing projects in general terms
  - Not enough detail for project planning
- **Examples:**
  - Sequential models: Waterfall, V model
  - Rapid Prototyping
  - Phased Models: Incremental, Evolutionary
  - Iterative Models: Spiral
  - Agile Models: eXtreme Programming
- **Comparison: Process Models**
  - Used for capturing and improving the development process



Waterfall Model

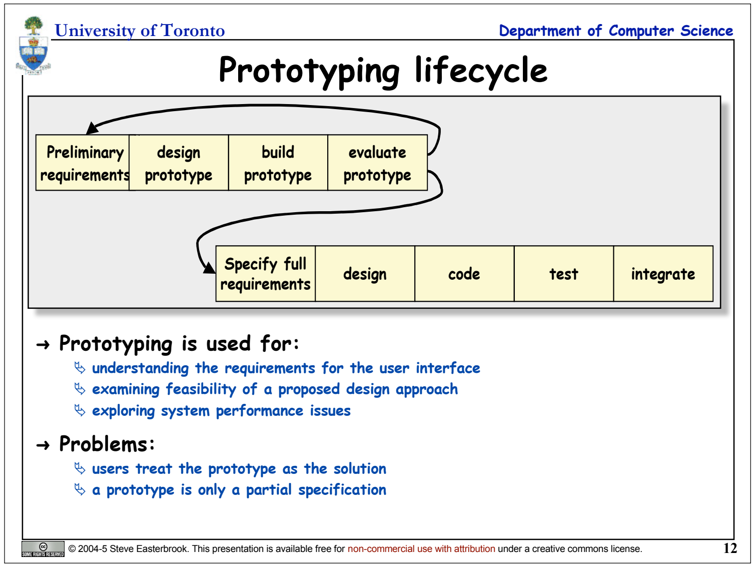
perceived need
requirements
design
code
test
integrate

- **View of development:**
  - a process of stepwise refinement
  - largely a high level management view
- **Problems:**
  - Static view of requirements - ignores volatility
  - Lack of user involvement once specification is written
  - Unrealistic separation of specification from design
  - Doesn't accommodate prototyping, reuse, etc.



V-Model

Level of abstraction
system requirements
software requirements
preliminary design
detailed design
code and debug
unit test
component test
software integration
acceptance test
system integration
"analyse and design"
"test and integrate"
time



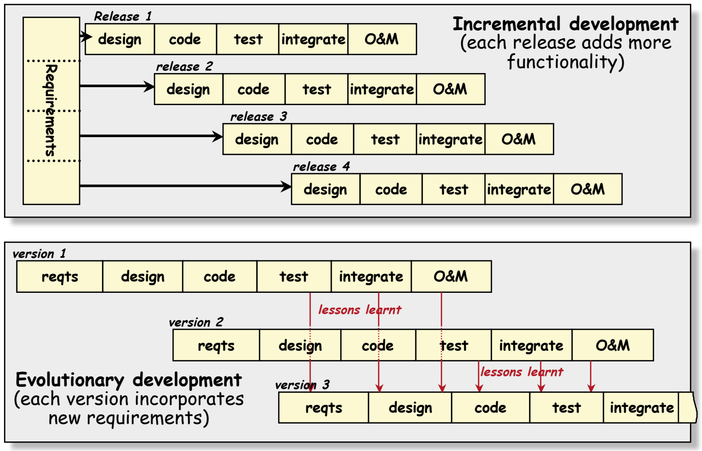
Prototyping lifecycle

Preliminary requirements
design prototype
build prototype
evaluate prototype
Specify full requirements
design
code
test
integrate

- **Prototyping is used for:**
  - understanding the requirements for the user interface
  - examining feasibility of a proposed design approach
  - exploring system performance issues
- **Problems:**
  - users treat the prototype as the solution
  - a prototype is only a partial specification

Source: Adapted from Dorfman, 1997, p10

Phased Lifecycle Models

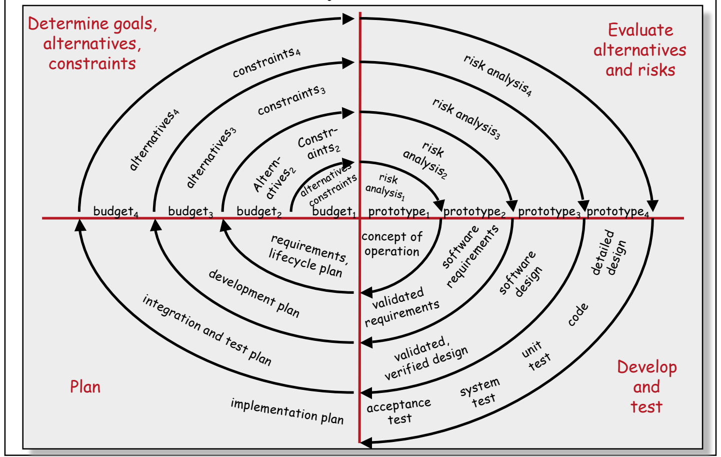


Incremental development
(each release adds more functionality)

Evolutionary development
(each version incorporates new requirements)

