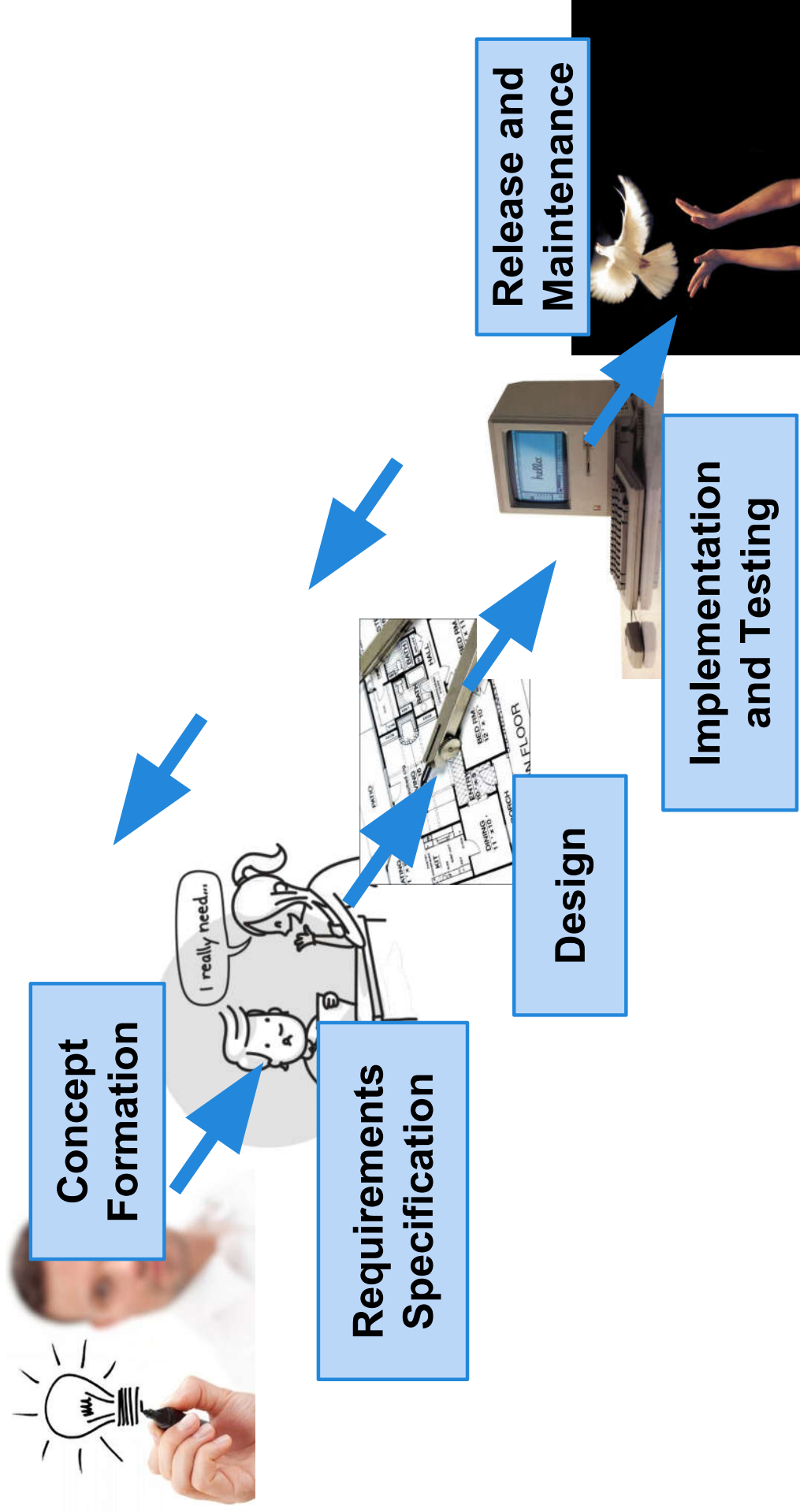


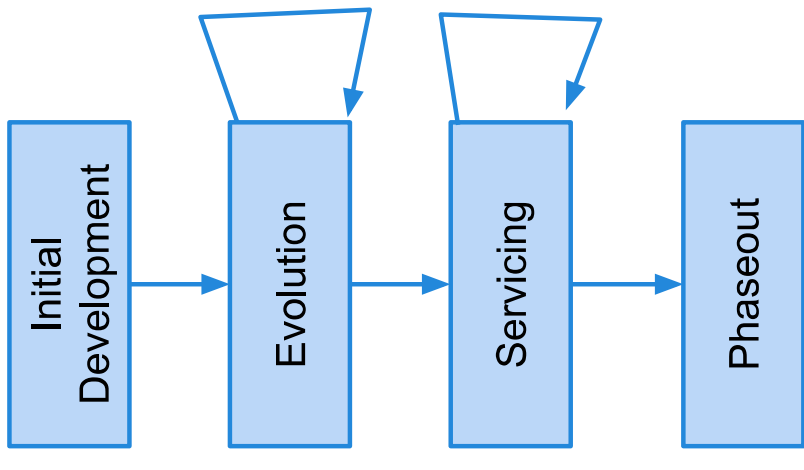
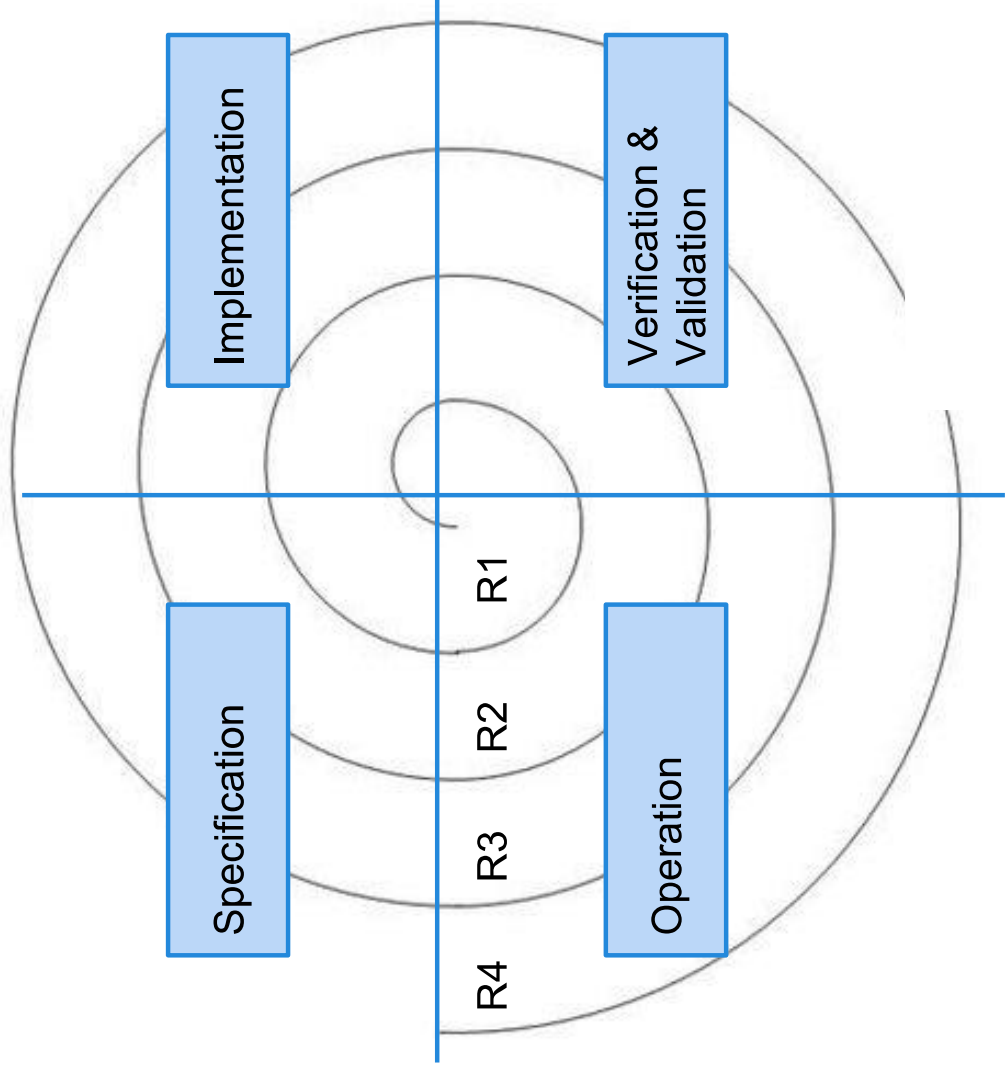
We Will Cover

- We have written, rewritten, and obsessed over the requirements, design, and code.
- We have tested this software until it cried.
- Now what?
 - Maintenance, evolution, and what the %\$#& you do with bad legacy code.

