Software Process

Overview

- What is **software process**?
- Generic process framework

- Examples of process models
- Unified Process (UP)
- Agile software development

Software Process

- Definition [Pressman]
  - a framework for the tasks that are required to build high-quality software.
  - to provide stability, control and organization to an otherwise chaotic activity

What does SW process mean?

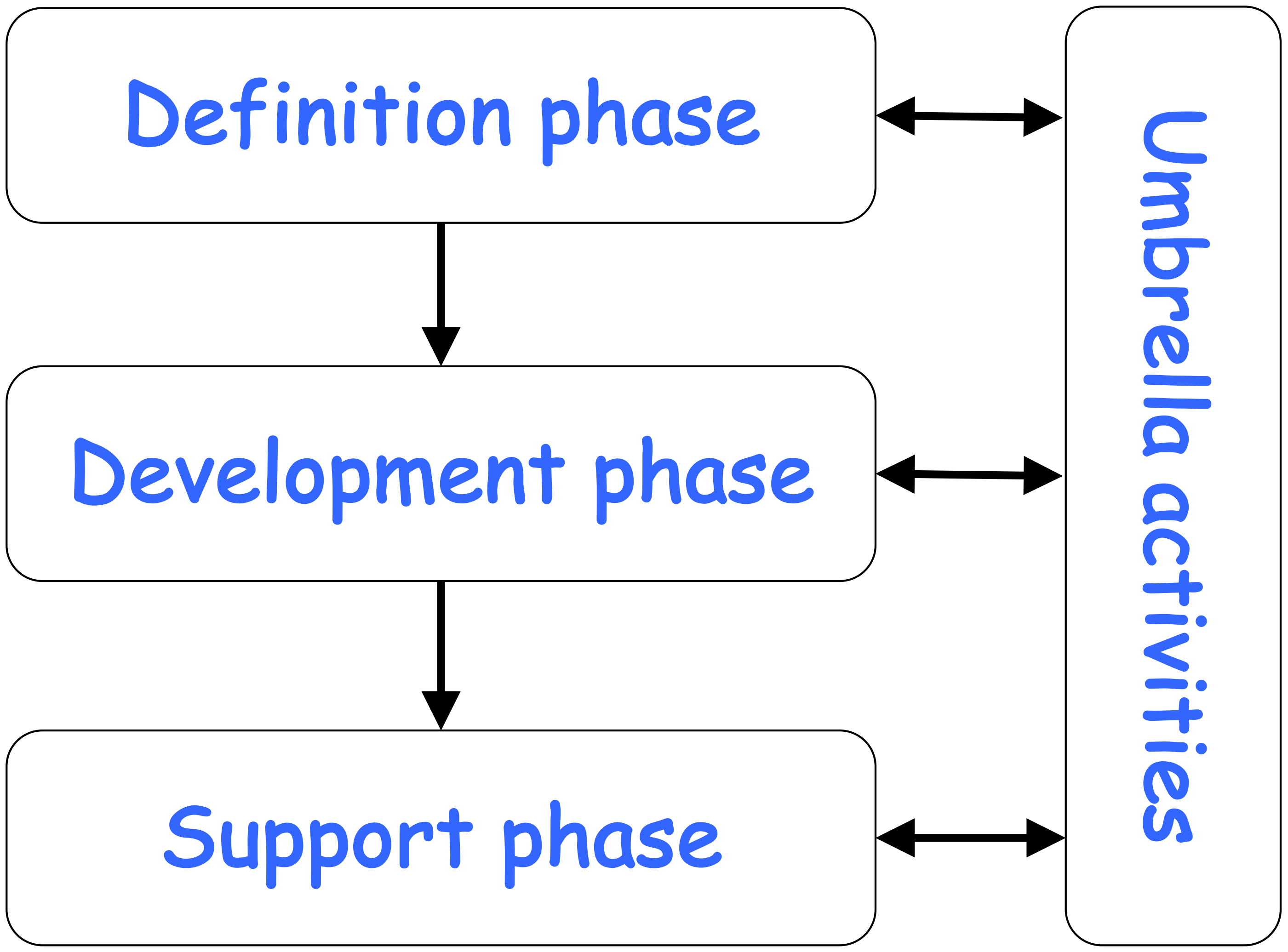
- For a single programmer
  - Planning (time, resources, assignments)
  - Design and development
  - Tracking and measuring progress
- For a team of practitioners
  - Organizational planning (time, resources, etc.)
  - Hiring, training, tool acquisition, etc.
  - Process assessment and improvement
- For software engineering in general
  - Helps organize SE around 'best practices'

Elements of SW process

Term	Examples
People	*Software developers, project managers, customers*
Tasks	*Analyze requirements*
Work products	*Requirements specification*
Planning	*Estimate needed resource, time, defects*
Conducting	*Track progress and work results*
Assessing	*Define and measure metrics like quality, progress, etc.*

A process defines **who** is doing **what**, **when** and **how** to reach a certain goal.

