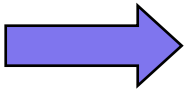
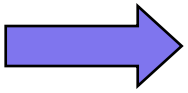
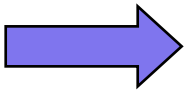
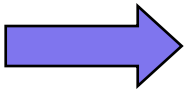
Software Development Life-Cycle Models

Four Essential Phases of any Software Development Process

- **Requirements** Elicitation, Analysis, Specification
- System **Design**
- Program **Implementation**
- **Test**

Each Phase has an "Output"

Phase	Output
Requirements analysis	Software Requirements Specification (SRS), Use Cases
Design	Design Document, Design Classes
Implementation	Code
Test	Test Report, Change Requests

Models

- Different projects may interpret these phases differently.
- Each particular style is called a

  "Software Life-Cycle Model"

"Life-Cycle" Models

- Single-Version Models
- Incremental Models
  - Single-Version with Prototyping
- Iterative Models
- "Continuous" Models

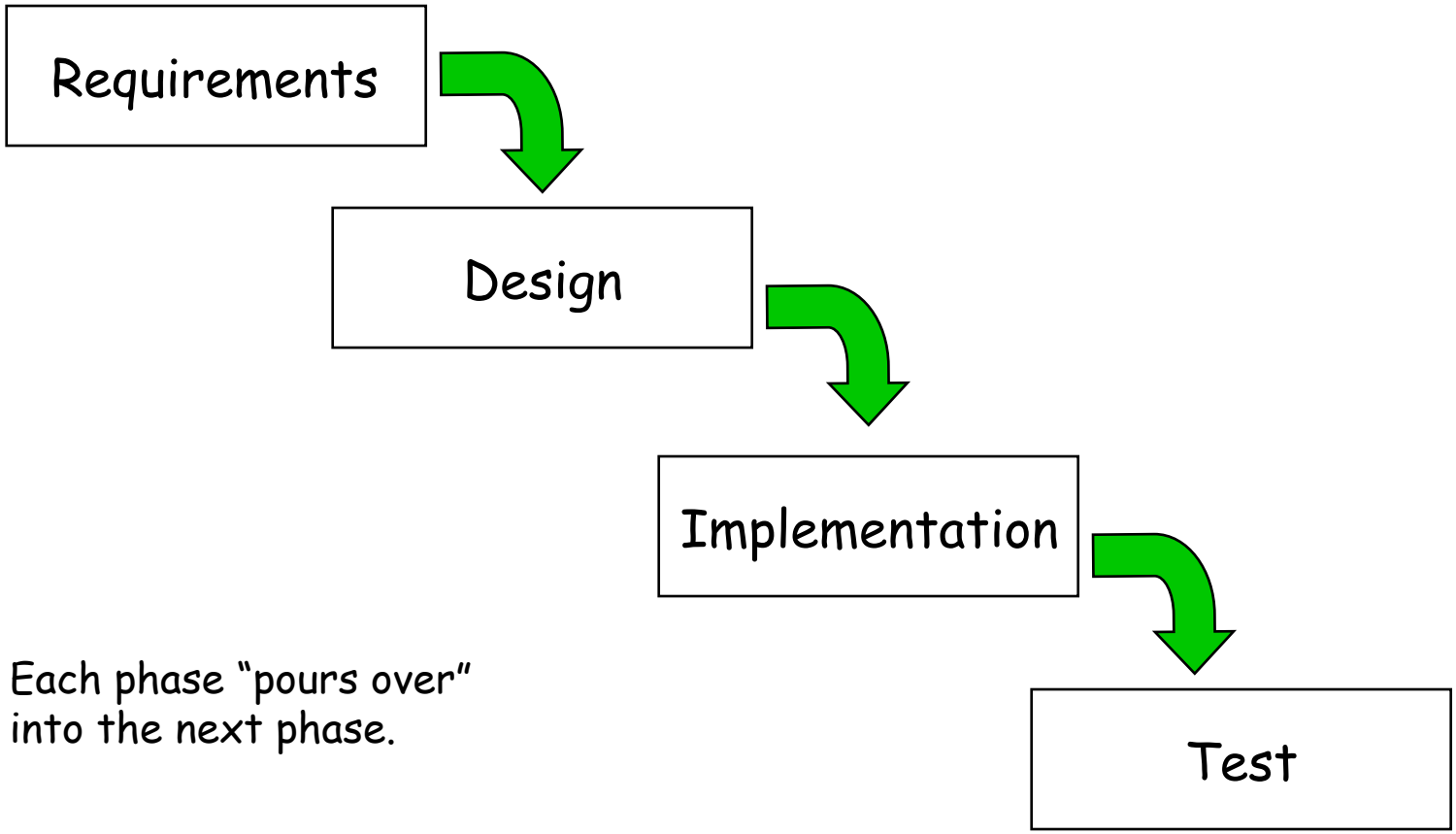
"Life-Cycle" Models (1)

- Single-Version Models
  - Big-Bang Model
  - Waterfall Model
    - Waterfall Model with "back flow"
  - "V" model: Integrating testing

Big-Bang Model

- Developer receives problem statement.
- Developer works in isolation for some extended time period.
- Developer delivers result.
- Developer *hopes* client is satisfied.
- [The "big bang" may be when the client explodes at the developer.]

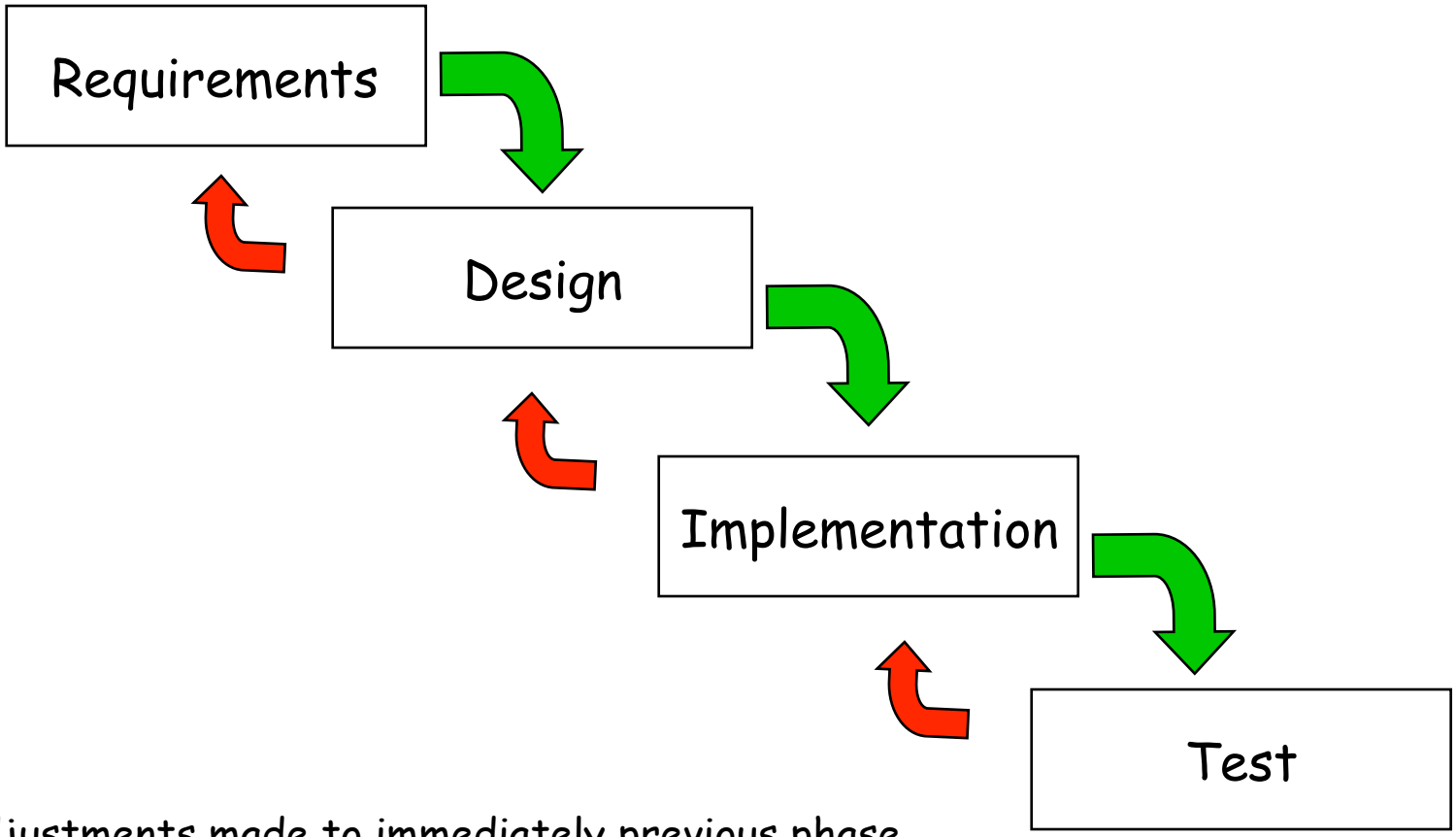
Waterfall Model



Each phase "pours over"
into the next phase.