The Software Lifecycle



The Real Lifecycle



Software Maintenance

- **Fault Repairs**
 - Changes made in order to correct coding, design, or requirements errors.
- **Environmental Adaptations**
 - Changes made to accommodate changes to the hardware, OS platform, or external systems.
- **Functionality Addition**
 - New features are added to the system to meet new user requirements.

Software Maintenance Effort

- Maintenance costs more than the initial development.
 - 2/3rds of budget goes to maintenance on average.
 - Up to four times the development cost to maintain critical systems.
- General breakdown:
 - 65% of effort goes to functionality addition
 - 18% to environmental adaptation
 - 17% to fault repair

Maintenance is Hard

It is harder to maintain than to write new code.

- Must understand code written by another developer, or code that you wrote long ago.
- Creates a “house of cards” effect.
- Developers tend to prioritize new development.

Smooth maintenance requires planning and design that supports maintainability.

The Laws of Software Evolution

- **Maintenance is an inevitable process.**
 - Requirements change as the environment changes.
 - Changing the software causes environmental changes, which leads to more requirement changes.
- **As changes occur, the structure degrades.**
 - When changes are made, the structure becomes more complex.
 - To prevent this, resources must go into *preventative maintenance* - refactoring to preserve and simplify the structure without adding to functionality.

The Laws of Software Evolution

- The amount of change in each release is approximately constant.
 - The more functionality introduced, the more faults.
 - A large functionality patch tends to be followed by a patch that fixes faults without adding additional functionality. Small functionality changes do not require a fault-correcting patch.
- Functionality must continually increase to maintain user satisfaction.

The Laws of Software Evolution

- The quality of the system will decline unless updated to work with changing environment.
- To improve quality, evolution must be treated as a feedback system.
 - Stakeholders must be continually involved in evolution, and changes should be influenced by their needs.

Preventative Maintenance

Partially adapted from Marty Stepp
<http://www.cs.washington.edu/403/>

Refactoring

- Process of revising the code or design to improve its structure, reduce complexity, or otherwise accommodate change.
- When refactoring, you do not add functionality.
- Continuous process of improvement throughout the evolution of the system.

Why Refactor?

Why fix what isn't broken?

- Components have three purposes:
 - To perform a service.
 - To allow change.
 - To be understood by developers reading it.
- If it does not do any of these, it is “broken”.
- Enables change and improves understandability.

Refactoring is an Iterative Process

- Refactoring should take place as an iterative cycle of small transformations.
 - Choose a small part of the system, redesign it, and make sure it still works.
 - Choose a new section of the system and refactor it.
- Refactoring requires unit tests.
 - Make sure the code works before and after.

Choosing What to Refactor

- Refactor any piece of the system that:
 - Seems to work,
 - But isn't well designed,
 - And now needs new functionality.
- There are stereotypical situations that indicate the need for refactoring.
 - These are called “**bad smells**” .

Code Smells

- **Code is duplicated** in multiple places.
- A method is **too long**.
- Conditional statements control behavior based on an **object type**.
- Groups of data **attributes are duplicated**.
- A class has **poor cohesion** or **high coupling**.
- A method has **too many parameters**.
- **Speculative generality** - adding functionality that “we might need someday.”

More Code Smells

- Changes must be made in **several places**.
- **Poor encapsulation** of data that should be private.
- If a **weak subclass** does not use inherited functionality.
- If a class contains **unused code**.
- If a class contains **potentially unused attributes** that are only set in particular circumstances.
- There are data classes containing only attributes, getters, and setters, but nothing else - **objects should encapsulate data and behaviors**.
 - Unless that data is used by multiple classes.

