Introduction to Software Engineering

What is Software Engineering?

- The establishment and use of sound engineering principles in order to obtain economically software that is reliable and works efficiently on real machines.

- As defined in IEEE Standard 610.12:
  - The application of a **systematic**, disciplined, **quantifiable** approach to the **development**, **operation**, and **maintenance** of **software**; that is, the application of engineering to software.

An Opinion

- These definitions are really pretty good
- But they are descriptive, not prescriptive
  - They do not say how to do anything
  - They just say what qualities S.E. should have
  - As a result many people understand SE differently

What is Software Engineering?

- Often compared to civil engineering
  - E.g., building a bridge
- A surprisingly good analogy
  - Size matters: a dog house vs. a skyscraper
  - Team effort with careful planning
  - Similar difficulties to change a given design
  - Many terms come from this metaphor:
    - building, scaffolding, architecture, components, …

What is particular about engineering?

- Any ideas?

What is particular about engineering?

- Many aspects, just some:
  - If you manage to get something to work, remember for next time
  - If something does not work, carefully analyze why and remember the pitfalls
  - Many products have a history of previous versions that get improved, don't start from scratch unless necessary
  - Use standard components with known properties
  - Work & Quality Assessment documented
  - Extensive testing of prototypes before production

Software Engineering vs. Civil Engineering

- But software building often cannot leverage components
  - "Computing is the only profession in which a single mind is obliged to span the distance from a bit to a few hundred megabytes, or nine orders of magnitude." Steve McConnell, "Code Complete"
- Physics guides civil engineering
  - "Einstein argued that there must be a simple explanation of nature, because God is not capricious or arbitrary. No such faith comforts the software engineer."

Software: Axis of variability

- Size
- How humans interact with it
- Requirements stability/knowledge
- Need for reliability
- Need for security
- Portability
- Cost

Microsoft Word

- Size:
- Interactiveness:
- Requirements:
- Reliability:
- Security:
- Portability:
- Cost:

Microsoft Word

- Size: large
- Interactiveness: high
- Requirements: frequent new features
- Reliability: moderate
- Security: low
- Portability: high
- Cost: high

Space shuttle software

- Size:
- Interactiveness:
- Requirements:
- Reliability:
- Security:
- Portability:
- Cost:

Space shuttle software

- Size: large
- Interactiveness: low
- Requirements: stable
- Reliability: very high
- Security: low
- Portability: low
- Cost: high

eBay software

- Size:
- Interactiveness:
- Requirements:
- Reliability:
- Security:
- Portability:
- Cost:

eBay software

- Size: moderate
- Interactiveness: high
- Requirements: frequent new features
- Reliability: moderate
- Security: high
- Portability: low
- Cost: low