Generic View of SW Process



Definition Phase

- Tasks related to problem definition
  - What? - requirements, constraints, environment, etc.
- Step 1: System engineering
  - Ascertain roles of hardware, software, people, databases, operational procedures, etc. in system
- Step 2: Analysis of the problem
  - Requirement analysis
    - Understanding what the users need and want
  - Domain analysis
    - Illustrate key concepts in a set of SW systems (reuse)
- Step 3: Project planning
  - Resources (e.g., people), cost, schedule

Development Phase

- Tasks related to problem solution
  - How? - architecture, programming, testing, etc.
- Step 1: software design (the blueprint)
  - Design models that describe structure, interactions, etc.
- Step 2: code generation/implementation
- Step 3: software testing
  - Goal: uncover as many errors as possible

Support (Maintenance) Phase

- Tasks related to software evolution
  - Changes? – Definition and development in the context of existing software
- Adaptation to change in the environment
  - New hardware, changes in OS, business rules, etc.
- Correction of defects (Y2K problem, $308B)
- Enhancements (new features, etc.)
- Refactoring (to ease future changes)

Some Umbrella Activities

- Project management
  - Tracking and control of people, process, cost, etc.
- Quality assurance (QA)
  - Formal technical reviews of work products
  - Software testing
  - Keeping docs consistent with code base
- Configuration management
  - Controls the changes in work products using systems like SVN, Git

Observations

- Process models are idealizations
  - The real world is a very complex place
- They can be very difficult to execute
  - Conformance can be faked
- But, they provide a roadmap for SE work to organize an otherwise chaotic activity

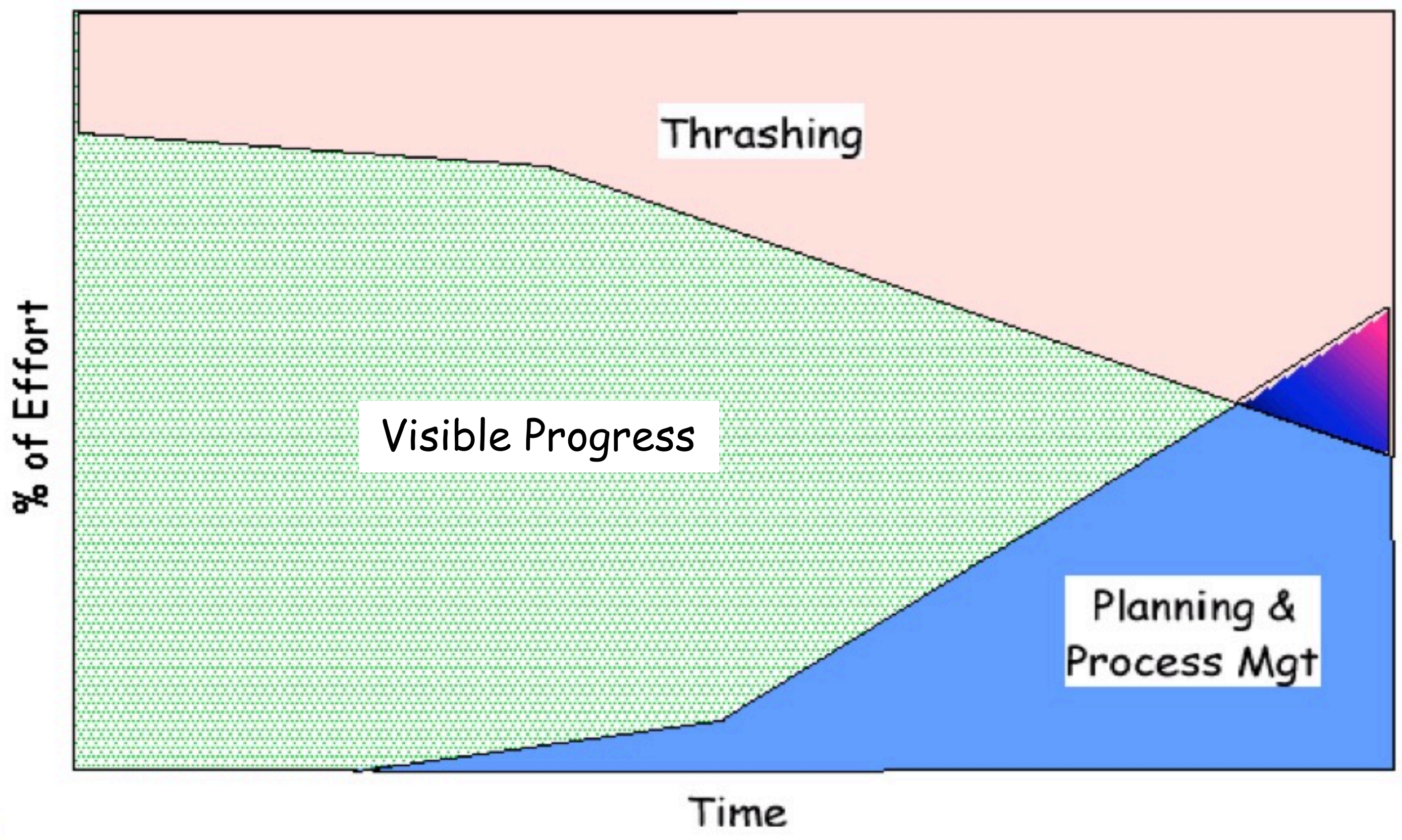
Code-and-Fix Process

- The first thing people tried in the 1950s
  1. Write program
  2. Improve it (debug, add functionality, improve efficiency, ...)
  3. GOTO 1
- Works for small 1-person projects and for some CS course assignments