Waterfall Model with Back Flow

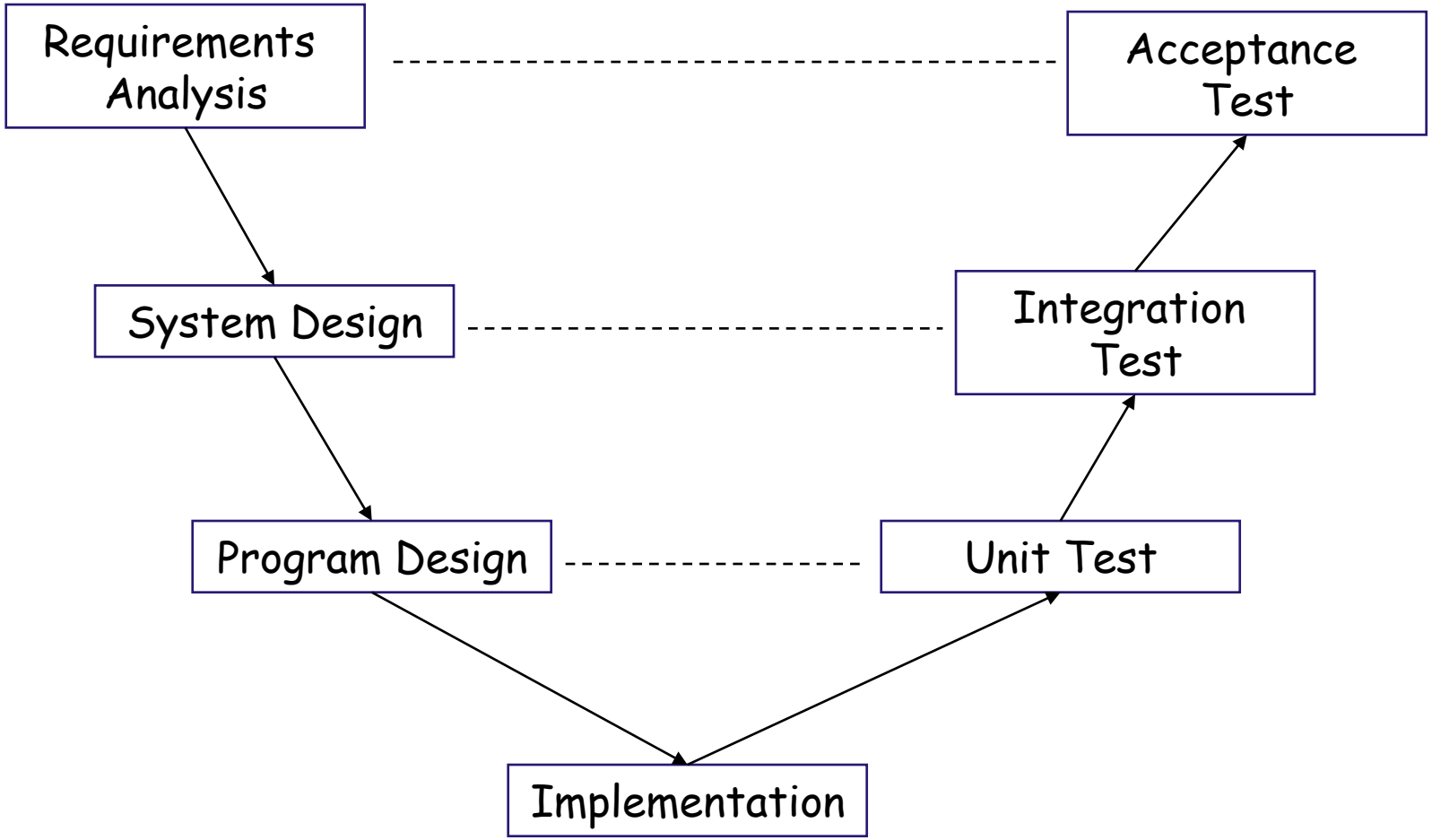
(sometimes this is implied by "waterfall")



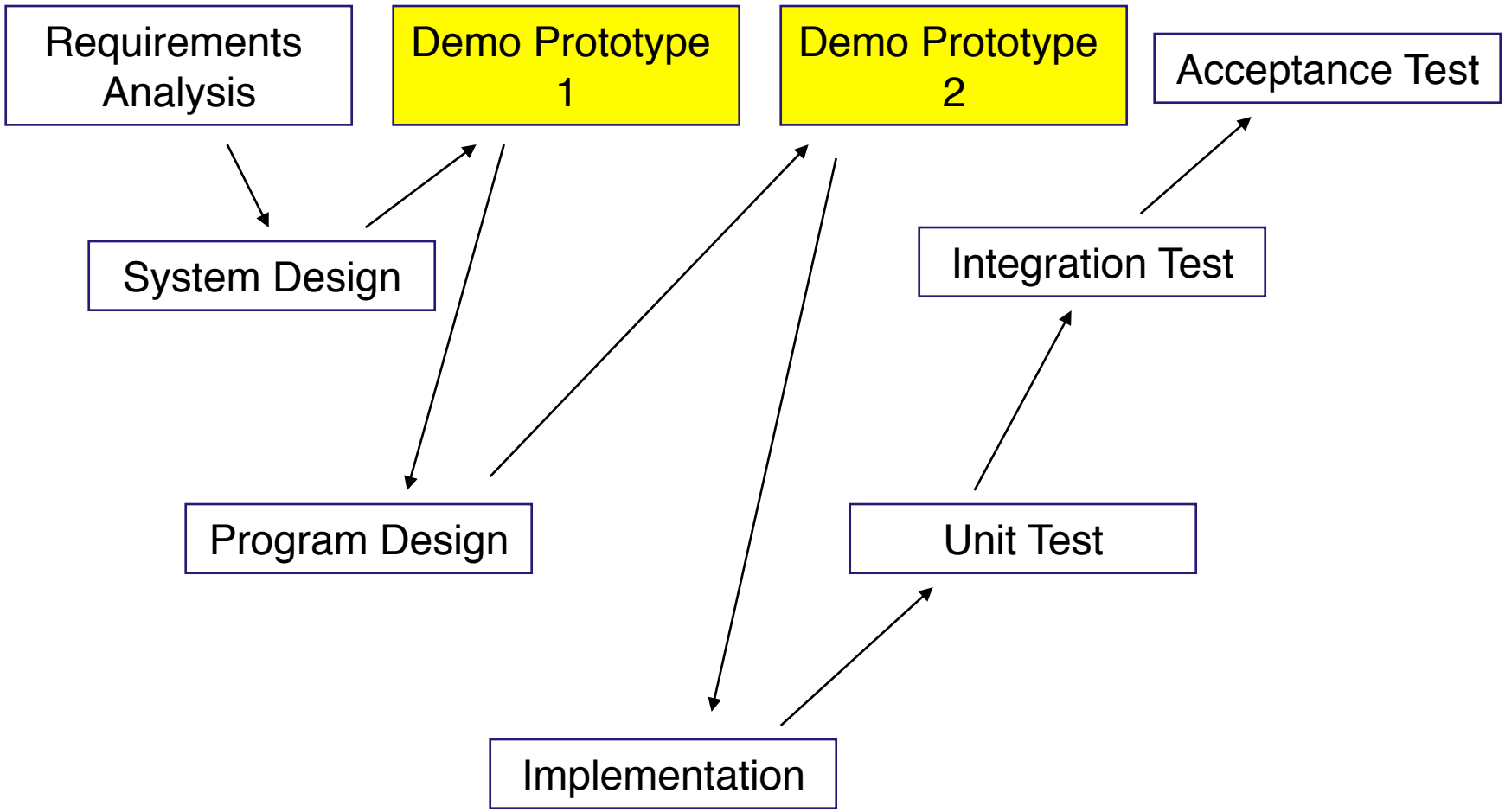
Adjustments made to immediately previous phase based on issues with successive phase.