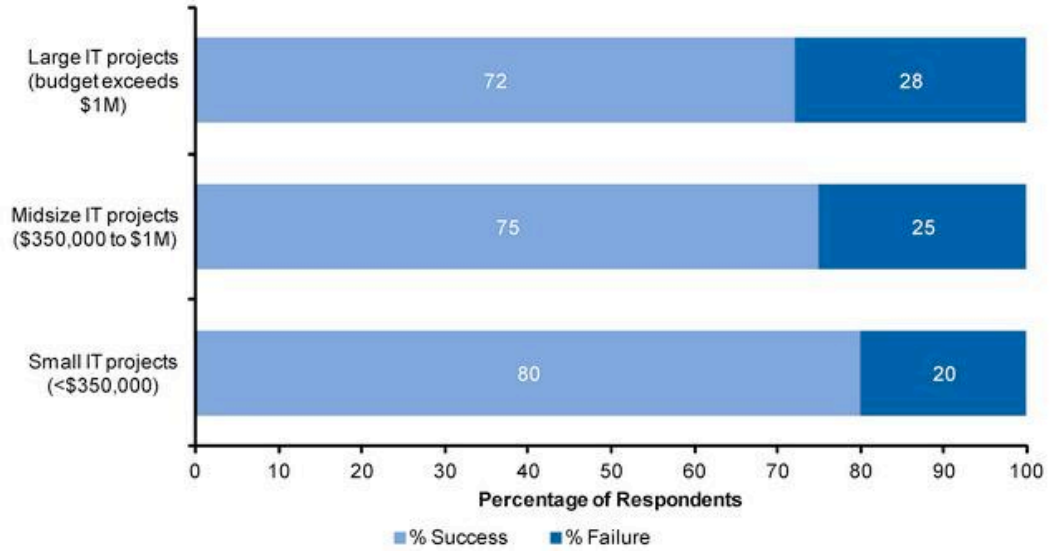
Sample Sizes

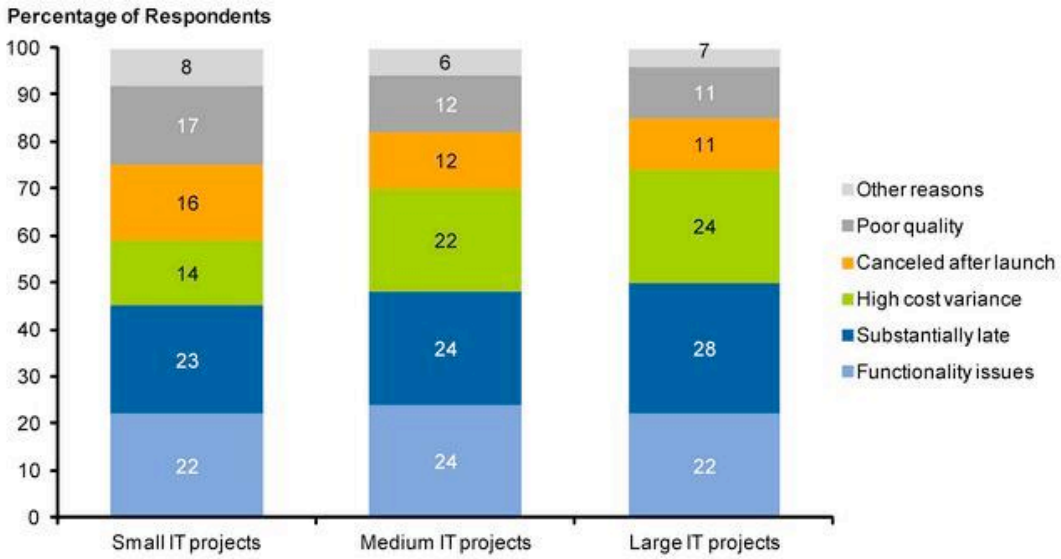
How many lines of code in…

- OS X
  - 86 million
    - http://www.engadget.com/2006/08/07/live-from-wwdc-2006-steve-jobs-keynote/
- Windows XP
  - 40 million
    - http://www.dwheeler.com/sloc/
- Open Office
  - > 10 million
    - http://www.ohloh.net/p/openoffice/analyses/latest
- Eclipse
  - > 10 million
    - http://www.ohloh.net/p/eclipse/analyses/latest

Size doesn't matter?

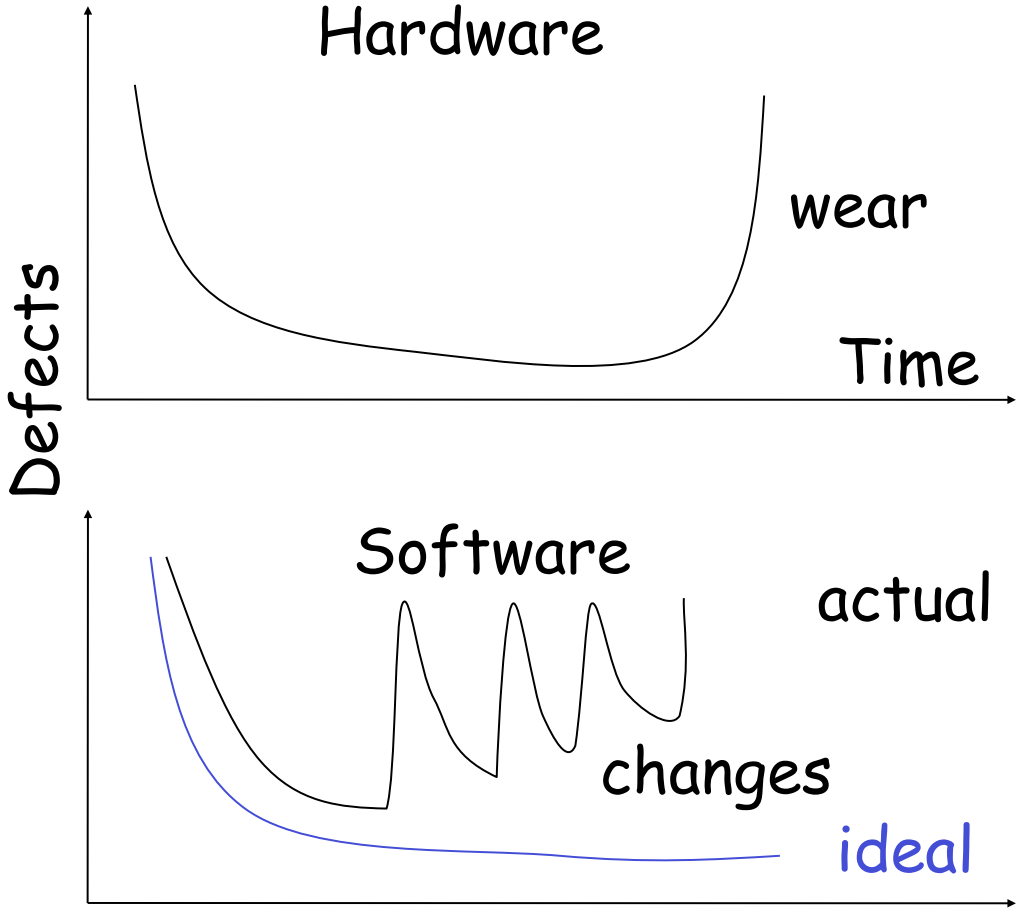
- 6 frequently mentioned reasons for project failure:
- Functionality issues
- Substantially late
- Quality issues
- High cost variance
- Canceled after launch
- Rejected or not implemented for other reasons