Problems with Code-and-Fix

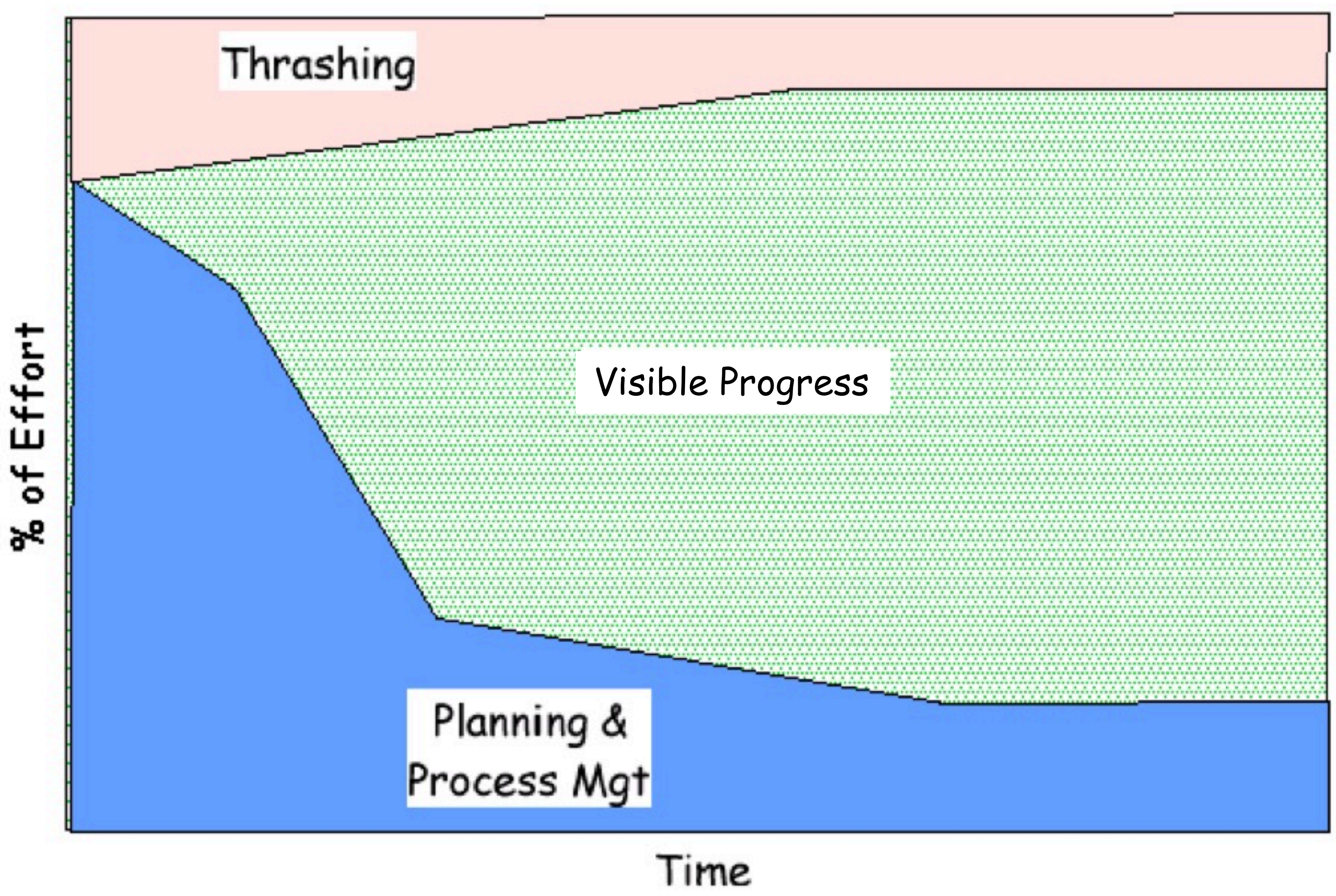
- Poor match with user needs
- Bad overall structure – No blueprint
- Poor reliability - no systematic testing
- Maintainability? What’s that?
- What happens when the programmer quits?