"V" Model

Each phase has corresponding test or ***validation counterpart***



Sawtooth Model (Brugge)



Incremental vs. Iterative

- These *sound* similar, and sometimes are equated.
- Subtle difference:
  - **Incremental**: ***add to*** the product at each phase
  - **Iterative**: ***re-do*** the product at each phase
- Some of the models could be used either way

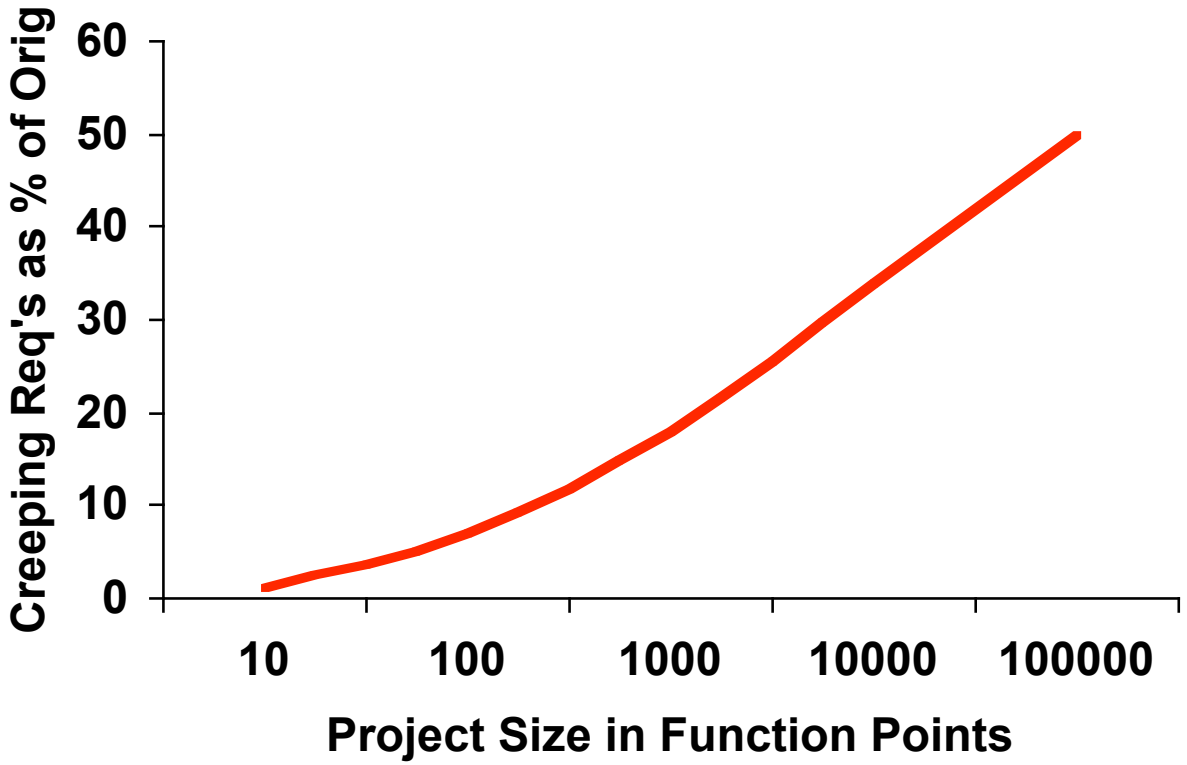
Example: Building a House

- **Incremental**: Start with a modest house, keep adding rooms and upgrades to it.
- **Iterative**: On each iteration, the house is re-designed and built anew.
- Big Difference: One can live in the incremental house the entire time! One has to **move** to a new iterative house.

Winchester Mystery House
San Jose, CA

Why Not Waterfall?

1. Complete Requirements Not Known at Project Start



Source: Applied Software Measurement, Capers Jones, 1997. Based on 6,700 systems.

Function Point?

- A **function point** is a unit of complexity used in software cost estimation. Function points are based on number of user interactions, files to be read/written, etc.

- **SLOC** means number of source lines of code, also a measure of program complexity.

- There are **models** (such as COCOMO) for translating function points into lines of code.

Why Not Waterfall?

2. Requirements are not stable/unchanging.

- The market changes—constantly.
- The technology changes.
- The goals of the stakeholders change.

Source: Craig Larman

Why Not Waterfall?

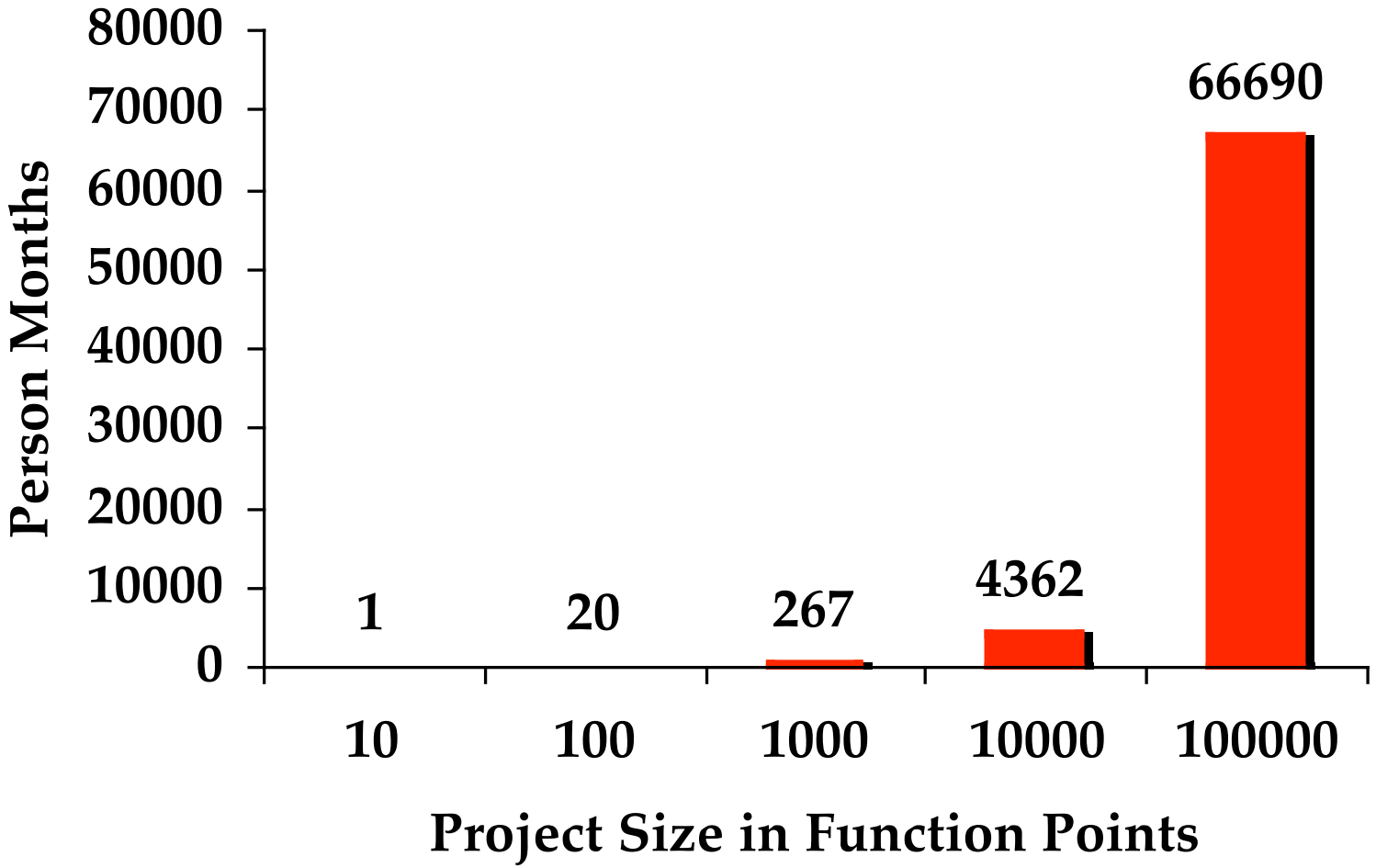
3. The design may need to change during implementation.