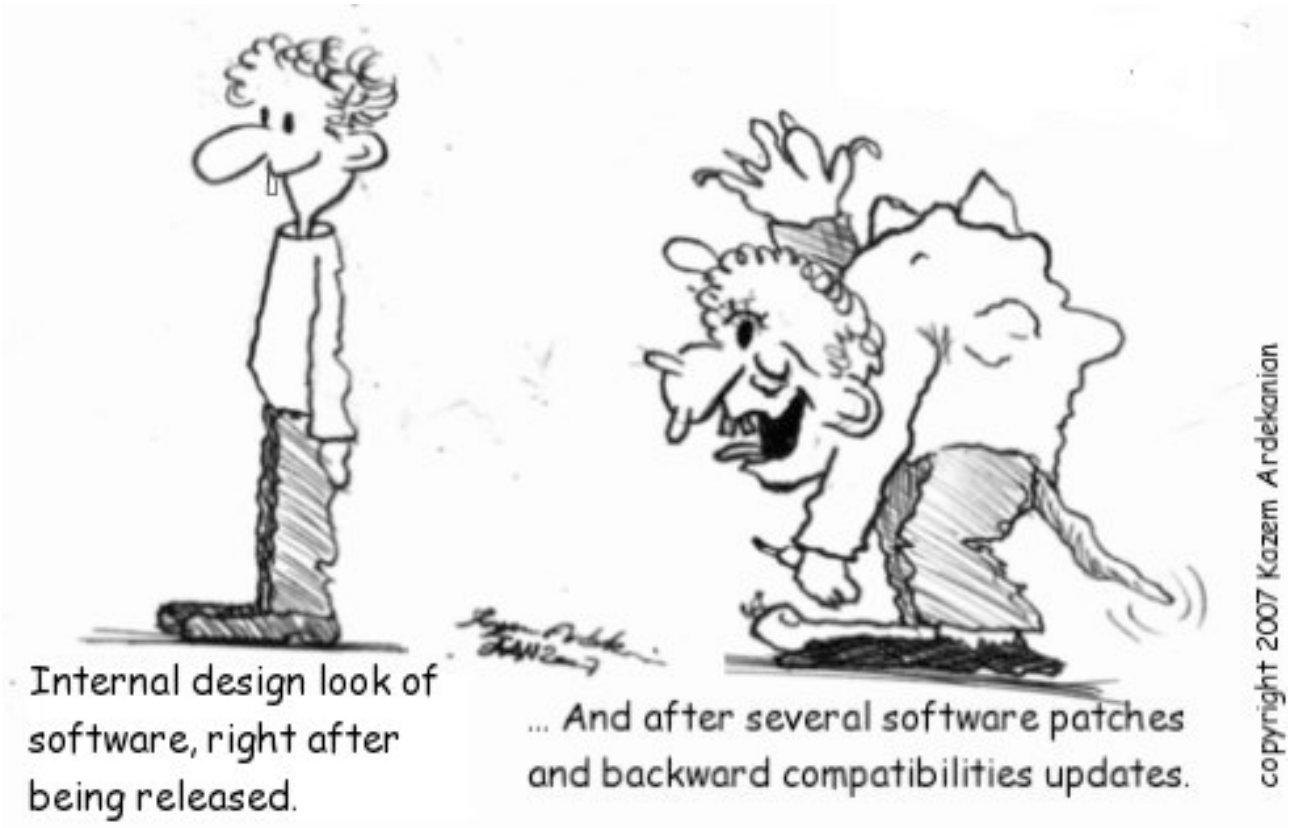


from http://thisiswhatgoodlookslike.com/2012/06/10/gartner-survey-shows-why-projects-fail/

Software vs. Hardware Reliability Curve



- Hardware wears out
- Software changes
  - or its environment changes
  - called "bit-rot"


Internal design look of software, right after being released.
... And after several software patches and backward compatibilities updates.
copyright 2007 Kazem Ardekanian

Software Engineering Myths: Management

- "We have books with rules. Isn't that everything my people need?"
  - Which book do you think is perfect for you?
- "If we fall behind, we add more programmers"
  - "Adding people to a late software project, makes it later" – Fred Brooks (The Mythical Man Month)
- "We can outsource it"
  - If you do not know how to manage and control it internally, you will struggle to do this with outsiders

Software Engineering Myths: Customer

- "We can refine the requirements later"
  - A recipe for disaster.
- "The good thing about software is that we can change it later easily"
  - As time passes, cost of changes grows rapidly

Software Engineering Myths: Practitioner

- "Let's write the code, so we'll be done faster"
  - "The sooner you begin writing code, the longer it'll take to finish"
  - 60-80% of effort is expended after first delivery
- "Until I finish it, I cannot assess its quality"
  - Software and design reviews are more effective than testing (find 5 times more bugs)
- "There is no time for software engineering"
  - But is there time to redo the software?