Code-and-Fix Process



From McConnell, After the Goldrush, 1999

A More Advanced Process

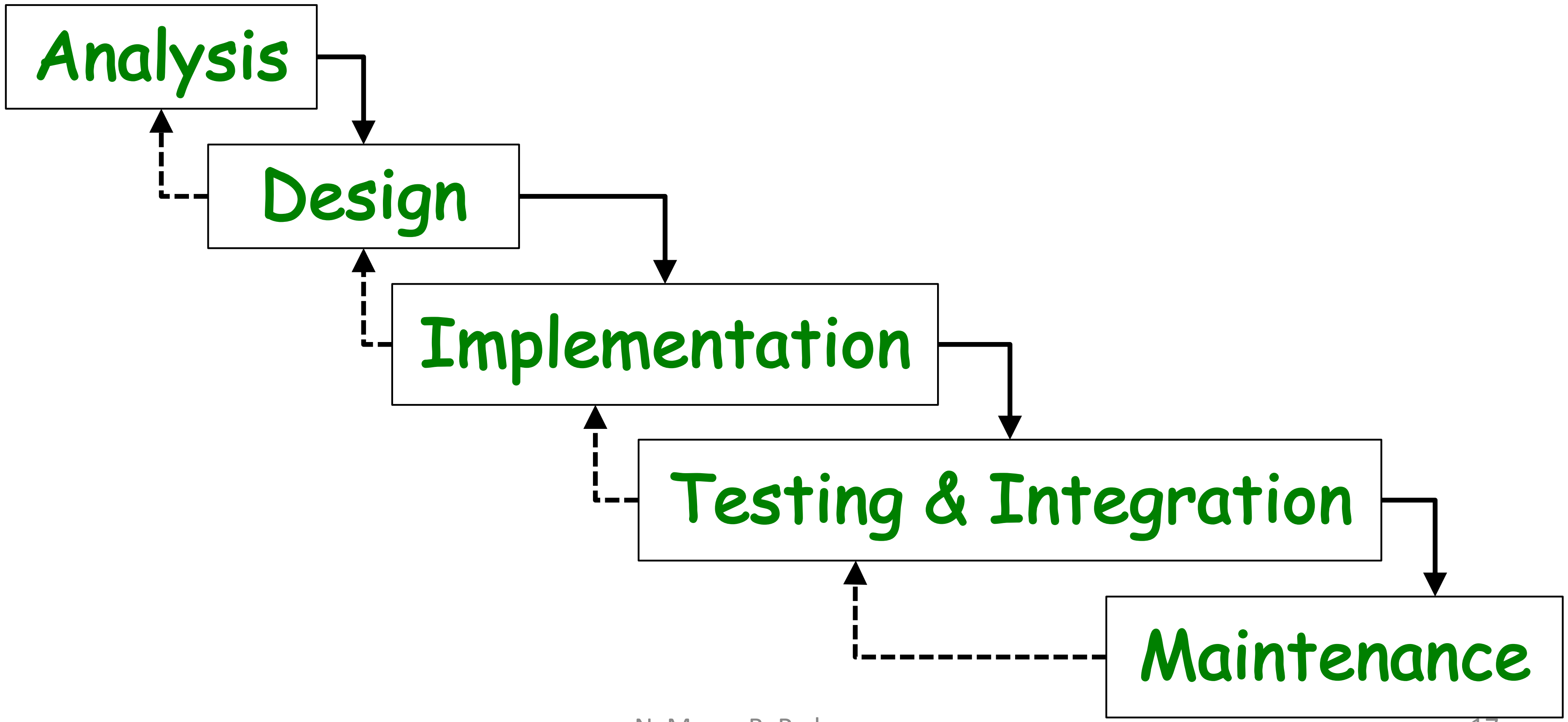


Examples of Process Models

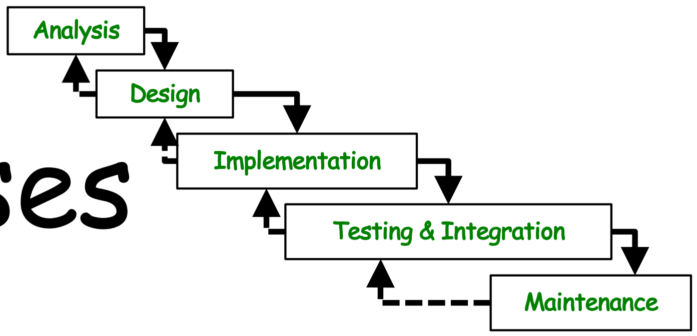
- Waterfall model
- Prototyping model
- Spiral model
- Incremental model

Waterfall Model

- The "classic" process model since 1970s
  - Also called "software life cycle"



Waterfall Phases



- Analysis: Define problems
  - requirements, constraints, goals and domain concepts
- Design: Establish solutions
  - System architecture, components, relationship
- Implementation: Implement solutions
- Testing and integration: Check solutions
  - Unit testing, system testing
- Maintenance: the longest phase

Key Points of the Model

- The project goes through the phases sequentially
- Possible feedback and iteration across phases
  - e.g., during coding, a design problem is identified and fixed
- Typically, few or no iterations are used
  - e.g., after a certain point of time, the design is "frozen"

Waterfall Model Assumptions

- All requirements are known at the start and stable
- Risks(unknown) can be turned into known through schedule-based invention and innovation
- The design can be done abstractly and speculatively
  - i.e., it is possible to correctly guess in advance how to make it work
- Everything will fit together when we start the integration

How was the model developed?

a) A group of researchers developed and proposed it as the best option of existing methods

b) A group of practitioners innovated a method that became the most widely used model

c) A person copied a picture of a method that he understood and could explain

Winston Royce wrote a recommendation about how to structure process for large software projects based on his experiences from NASA

Success story: space shuttle software

Charles Fishman, 1996

As the 120-ton space shuttle sits surrounded by almost 4 million pounds of rocket fuel, exhaling noxious fumes, visibly impatient to defy gravity, its on-board computers take command.