- Requirements are incomplete and changing.
- Too many variables, unknowns, and novelties.
- A complete specification must be as detailed as code itself.
- Software is very "hard".
  - Discover Magazine, 1999: Software characterized as the most complex "machine" humankind builds.

Source: Craig Larman

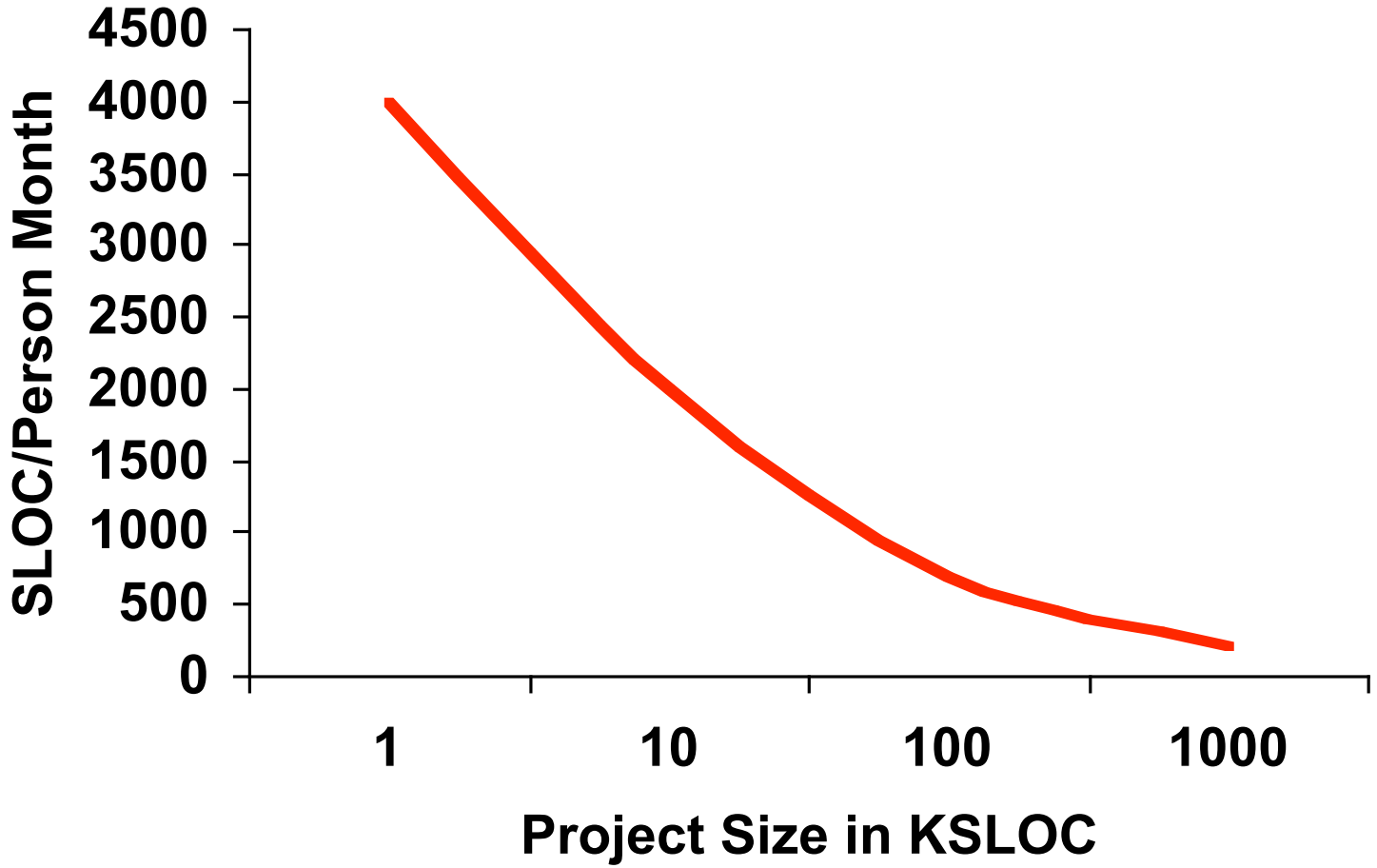
Large vs. Small Steps:

Project Duration



Source: Craig Larman

Large vs. Small Steps: Productivity



Source: Measures For Excellence, Putnam, 1992. Based on 1,600 systems.

"Life-Cycle" Models (3)

- **Iterative** Models
  - Spiral Model & Variants
    - ROPES Model
    - Controlled Iteration Model: Unified Process
    - Time Box Model
  - Scrum Model
    - Fountain Model

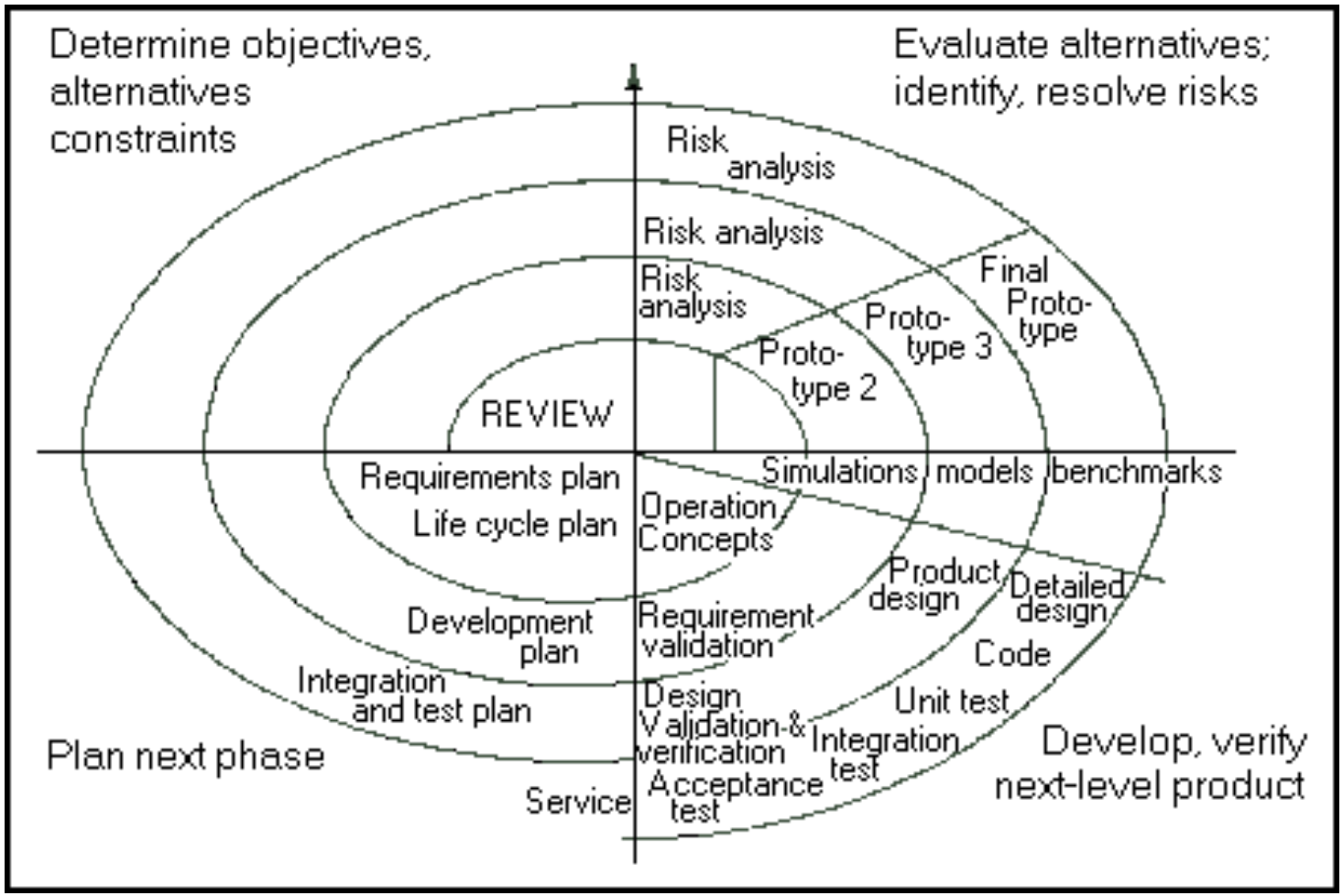
Boehm Spiral Model

(of which some other models are variants)

- An iterative model developed by Barry Boehm at TRW (1988), now Prof. at USC
- Iterates cycles of these project phases:
  1. Requirements definition
  2. Risk analysis
  3. Prototyping
  4. Simulate, benchmark
  5. Design, implement, test
  6. Plan next cycle (if any)

Prof. Barry Boehm

Boehm Spiral Model



Risk? What risk?