My List: What is Software Engineering For?

- We want to build a system
- How will we know the system works?
- How do we develop a system efficiently?
  - Minimize time
  - Minimize costs
  - Minimize …

Problem 1: How Do We Know It Works?

- Buggy software is a huge problem
  - But you likely already know that
- Defects in software are commonplace
  - Much more common than in other engineering disciplines
- Examples
  - (your exploration of recent IT disasters)
- This is not inevitable---we can do better!

What is It?

- But how do we know behavior is a bug?

Software Bug => Space Disaster

- Ariane 5 Space mission
- $7,000,000,000
- 10 Years in the making
- 40 seconds after take off the rocket exploded

Software Bug => Space Disaster

Smoke from the explosion
June 4, 1996 (AP Photo)

Attempt to cram a 64-floating point number to a 16-bit integer failed

AT&T long distance service failed for 9 hours

- On January 15, 1990, one of AT&T's #4ESS toll switching systems in New York City experienced an intermittent failure that caused a major service outage.
- Wrong BREAK statement in C-Code
- Complete coverage could have revealed this bug during testing

```
/* ``C'' Fragment to Illustrate AT&T
   Defect */


do {
   switch expression {
         ...
         case (value):
                  if (logical) {
                       some statements
                       break;
                  }
                  else
                  {
                        some statements
                  }
                  more statements
         case (value2):
                  ...
}
...
```


Reference: ACM SIGSOFT, Software Engineering Notes, Vol. 15, No. 2, Page 11ff, April 1990

Software Bugs: Cause of Deaths

- Several deaths of cancer patients were due to overdoses of radiation resulting from a race condition between concurrent tasks in the Therac-25 software.

180 Degree Bug

Torpedoes, that deviate more than 90 degrees, explode to avoid self destruction of the ship.

Once upon a time a ship fired a torpedo but the torpedo was jammed in the tube. Then the captain gave the command: Let's turn around and return to the harbor!

... No, they did not live happily ever after.

What is It?

- But how do we know behavior is a bug?

- Because we have some separate specification of what the program must do
  - Separate from the code

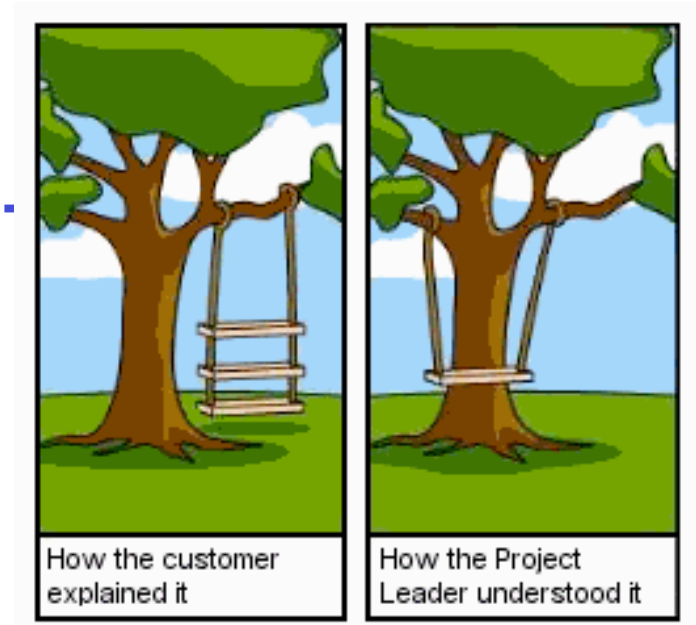
- Thus, knowing whether the code works requires us first to define what "works" means
  - A specification

Teams and Specifications

- Do we really need to write specifications?