"This software is bug-free"

- Impressive statistics
  - The last 3 versions of the program--420,000 lines of code had just 1 error each
  - The last 11 versions of the software had a total of 17 errors
  - Commercial programs of equivalent complexity would have 5,000 errors

How did they write the right stuff?

- 1/3 of the process before coding
- NASA and Lockhead Martin groups agree in the most minute detail about everything
- Specs are almost pseudo-code
- Nothing in the specs is changed without agreement and understanding
- Task: upgrade software to add GPS navigation
  - 1.5% changes in program/6366 LOC
  - 2500 page specs for the change

How expensive is the software?

- 260 people
- >40,000 pages of specifications
- 20 years
- $35 million Annual budget
- $700 million overall budget
- 700 million/420k = $1600/line of code

Pros and Cons

- Pros: widely used, systematic, good for projects with well-defined requirements
  - Makes managers happy
- Cons:
  - The actual process is not so sequential
    - A lot of iterations may happen
  - The assumptions usually don't hold
  - Working programs are not available early
    - High risk issues are not tackled early enough
  - Expensive and time-consuming

When would you like to use waterfall?

- Work for big clients enforcing formal approaches on vendors
- Work on fixed-scope, fixed-price contracts without many rapid changes
- Work in an experienced team

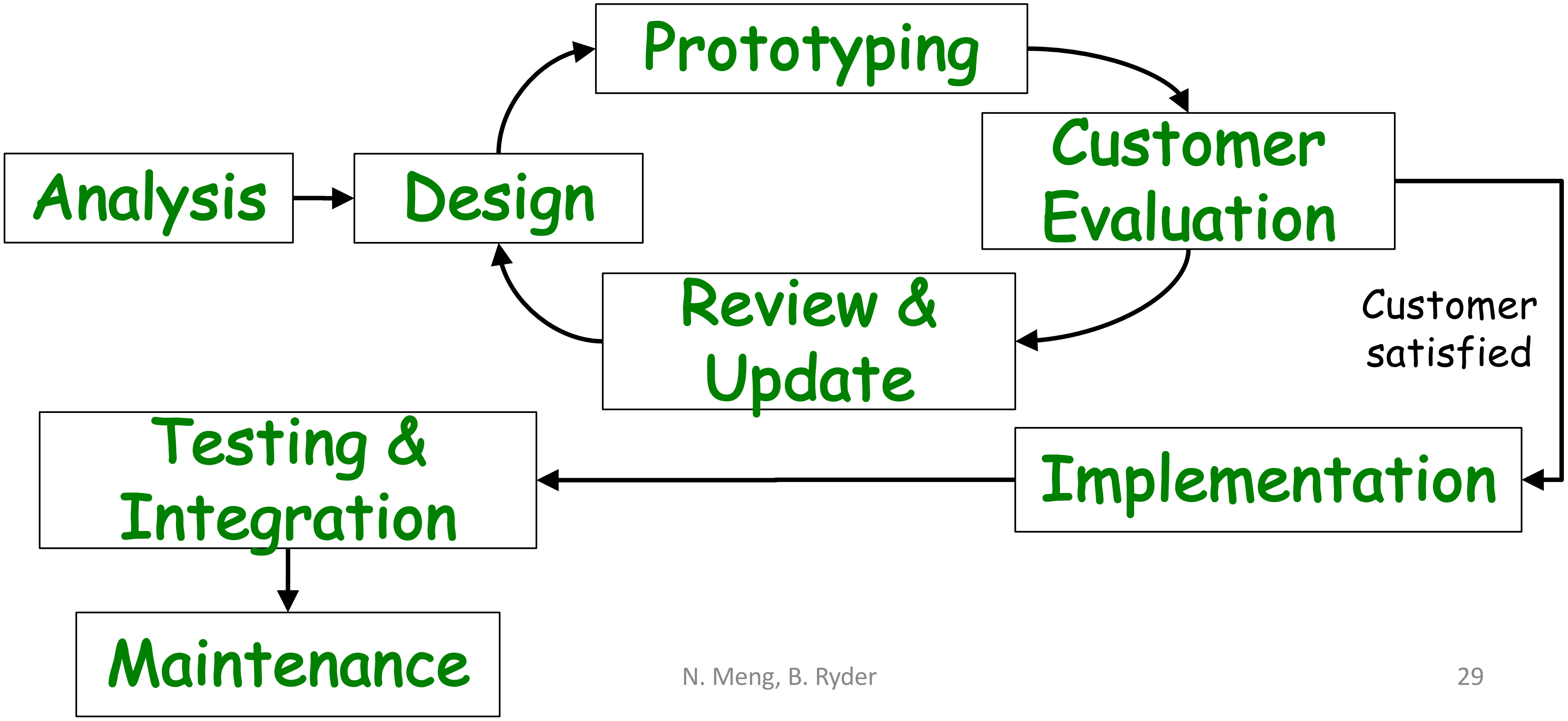
Observation

Standish group 1995

- Top three reasons for at least partial failure projects
  - lack of user input
  - incomplete requirements, and
  - changing requirement

Prototyping Model

- Build a prototype when customers have ambiguous requirements



Key Points of the Model

- Iterations: customer evaluation followed by prototype refinement
- The prototype can be paper-based or computer-based
- It models the entire system with real data or just a few screens with sample data
- Note: the prototype is thrown away!