- One major area of risk is that the scope and difficulty of the task is **not well understood at the outset**.

- This is the so-called "wicked problem" phenomenon.

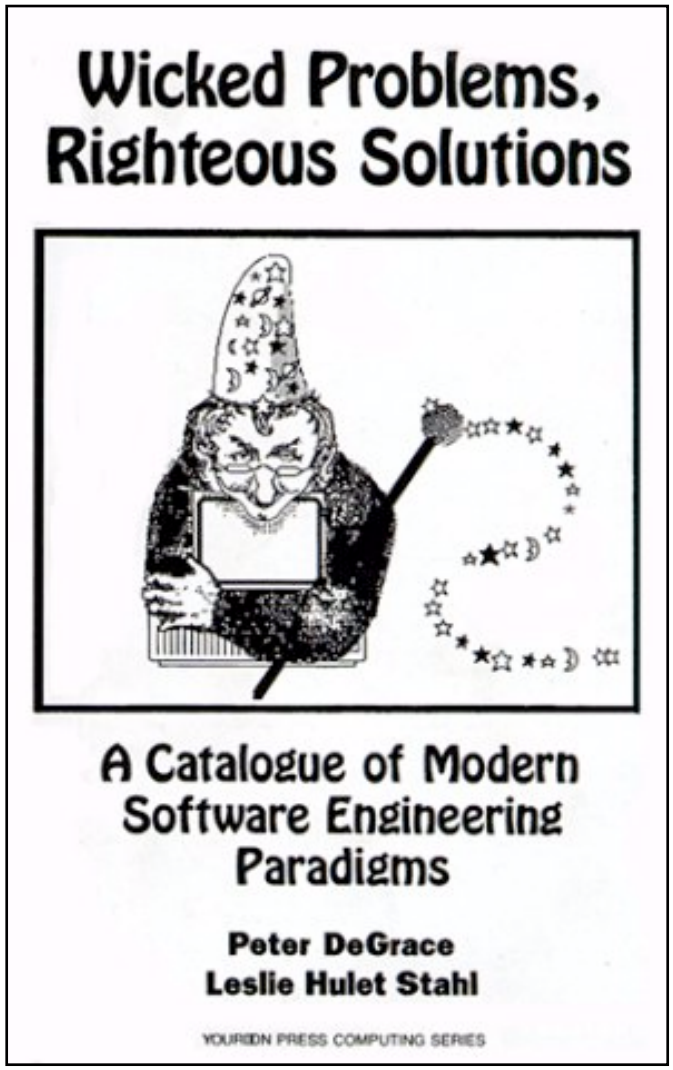
"Wicked Problems"

- Many software development projects have been characterized as "wicked problems", meaning:

  "problems that are fully understood only after they are solved the first time" (however poor the "solution" might be)

- Does not apply only to software

Source of some of this



Prentice-Hall, 1990

basically a criticism of the waterfall model

"wicked" term first used in

H. Rittel and M. Webber, *Dilemmas in a general theory of planning*, Policy Sciences, **4**, pp. 155-169, Elsevier, 1973.

Some Roots of Wickedness

- **Risk**: *A customer* not knowing exactly what he/she wants; changing expectations as project progresses.
- **Risk**: *Staff* who are inexperienced in the problem domain, or with the appropriate implementation techniques.

Class Exercise

- Enumerate as many risks (in a software development project) as you can.

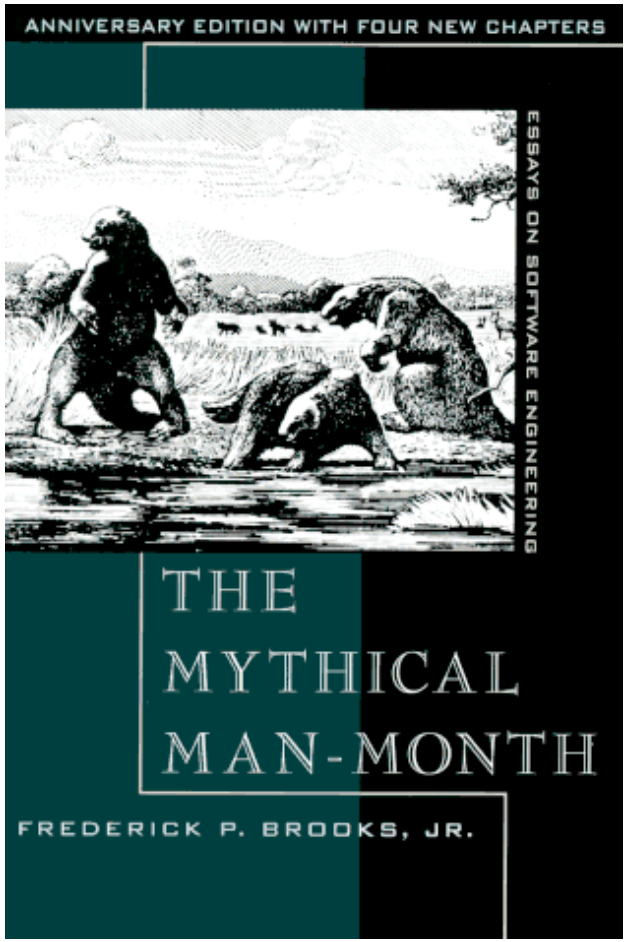
The Waffle Principle

- "Plan to throw the first one away; you will anyhow."

  Fred Brooks, "The Mythical Man-Month: Essays on Software Engineering", Addison Wesley, 1975.
  Revised in 1995.

- another indication that building a large software system is wicked

The Mythical Man-Month



Addison-Wesley

First published in 1975, re-published in 1995.

Possibly the most widely-read software development book.

Wicked Problems

- The presence of wickedness is what makes the **iterative / incremental** approaches most appealing.
- Methodologies and organizational techniques can help control the degree of wickedness.

US Air Force Risk Classification

- **Performance risk**: The project might not meet requirements or otherwise be fit for use.
- **Cost risk**: The budget might get overrun.
- **Support risk**: The software might not be adaptable, maintainable, extendable.
- **Schedule risk**: The project might be delivered too late.

USAir Force
Software Risk *Impact* Classification

- Negligible
- Marginal
- Critical
- Catastrophic

Ways to Manage Risk

- Risk cannot be eliminated; it must be managed.
  - Do as thorough **requirements** analysis as possible before the design.
  - Use **tools** to track requirements, responsibilities, implementations, etc.
  - Build ***small*** **prototypes** to test and demonstrate concepts and assess the approach, prior to building full product.
  - Prototype **integration** as well as components.

Front-Loading

- Better to find out about infeasible, intractable, or very hard problems early.
- Thus tackle the unknown and harder parts earlier rather than later.
- The easy parts will be worthless if the hard parts are impossible.
- Find out about design flaws early rather than upon completion of a major phase.