- People will
  - Discuss what to do
  - Divide up the work
  - Implement incompatible components
  - Be surprised when it doesn't all just work together

How the customer explained it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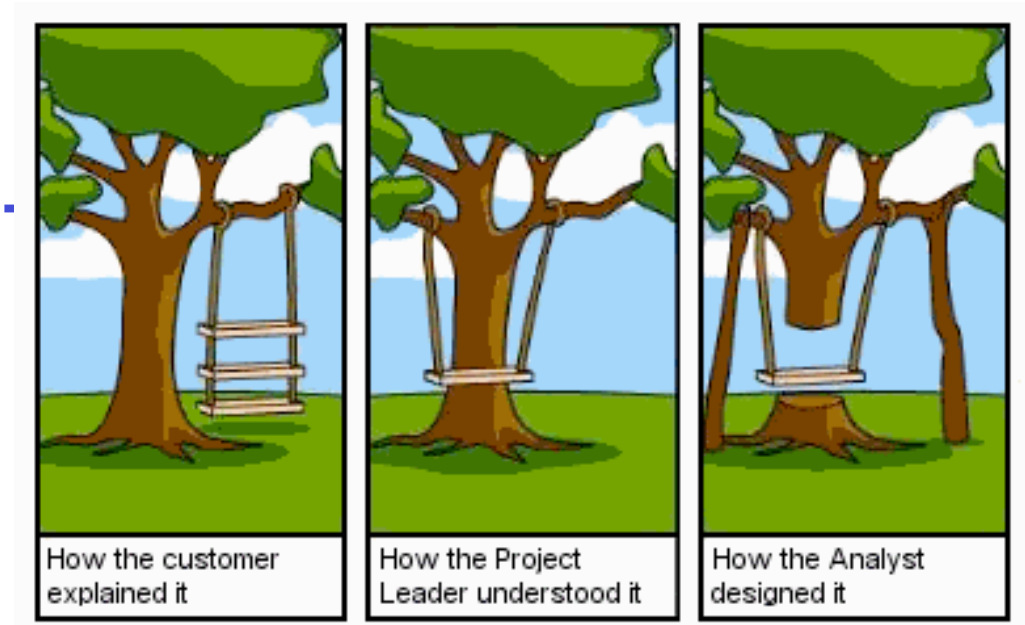
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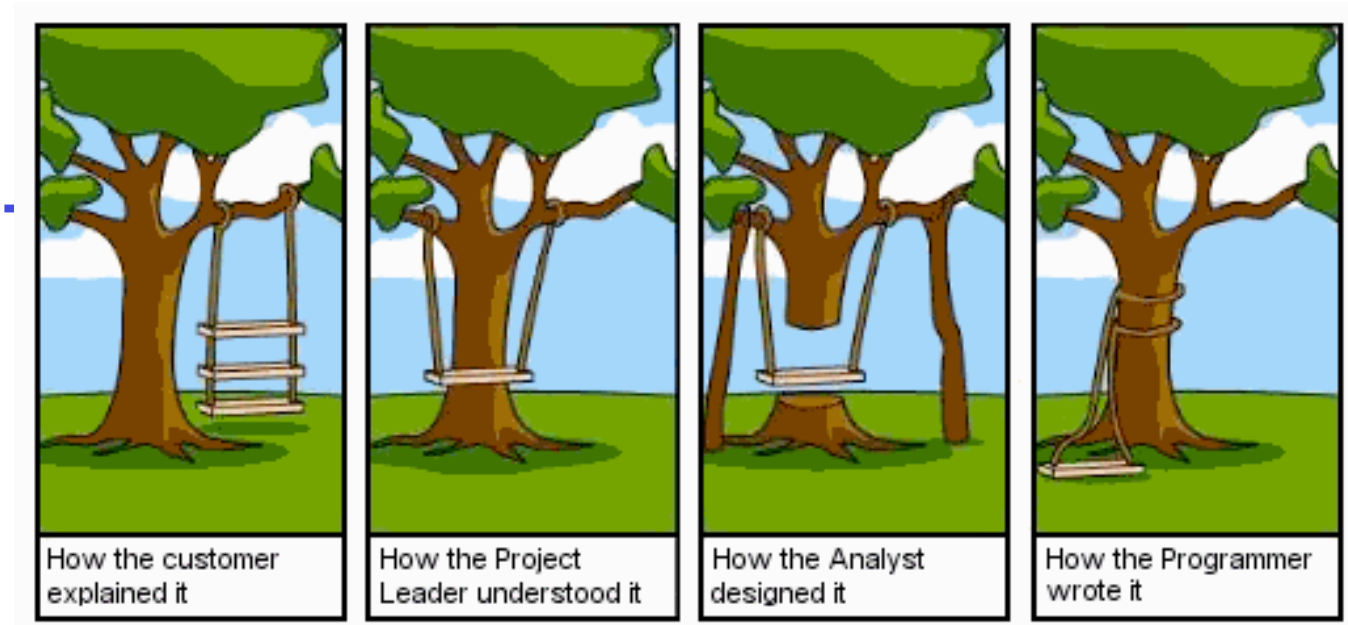
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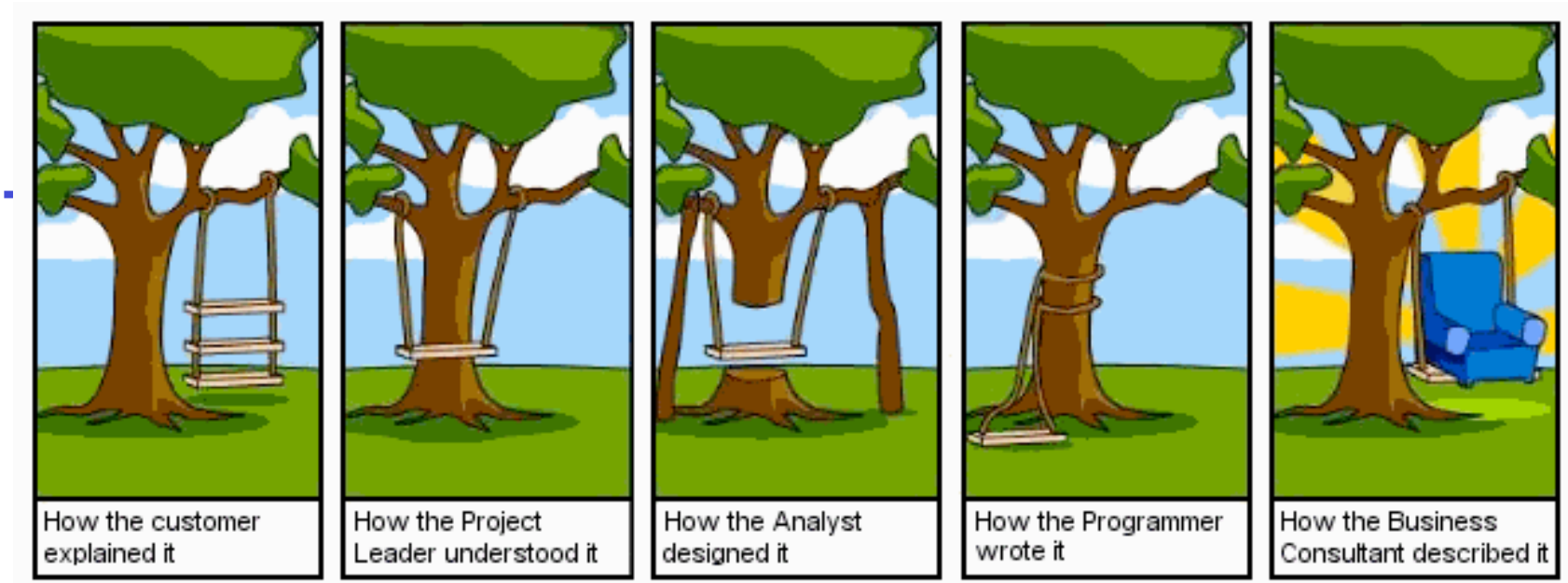