Common Refactorings

(more at <http://www.refactoring.com>)

Composing Methods

- Extract Method
- Inline Method; Inline Temp
- Introduce Explaining Variable
- Split Temporary Variable
- Remove Assignments to Parameters
- Substitute Algorithm

Moving Features Between Objects

- Move Method; Move Field
- Extract Class
- Inline Class
- Hide Delegate
- Remove Middleman
- Introduce Foreign Method

Organizing Data

- Replace Data Value with Object
- Change Value to Reference; Change Reference to Value
- Replace Array with Object
- Duplicate Observed Data
- Change Unidirectional Association to Bidirectional
- Change Bidirectional Association to Unidirectional

Simplifying Conditional Expressions

- Decompose Conditional
- Consolidate Conditional Expression
- Consolidate Duplicate Conditional Fragments
- Replace Conditional with Polymorphism
- Introduce Null Object
- Introduce Assertion

Making Method Calls Simpler

- Rename Method
- Add/Remove Parameter
- Separate Query from Modifier
- Parameterize Method
- Replace Parameter with Explicit Methods
- Preserve Whole Object
- Replace Parameter with Method
- Introduce Parameter Object
- Remove Setting Method
- Hide Method
- Replace Constructor with Factory Method
- Encapsulate Downcast
- Replace Error Code with Exception
- Replace Exception with Test

Dealing with Generalization

- Pull Up Field; Method; Constructor Body
- Push Down Method; Push Down Field
- Extract Subclass; Extract Superclass; Interface
- Collapse Hierarchy
- Form Template Method
- Replace Inheritance with Delegation (or vice versa)

Big Refactorings

- Nature of the Game
- Tease Apart Inheritance
- Convert Procedural Design to Objects
- Separate Domain from Presentation
- Extract Hierarchy

Refactorings - Composing Methods

- If you have a complex code fragment that can exist independently, **extract it into its own method**.
- If you have a method that is extremely simple, **inline it** into locations where it is used.
- If you assign values to a temporary variable more than once, **split it into additional temporary variables**.
- If assignments are made to parameter variables in a method, instead **assign to a temporary variable**.
- If an algorithm is hard to understand, **swap it for a version that is clearer**.

Refactorings - Moving Features Between Objects

- If a method or field is used more by a calling class than the class it is placed in, **move** it.
- If a class is doing more work than it should (or has low cohesion), **extract** a subset of related methods into a new class.
- If a class is doing too little, **combine** it with another.
- If a class delegates too many calls to a middleman class, **get rid of the middleman** and call the client directly.
- If an imported class needs an additional method, but you can't modify it directly, **create a method in the client class with the imported object as a parameter.**

Refactorings - Conditional Expressions & Data

- If your conditional statements are too complex, **extract methods from the if, then, and else conditions**.
- If you have a sequence of conditional tests with the same result or repeated conditions in each branch, **consolidate them into fewer conditional statements**.
- If you have conditional statements to choose behavior based on object type, instead **use polymorphism**.
- If you have an attribute that needs additional data or operations, turn it into a new type of **data object**.
- If certain array values have special meaning, use **a class to store items instead**.

(Data Object: An API to store the data into database, or files)

Refactorings - Simplifying Method Calls and Generalization

- If a method both returns a value and changes the state of a passed object, split into two methods and **separate the query from the modifier**.
- If several methods do similar things - differentiated by value - create one method that takes the **value as a parameter**.
- If two classes have the same attribute/method/constructor body, **pull it up into the parent**. If an item is only used by some subclasses, **push it into the children**.
- If a class has features only used situationally, **extract subclasses** for those situations.

IDE Support for Refactoring

- Variable/method/class renaming
- Method or constant extraction
- Extraction of redundant code snippets
- Method signature change
- Extraction of an interface from a type
- Providing warnings about method invocations with inconsistent parameters
- Help with self-documenting code through auto-completion



Dangers of Refactoring

- Code that used to be well commented, well tested, and fully reviewed might not be any of these things after refactoring.
- You might have inserted faults into code that previously worked.
 - This is why unit tests are important. If the new code is broken, revert back to the old code.
- What if the new design is not better?

“I Don’t Have Time”

- Most common excuse for not refactoring.
- Refactoring incurs an up-front cost.
 - Developers don’t want to do it.
 - Neither do managers - they lose time and get “nothing” (no new features)
- Small companies (start-ups) avoid it.
 - “We can’t afford it.” “We don’t need it.”
- So do large companies.
 - “We’d rather add new features.”
 - “No one gets promoted for refactoring.”