ROPES Model - Similar to Spiral

Rapid **O**bject-Oriented **P**rocess for **E**mbedded **S**ystems

Bruce Douglass

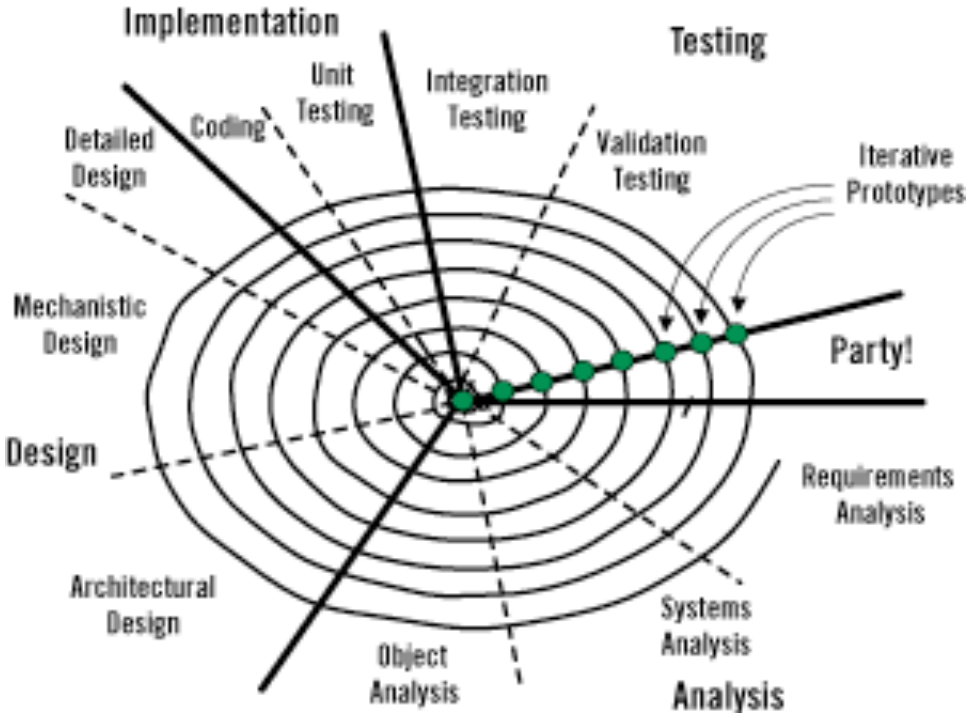
- Iterates the following sequence of phases repeatedly:
  - Requirements analysis
  - System analysis
  - Object analysis
  - Architectural design
  - Design
  - Mechanistic design
  - Detailed design
  - Coding
  - Unit testing
  - Integration testing
  - Validation testing
  - Iterative prototypes

http://www.sdmagazine.com/breakrm/features/s999f1.shtml

ROPES Model

Rapid **O**bject-Oriented **P**rocess for **E**mbedded **S**ystems

Bruce Douglass

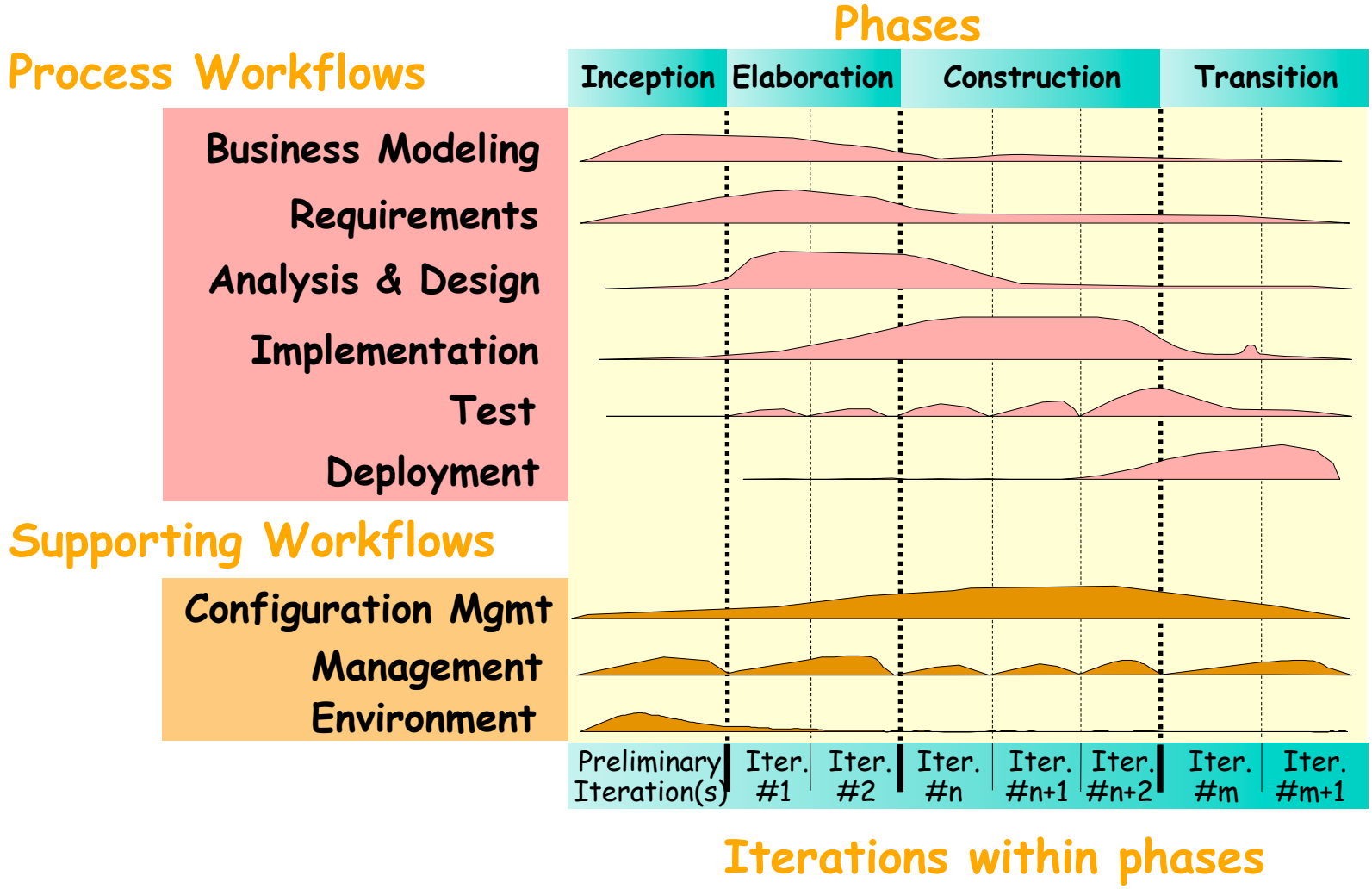


Controlled-Iteration Model

- Four phases per major cycle
  - **Inception**: Negotiate and define product for this iteration
  - **Elaboration**: Design
  - **Construction**: Create fully functional product
  - **Transition**: Deliver product of phase as specified
- The next phase is started **before** the end of the previous phase (say at 80% point).

Rational Unified Process

(a form of controlled iteration)



Time-Box Model/Aspect

(can be used in iterative or incremental)

- Requirements analysis
- Initial design
- while(not done)

  {

  Develop a *version* **within a bounded time**

  Deliver to customer

  Get feedback

  Plan next version

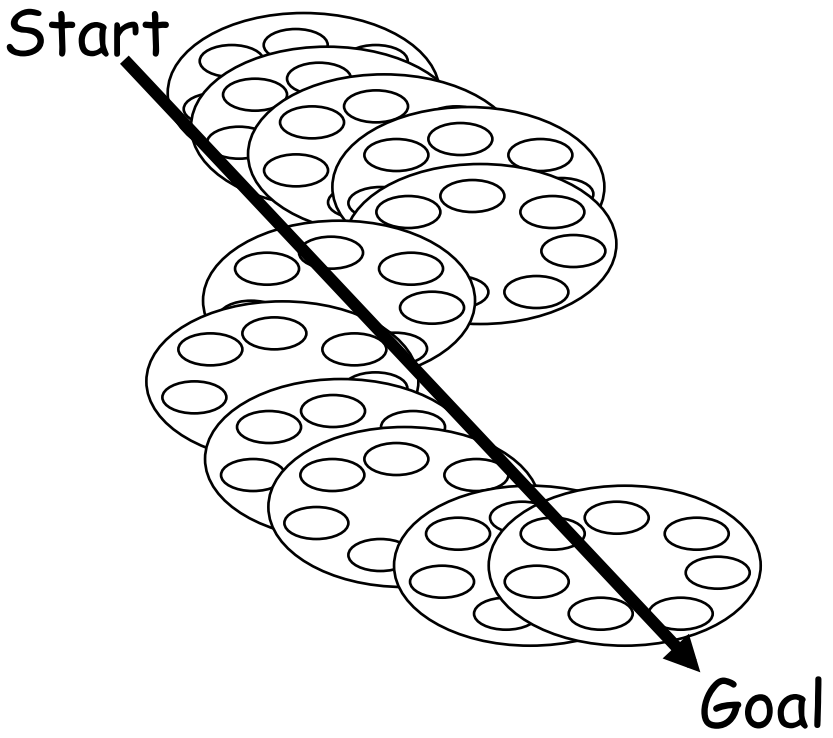
  }

Scrum,
A cure for the Wicked?