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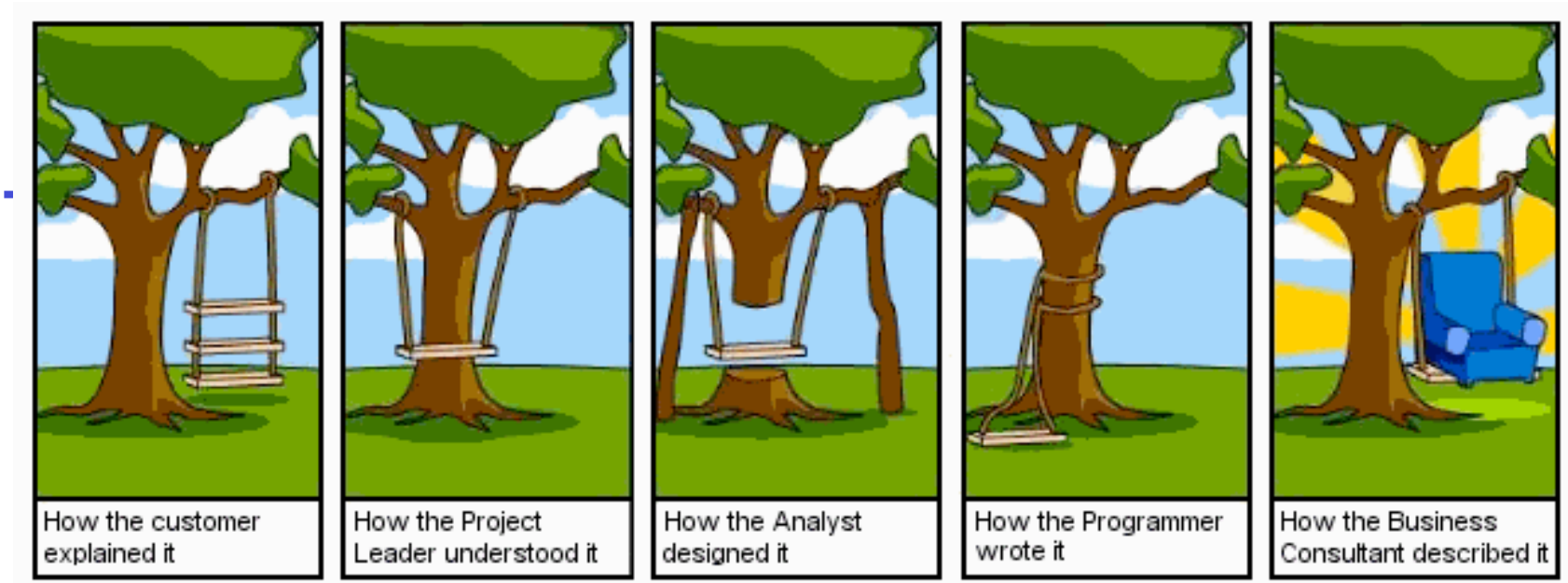
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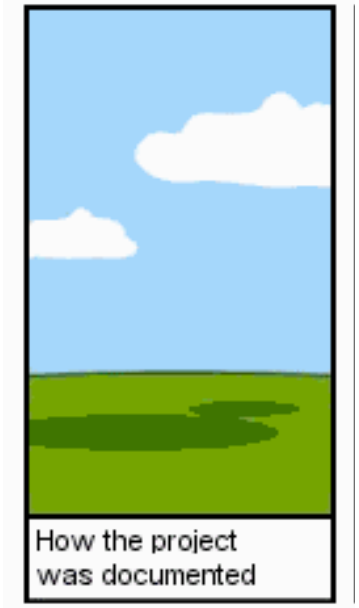
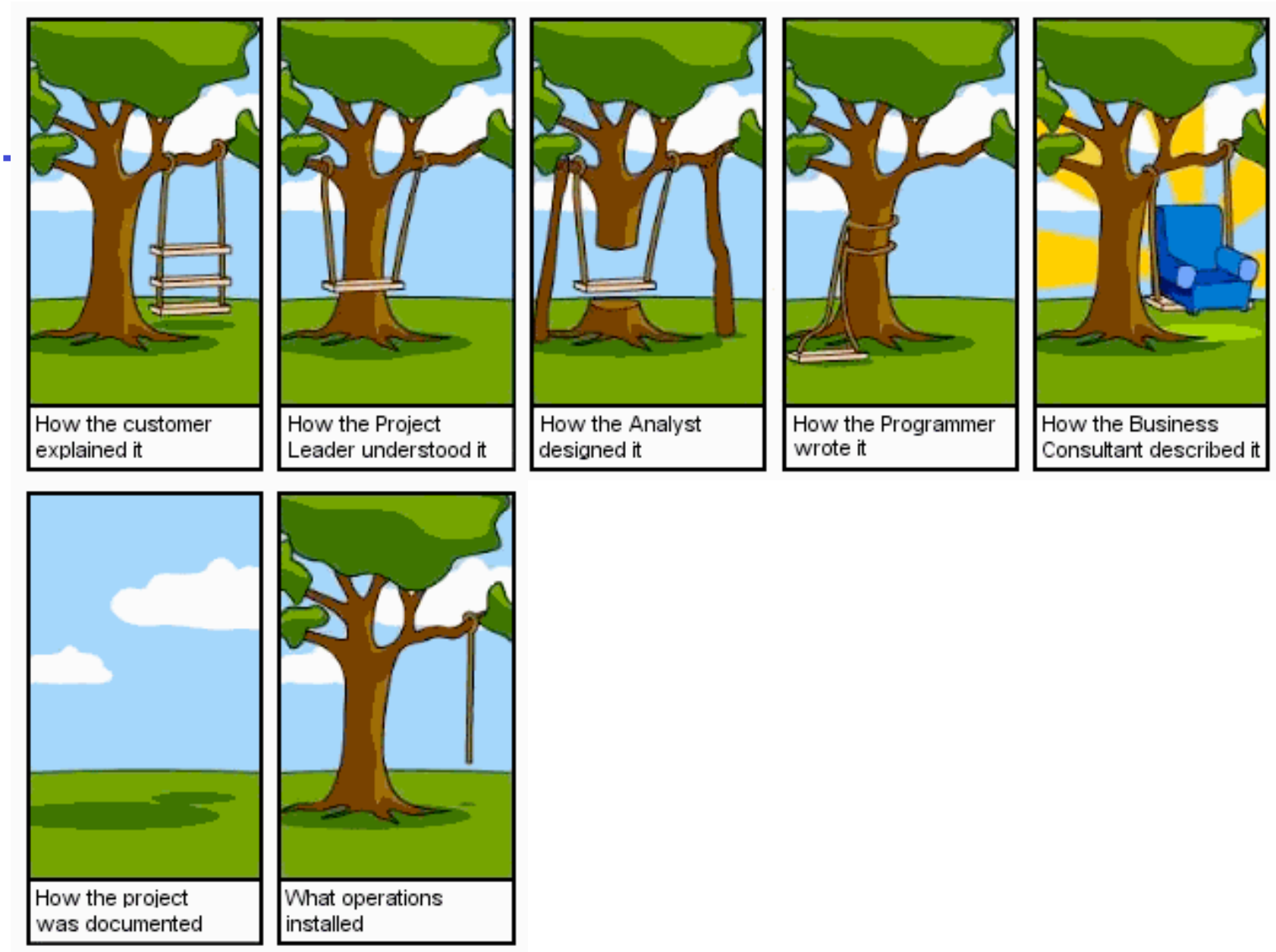