Success stories of prototyping

- Organizations of all types do it
  - Boeing builds digital prototypes of its aircraft allowing the detection of design conflicts
  - Disney uses storyboards to work through the process of producing feature-length films
- Online systems and web interfaces

Pros and Cons

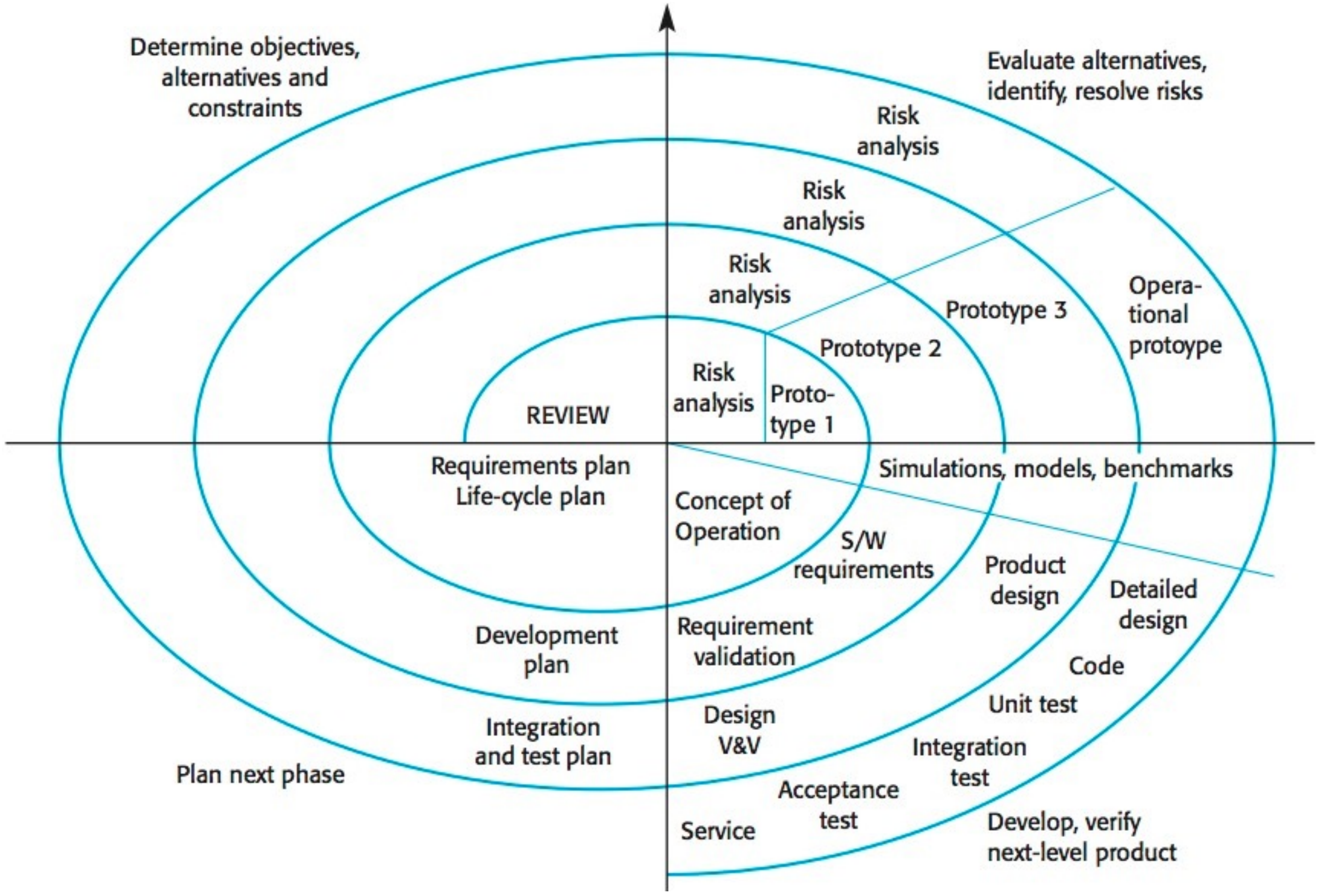
- Pros
  - Facilitate communication about requirements
  - Easy to change or discard
  - Educate future customers
- Cons
  - Iterative nature makes it difficult to plan and schedule
  - Excessive investment in the prototype
  - Bad decisions based on prototype
    - E.g., bad choice of OS or PL

When would you like to use prototyping?

- When the desired system has a lot of interactions with users

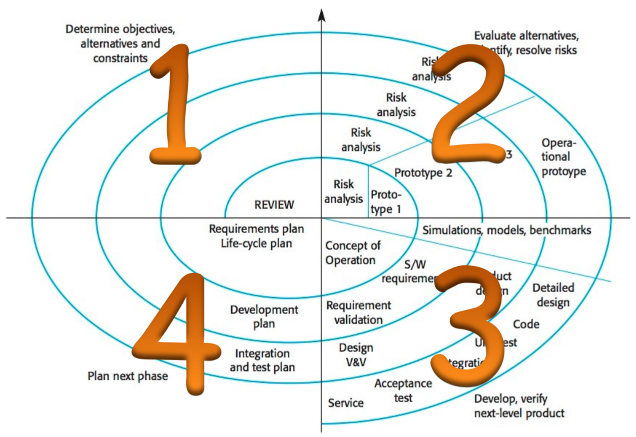
Spiral Model

- A risk-driven evolutionary model that combines development models (waterfall, prototype, etc.)