Scrum first mentioned in
"The New New Product Development Game" (Harvard Business Review 86116:137-146, 1986)

Scrum Model

(incremental model,
includes some aspects of team structure, as well as process)



A **small group** is responsible for

picking up the ball and moving it toward the goal.

See http://www.cetus-links.org/oo_ooa_ood_methods.html

Is the SCRUM metaphor to be taken literally?

"Mills proposes that each segment of a large job
be tackled by a team,

but that the team be organized like a surgical team
rather than a hog-butchering team. "

Brooks, 1995

Argument for the Scrum Model over other iterative models

- A software development project might not be compartmentalizable into nice clean phases as the Spiral models suggest.
- Scrum may be "just the thing" for wicked problems, because the team can quickly react to new information.

Some Principles of Scrum Model

- **Always have a product** that you can theoretically ship: "done" can be declared at any time.
- **Build early, build often**.
- **Continuously test** the product as you build it.
- **Assume requirements may change**; Have ablility to adapt to marketplace changes during development.
- **Small teams** work in parallel to maximize communication and minimize overhead.

Concepts Used in Scrum

(from http://www.controlchaos.com)

- **Backlog** - an identification of all **requirements** that should be fulfilled in the completed product. Backlog items are **prioritized**.
- **Objects/Components** - self-contained reusable **modules**
- **Packets** - a group of **objects** within which a backlog item will be implemented.
  - **Coupling** between the objects ***within*** a packet is **high**.
  - **Coupling *between*** packets is **low**.
- **Team** - a group of 6 or fewer members that works on a packet.
- **Problem** - what must be solved by a team member to implement a backlog item within an object (includes removing errors).
- **Issues** - Concerns that must be resolved prior to a backlog item being assigned to a packet or a problem being solved by a change to a packet.
- **Solution** - the resolution of an issue or problem
- **Changes** - the activities that are performed to resolve a problem
- **Risks** - the risk associated with a problem, issue, or backlog item

Use of Iteration in Scrum

(from http://www.controlchaos.com)

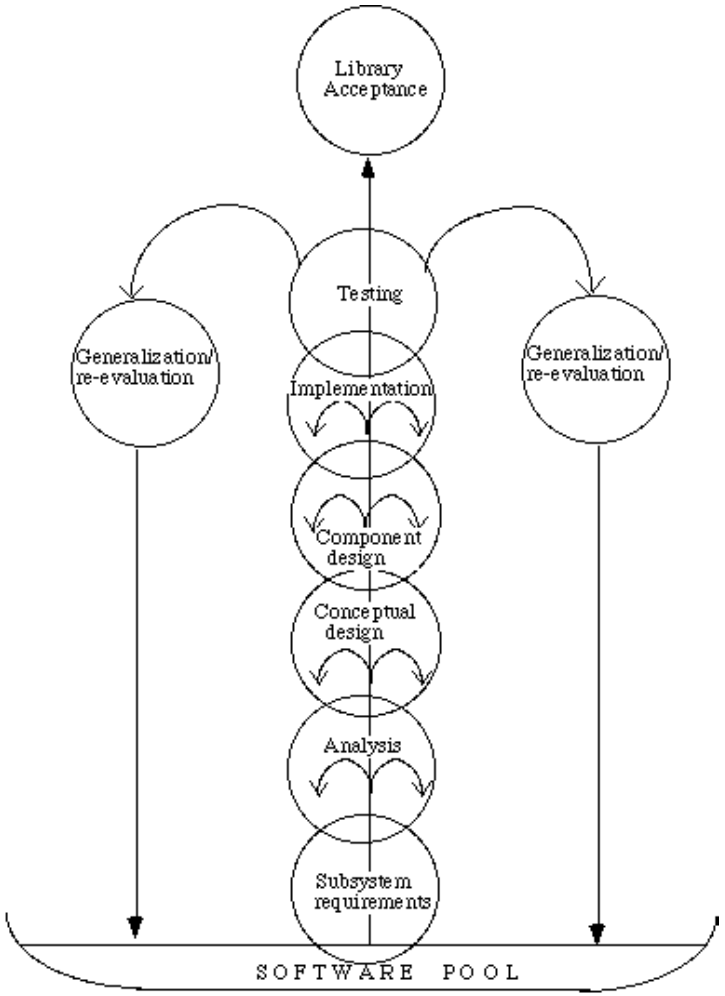
- Each **iteration** consists of all of the standard ***Waterfall* phases**,

  but each iteration only addresses **one set of functionality**.
- Overall project deliverable has been **partitioned** into prioritized subsystems, each with clean interfaces.
- **Test the feasibility** of subsystems and technology in the initial iterations.
- Further iterations can **add resources** to the project while ramping up the speed of delivery.
- Underlying development **processes are still defined** and **linear**.

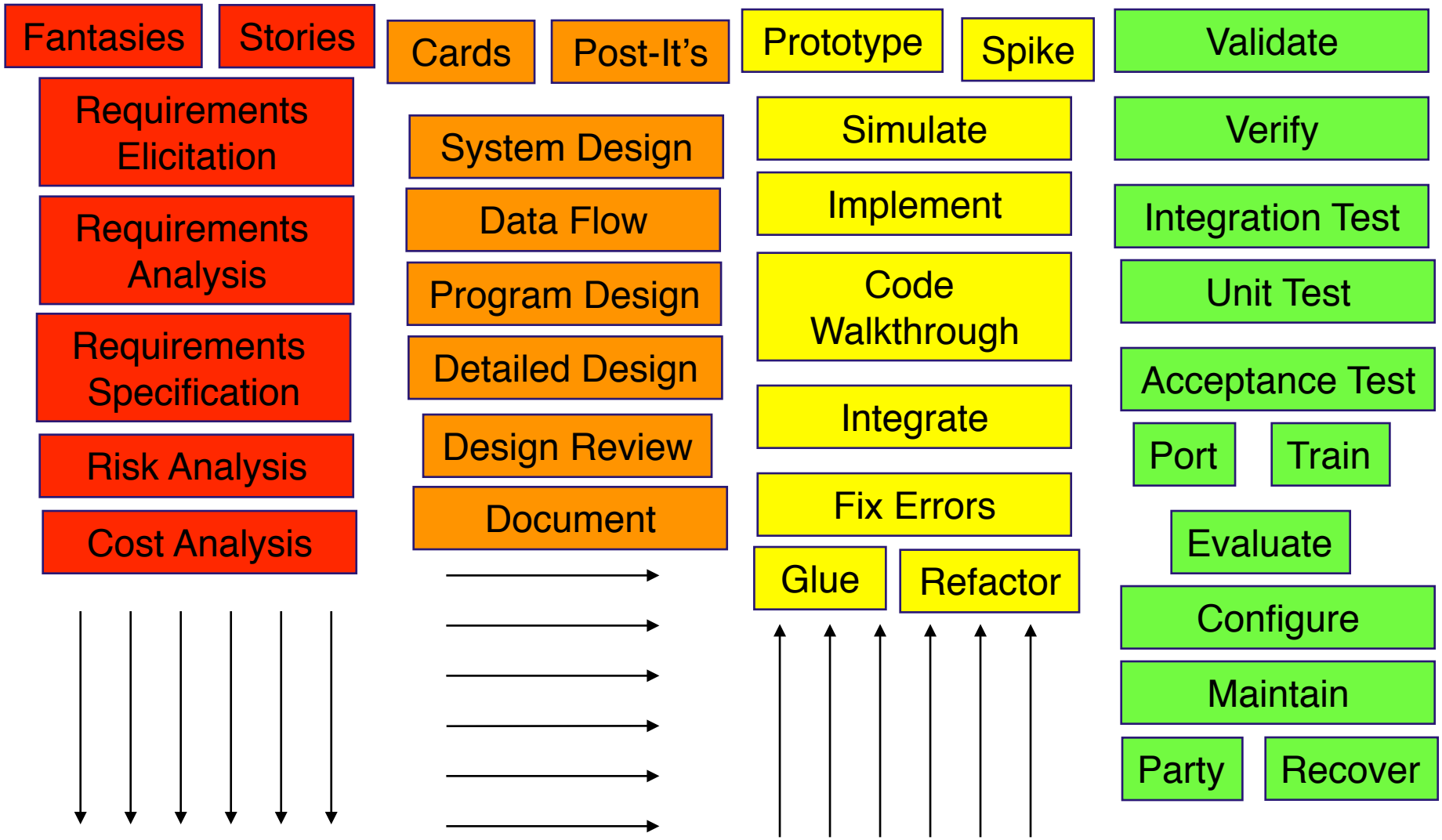
Fountain Model

(Ian Graham, et al., The OPEN Process Specification

OPEN = Object-oriented Process Environment and Notation)



Keller's Roll-Your-Own Software Life-Cycle Construction Kit



Continuous Models

"Agile" Models: XP

[Scrum is now also classified as agile]

Earlier Models/Acronyms

- **RAD** (Rapid Application Development): time-boxed, iterative prototyping
- **JAD** (Joint Application Development): Focus on developing **models** shared between users and developers.
- See SDLC, JAD, and RAD: "Finding the Right Hammer" http://faculty.babson.edu/osborn/cims/rad.htm for additional points.