Source: Adapted from Pfleeger, 1998, p57

The Spiral Model



Agile Models

Source: Adapted from Nawrocki et al, RE'02

→ **Basic Philosophy**

- Reduce communication barriers
  - Programmer interacts with customer
- Reduce document-heavy approach
  - Documentation is expensive and of limited use
- Have faith in the people
  - Don't need fancy process models to tell them what to do!
- Respond to the customer
  - Rather than focusing on the contract

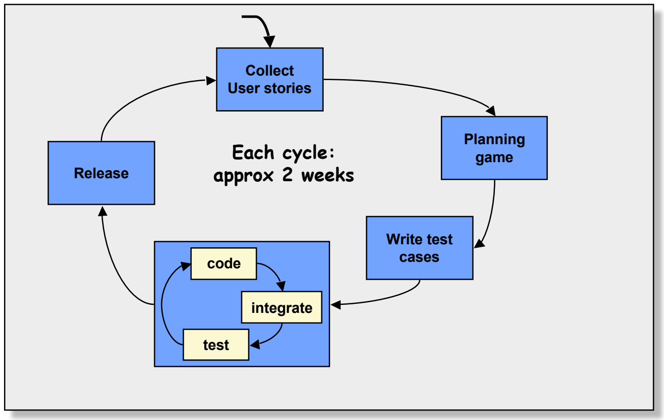
→ **Weaknesses**

- Relies on programmer's memory
  - Code can be hard to maintain
- Relies on oral communication
  - Mis-interpretation possible
- Assumes single customer representative
  - Multiple viewpoints not possible
- Only short term planning
  - No longer term vision

E.g. Extreme Programming

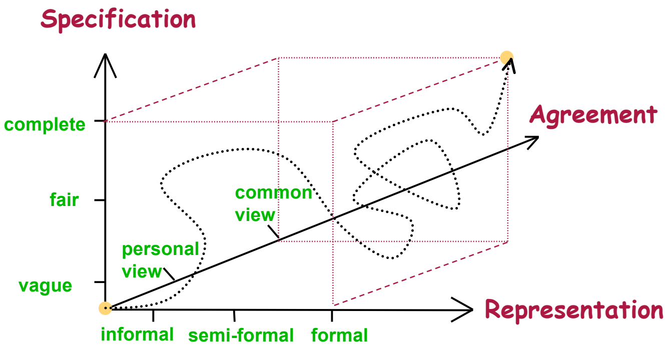
- Instead of a requirements spec, use:
  - User story cards
  - On-site customer representative
- Pair Programming
- Small releases
  - E.g. every three weeks
- Planning game
  - Select and estimate user story cards at the beginning of each release
- Write test cases before code
- The program code is the design doc
  - Can also use CRC cards (Class-Responsibility-Collaboration)
- Continuous Integration
  - Integrate and test several times a day

Extreme Programming

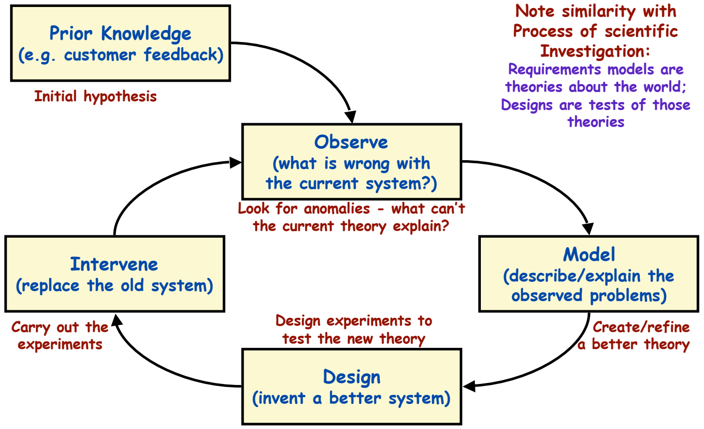


Is there a "Requirements Lifecycle"

Source: Adapted from Pohl, CAISE 1993



Inquiry Cycle


Prior Knowledge
(e.g. customer feedback)
Initial hypothesis
Observe
(what is wrong with the current system?)
Look for anomalies - what can't the current theory explain?
Model
(describe/explain the observed problems)
Create/refine a better theory
Design
(invent a better system)
Design experiments to test the new theory
Intervene
(replace the old system)
Carry out the experiments

Note similarity with Process of scientific Investigation:
Requirements models are theories about the world;
Designs are tests of those theories

Summary

- → What is engineering?
  - ✎ Not that different from science
  - ✎ Greater awareness of professional responsibility
    - ➢ because of immediate scope for harm to the public
  - ✎ Systems and Software Engineering involve radical design
- → Engineering Projects
  - ✎ You cannot control that which you cannot measure
    - ➢ …and many important measures are derived from initial problem analysis
  - ✎ Constraints:
    - ➢ Is there a customer?
    - ➢ Existing system / existing components / existing product family
- → Project Lifecycles
  - ✎ Useful for comparing projects in general terms
  - ✎ Represent different philosophies in software development
  - ✎ Requirements evolve through their own lifecycles too!