Spiral model (SOM)

Spiral Phases



- Objective setting
  - Define specific objectives, constraints, products, plans
  - Identify risks and alternative strategies
- Risk assessment and reduction
  - Analyze risks and take steps to reduce risks
- Development and validation
  - Pick development methods based on risks
- Planning
  - Review the project and decide whether to continue with a further loop

What Is Risk?

- Something that can go wrong
  - People, tasks, work products
- Risk management
  - risk identification
  - risk analysis
    - the probability of the risk, the effect of the risk
  - risk planning
    - various strategies
  - risk monitoring

Risk Planning [Sommerville]

Risk	Strategy
☐ Recruitment problems	☐ *Alert customer of potential difficulties and the possibility of delays, investigate buying-in-components*
☐ Defective components	☐ *Replace potentially defective components with bought-in components of known reliability*
☐ Requirements changes	☐ *Derive traceability information to assess requirements change impact, maximize information hiding in the design*
☐ Organizational financial problems/restructuring	☐ *Prepare a briefing document for senior management showing how the project is making a very important contribution to the goals of the business*
☐ Underestimated development time	☐ *Investigate buying-in components, investigate the use of a program generator*

Key Points of the Model

- Introduce risk management into process
- Develop evolutionary releases to
  - Implement more complete versions of software
  - Make adjustment for emergent risks

Pros and Cons

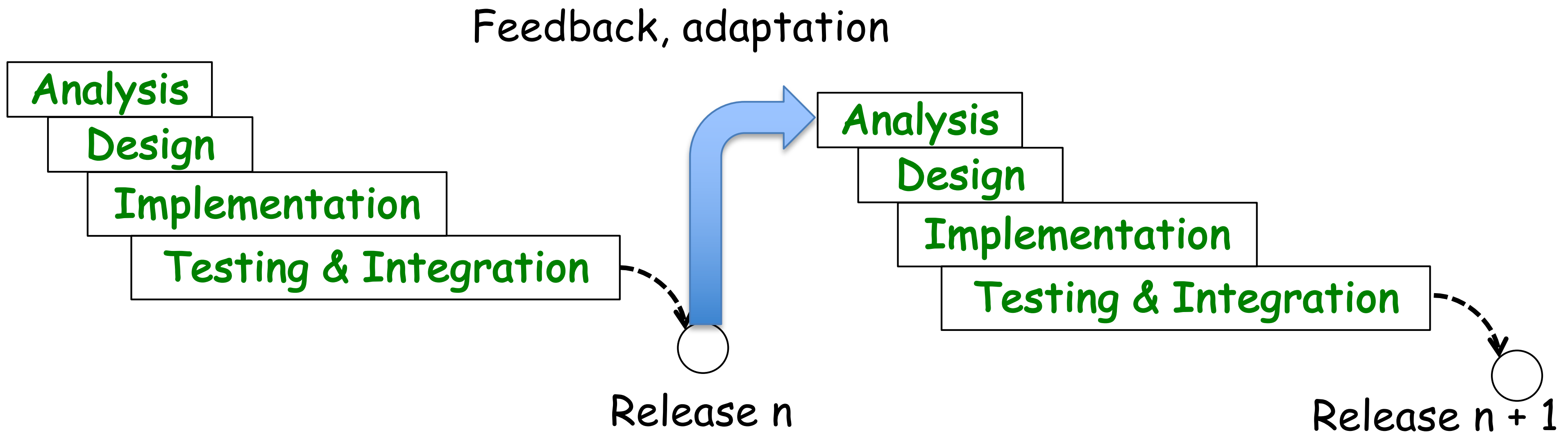
- Pros
  - High amount of risk analysis to avoid/reduce risks
  - Early release of software, with extra functionalities added later
  - Maintain step-wise approach with “go-backs” to earlier stages
- Cons
  - Require risk-assessment expertise for success
  - Expensive

When to use the model?

- Large and mission-critical projects
- Medium to high-risk projects
- Significant changes are expected

Incremental Model

- A sequential of waterfall models



Iteration n: 3 weeks (for example)

Iteration n+1: 3 weeks (for example)

Key Points of the Model

- Iterative: many releases/increments
  - First increment: core functionality
  - Successive increments: add/fix functionality
  - Final increment: the complete product
- Require a complete definition of the whole system to break it down and build incrementally

Pros and Cons

- Pros
  - Early discovery of software defects
  - Early delivery of working software
  - Less cost to change/identify requirements
- Cons
  - Constant changes (“feature creep”) may erode system architecture

When to use the model?