Extreme Programming (XP)

(cf. http://www.extremeprogramming.org/rules.html)

- User **stories** (something like use cases) are written by the customer.
- Complex stories are **broken down** into simpler ones (similar to a WBS (Work Breakdown Structure), but less formal).
- Stories are used to **estimate** the required amount of work.
- Stories are used to create **acceptance tests**.
- A **release plan** is devised that determines which stories will be available in which release.
- Don't hesitate to change what doesn't work.

Extreme Programming (XP)

- Each release is preceded by a **release planning meeting**.
- Each day begins with a **stand-up meeting** to share problems and concerns.
- CRC cards are used for **design**. [XP and CRC were created by the same person, Kent Beck.]
- **"Spike solutions"** are done to assess risks.
- The **customer** is always available.

Extreme Programming (XP)

- All code must pass **unit tests**, which are coded before the code being tested (**test-driven design**).
- **Refactoring** is done constantly.
- **Integration** is done by one pair.
- Integration is done frequently.
- Optimization is done **last**.
- **Acceptance tests** are run often.

The Rules and Practices of Extreme Programming.

Lessons Learned

Planning

- User stories are written.
- Release planning creates the schedule.
- Make frequent small releases.
- The Project Velocity is measured.
- The project is divided into iterations.
- Iteration planning starts each iteration.
- Move people around.
- A stand-up meeting starts each day.
- Fix XP when it breaks.

Designing

- Simplicity.
- Choose a system metaphor.
- Use CRC cards for design sessions.
- Create spike solutions to reduce risk.
- No functionality is added early.
- Refactor whenever and wherever possible.

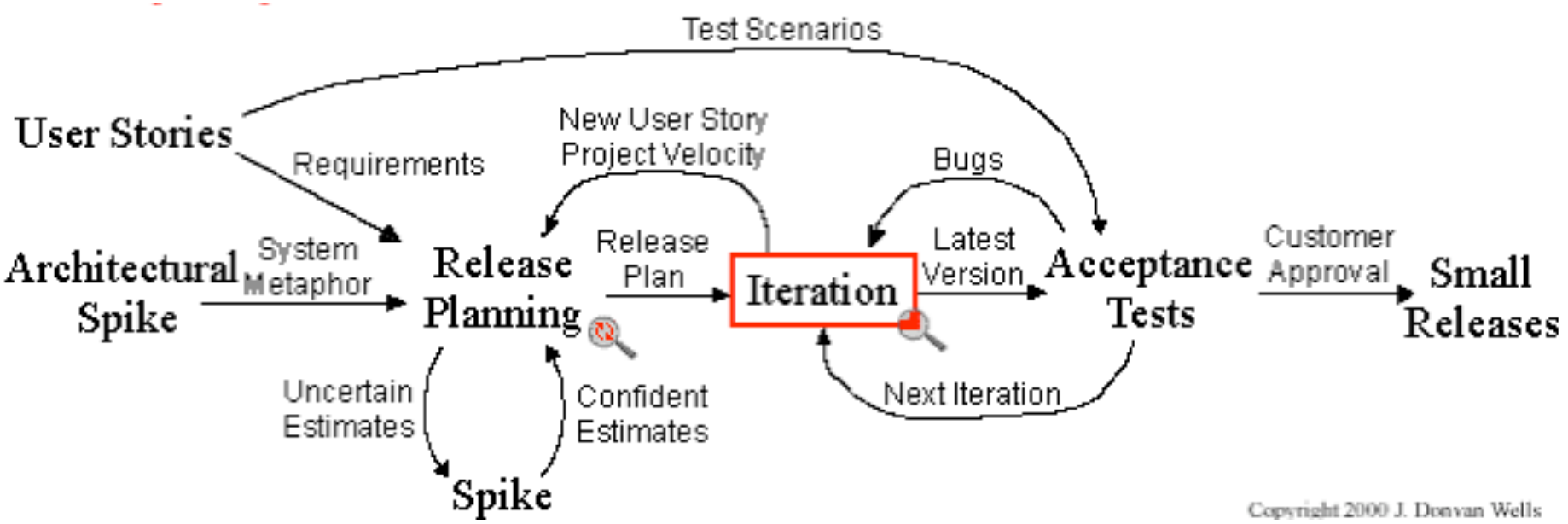
Coding

- The customer is always available.
- Code must be written to agreed standards.
- Code the unit test first.
- All production code is pair programmed.
- Only one pair integrates code at a time.
- Integrate often.
- Use collective code ownership.
- Leave optimization till last.
- No overtime.

Testing

- All code must have unit tests.
- All code must pass all unit tests before it can be released.
- When a bug is found tests are created.
- Acceptance tests are run often and the score is published.

Extreme Programming Project



System Metaphor?

"Choose a system metaphor to keep the team on the same page by **naming classes and methods consistently**.

What you name your objects is very important for understanding the overall design of the system and code reuse as well.

Being able to guess at what something might be named if it already existed and being right is a real time saver."

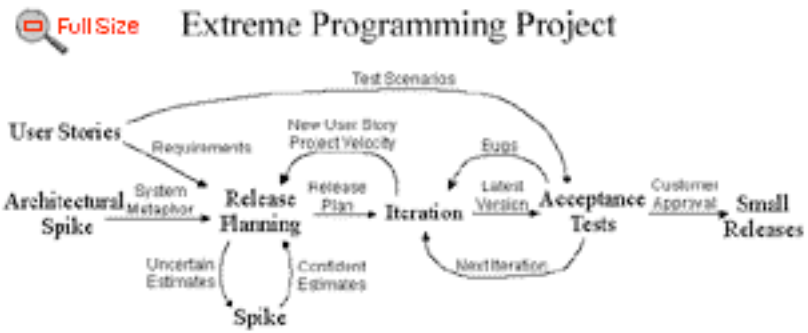
Extreme Programming

Choose a System Metaphor

Lessons Learned

Choose a system metaphor to keep the team on the same page by naming classes and methods consistently. What you name your objects is very important for understanding the overall design of the system and code reuse as well. Being able to guess at what something might be named if it already existed and being right is a real time saver. Choose a system of names for your objects that everyone can relate to without specific, hard to earn knowledge about the system.

For example the Chrysler payroll system was built as a production line. At another auto manufacturer car sales were structured as a bill of materials. There is also a metaphor known as the naive metaphor which is based on your domain itself. But don't choose the naive metaphor unless it is simple enough.



Wiki Wiki
The Portland Pattern Repository

XPlorations

(Some) XP Controversial Aspects (see wikipedia for more)

- There is **no Big Design Up Front**. Most of the design activity takes place on the fly and incrementally, starting with "the simplest thing that could possibly work" and adding complexity only when it's required by failing tests. Critics fear this would result in **more re-design effort** than only re-designing when requirements change.
- A **customer representative** is attached to the project. This role can become a single-point-of-failure for the project, and some people have found it to be a source of stress. Also, there is the danger of **micro-management by a non-technical representative** trying to dictate the use of technical software features and architecture.
- Software developers are required to work in pairs.

Snakes on a Workstation?

- "XP is like a ring of poisonous snakes, daisy-chained together. All it takes is for one of them to wriggle loose, and you've got a very angry, poisonous snake heading your way."