“I Don’t Have Time”

- Refactoring is the key to effective evolution.
 - Enables rapid addition of new features, with fewer faults (up to a 500% ROI). (ROI: Return on Investment)
 - Good for programmer morale.
- Refactoring is an investment in a company’s prime asset - its code base.
- Many start-ups use cutting-edge tech and agile processes that evolve rapidly. So should the code.
- Some of the most successful companies (Google) reward and require refactoring.

Cutting-edge technology refers to technological devices, techniques or achievements that employ the most current and high-level IT developments


Refactoring at Google

- Victoria KIRST, Software Engineer

- "Refactoring is very important and inevitable for any code base. If you're writing a new app quickly and adding lots of features, your initial design will not be perfect. Do small refactoring tasks early and often, as soon as there is a sign of a problem."
- "Refactoring is unglamorous because it does not add features. At many companies, people don't refactor because you don't get promoted for it, and their code turns into hacky beasts." (Hacky: mean cutting into pieces)
- But...

Refactoring at Google

- Victoria Kirst, Software Engineer

- "Common reasons not to do it are incorrect:
 - **'Don't have time; features more important'** - You will spend more time adding features (because it's painful in current design), fixing bugs (bad code is easy to add bugs into), ramping up others on code (because bad code is hard to read), and adding tests (because bad code is hard to test).
 - **'We might break something'** - Sign of a poor design, where you didn't have good tests. For same reasons as above, you should fix your testing situation and code.
 - **'I want to get promoted and companies don't recognize refactoring work'** - This is a common problem. Seek buy-in from your team, gather data about regressions and flaws in the design, and encourage them to buy-in to code quality."

Activity - Code Smells

The following code for a product ordering system contains several “bad smells” - signs that the code is not well-designed and needs to be refactored.

- 1: Identify as many code smells as you can in this code. Explain why each is a problem.**
- 2: Explain how you would fix each.**

Activity - Solution

Some of the bad smells include:

- Duplicated Code
- Long Method
- Data Class
 - What does `lineltemList` even do?
- Speculative Generality
- An attribute is only set in certain circumstances
- Inconsistent use of comments.
- Inconsistent naming.
- Too much casting.
- ... and several more!

Legacy Systems and Reengineering

Dealing with Legacy Systems

Legacy systems are often difficult to understand and change. Options include:

- Get rid of the system.
- Leave it unchanged and only perform important maintenance.
- Reengineer the system to improve its maintainability.
- Replace all or part of the system.

Software Reengineering

- Large-scale changes to system structure to improve quality and understandability.
- May involve:
 - Redocumenting the system
 - Refactoring the source code
 - Translating to a modern programming language
 - Modifying the structure and values of data
- **Functionality is not changed, and architecture should be left mostly intact.**

Why Not Replace the System?

- Reduced Risk

- There is a high risk in redeveloping software. The current system might not be maintainable, but it has already been tested. Time to replace is hard to predict.

- Reduced Cost

- The cost of reengineering is often less than the cost of developing replacement components.
 - Up to four times cheaper in one study.

Reengineering Techniques

- Source Code Translation
 - Translation tools can update a program from an older version of a language to a more modern version to take advantage of new features.
- Reverse Engineering
 - The program can be analyzed automatically to help document its functionality and organization.
- Refactoring
 - The structure of the program can be refactored in stages to make it easier to read and understand.

Reengineering Techniques

- **Program Modularization**
 - Related parts of the program are grouped together and redundancy is removed. This may allow the extraction of relevant subsystems for newer projects.
- **Data Reengineering**
 - Data processed by the program is changed to reflect program changes. May involve defining database schemas and converting existing databases to modern forms. Mistakes in old data should also be corrected.

Know Your Limitations

- If the cost of reengineering or required effort is too high, then it may be worth replacing the code.
- There are practical limits to how much a system can be improved by reengineering.

No way to automatically:

- Convert functional to OO programs.
- Impose radical architectural or data management changes. (Radical: relating to or affecting the fundamental nature of something)

We Have Learned

- Engineering does not end with release.
 - Evolving a system involves fault fixes, environmental adaptations, and new features.
- System evolution leads to structural degradation.
- The degradation can be slowed by refactoring the code to restructure the source code and make additions native.

We Have Learned

- When working with legacy systems, those systems may need to be reengineered to work with modern components.
- Reengineering can improve understandability and maintainability of legacy systems, but has limitations.