- The requirements of the complete system are clear
- Major requirements must be defined while some details can evolve over time
- Need to get a product to the market early

Spiral model vs. incremental model

- Iterative models
  - Most projects build software iteratively
- Risk-driven vs. client-driven

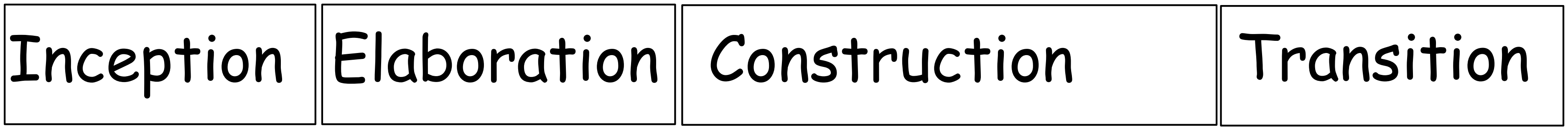
Unified Process (UP)

- An example of iterative process for building object-oriented systems
  - Very popular
  - By the same folks who develop UML
- It provides a context for our discussion of analysis and design

A Little History

- "The three amigos": Grady Booch, Ivar Jacobson, James Rumbaugh
  - Early 90s: Separated methodologies for object-oriented analysis and design (OOAD)
  - 1996: Created the Unified Modeling Language (UML)
  - 1999: Defined the Unified Process (UP) in Rational Software Inc.
    - Refinement: Rational Unified Process (RUP)
      - Adaptable process framework + tools

Phases in UP



- <u>Inception</u>: preliminary investigation
- <u>Elaboration</u>: analysis, design, and some coding
- <u>Construction</u>: more coding and testing
- <u>Transition</u>: beta tests and development
- Each phase may be enacted in an iterative way, and the whole set of phases may be enacted incrementally

Inception Phase

- Investigate approximate, business case, scope, and vague estimates
  - Should we even bother?
- Some basic analysis to decide whether to continue or stop
- Inception is NOT "requirement" in waterfall

Elaboration Phase

- Most requirement analysis
- Most design
- Some coding and testing
  - Implementation and testing for core architecture and high-risk requirements
- Deeper investigation of scope, risks, and estimates
- Work products
  - Requirement models (UML use cases)
  - An architectural description
  - A development plan

Construction Phase

- More coding and testing
  - Implementation and testing for the remaining lower risk and easier elements
  - Integration
- Work products ready for delivery
  - A working software system
  - Associated documentation

Transition Phase

- Beta tests and deployment
  - Moving the system from the development community to the user community
  - This is important but ignored in most software process model
- Work products
  - A documented software system that is working correctly in its operational environment

Iteration Length

- Iteration should be short (2-6 weeks)
  - Small steps, rapid feedback and adaptation
  - Massive teams with lots of communication – but no more than 6 months
- Iterations should be timeboxed (fixed length)
  - Integrate, test and deliver the system by a scheduled date
  - If not possible: move tasks to the next iteration

Reasons for Timeboxing

- Improve programmer productivity with deadlines
- Encourage prioritization and decisiveness
- Team satisfaction and confidence
  - Quick and repeating sense of completion, competency, and closure
  - Increase confidence for customers and managers

UP Disciplines

- Discipline: an activity and related artifact(s)
- Artifact: any kind of work product
- We will focus on artifacts related to two disciplines
  - Requirement modeling
    - requirement analysis + use-case models, domain models, and specs.
  - Design
    - design + design models

Agile Software Development

- A timeboxed iterative and evolutionary development process
- It promotes
  - adaptive planning
  - evolutionary development,
  - incremental delivery
  - rapid and flexible response to change

Any iterative method, including the UP, can be applied in an agile spirit.

The Agile Manifesto

Kent Beck et al. 2001

- We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:
  - Individuals and interactions over Processes and tools
  - Working software over Comprehensive documentation
  - Customer collaboration over Contract negotiation
  - Responding to change over Following a plan

Key Points of Agile Modeling

- The purpose of modeling is primarily to understand, not to document
- Modeling should focus on the smaller percentage of unusual, difficult, tricky parts of the design space
- Model in pairs (or triads)
- Developers should do the OO design modeling for themselves
- Create models in parallel
  - E.g., interaction diagram & static-view class diagram

Models are inaccurate

- Only tested code demonstrates the true design
- Treat diagrams as throw-away explorations
- Use the simplest tool possible to facilitate creative thinking
  - E.g., sketching UML on whiteboards
- Use “good enough” simple notation

Agile Methods

- Agile Unified Process (Agile UP)
- Dynamic systems development method (DSDM)
- Extreme programming (XP)
- Feature-driven development (FDD)
- Scrum

Agile UP

- Keep it simple
  - Prefer a small set of UP activities and artifacts
  - Avoid creating artifacts unless necessary
- Planning
  - For the entire project, there is only a high-level plan (Phase Plan), to estimate the project end date and other major milestones
  - For each iteration, there is a detailed plan (Iteration plan) created one iteration in advance

Pros and Cons

- Pros
  - Customer satisfaction by rapid, continuous delivery of useful software
  - Close, daily cooperation between business people and developers
  - Better software quality and lower cost
- Cons
  - People may lose sight of the big picture
  - Heavy client participation is required
  - Poor documentation support for training of new clients/programmers

When to use agile methods?

- Changing requirements
- Faster time to market and increased productivity
- Frequently used in start-up companies

A Borrowed Joke

How many software engineers does it take to change a light bulb?

Five. Two to write the specification, one to screw it in, and two to explain why the project was late.