How the project was documented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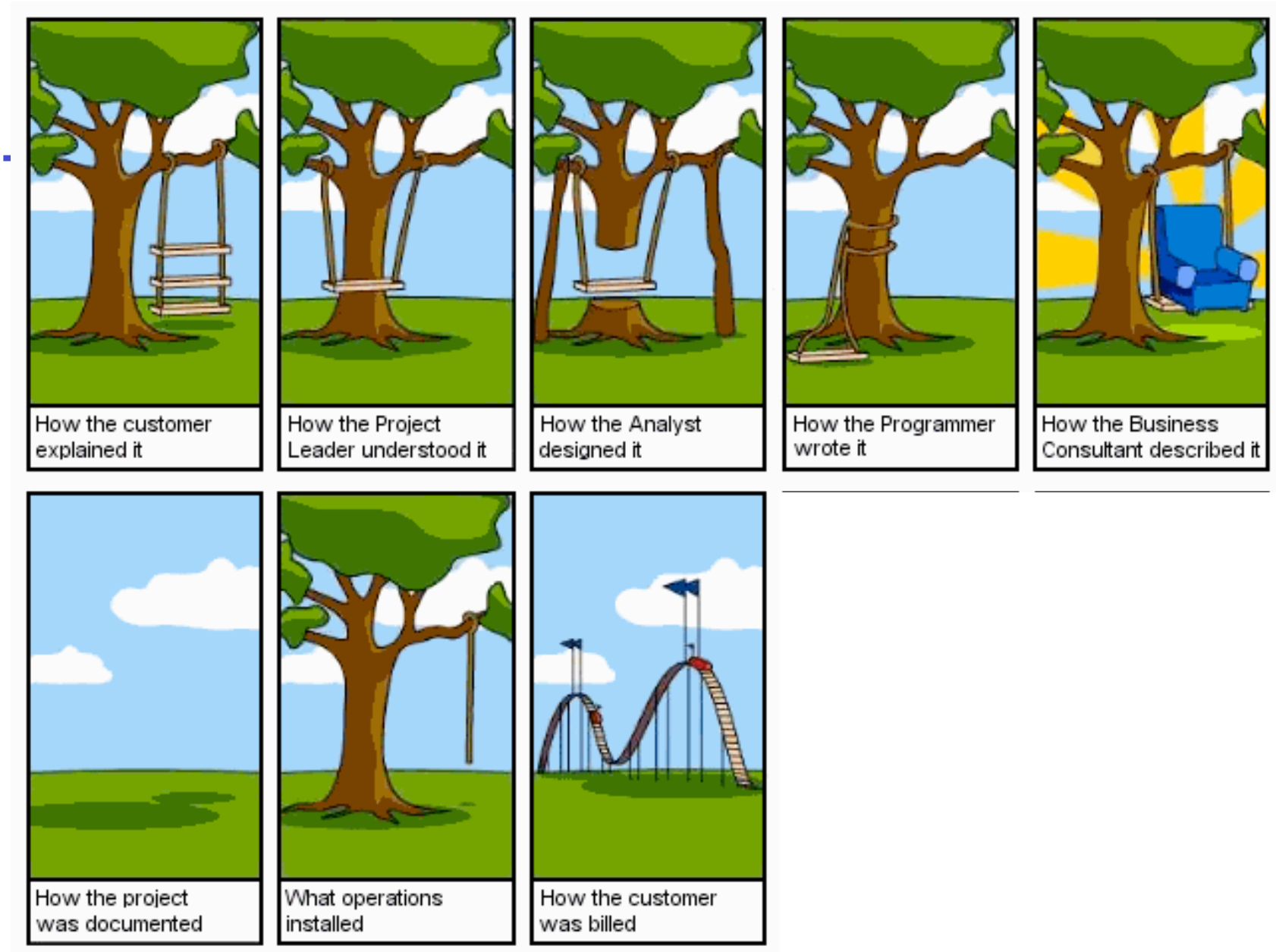
What operations installed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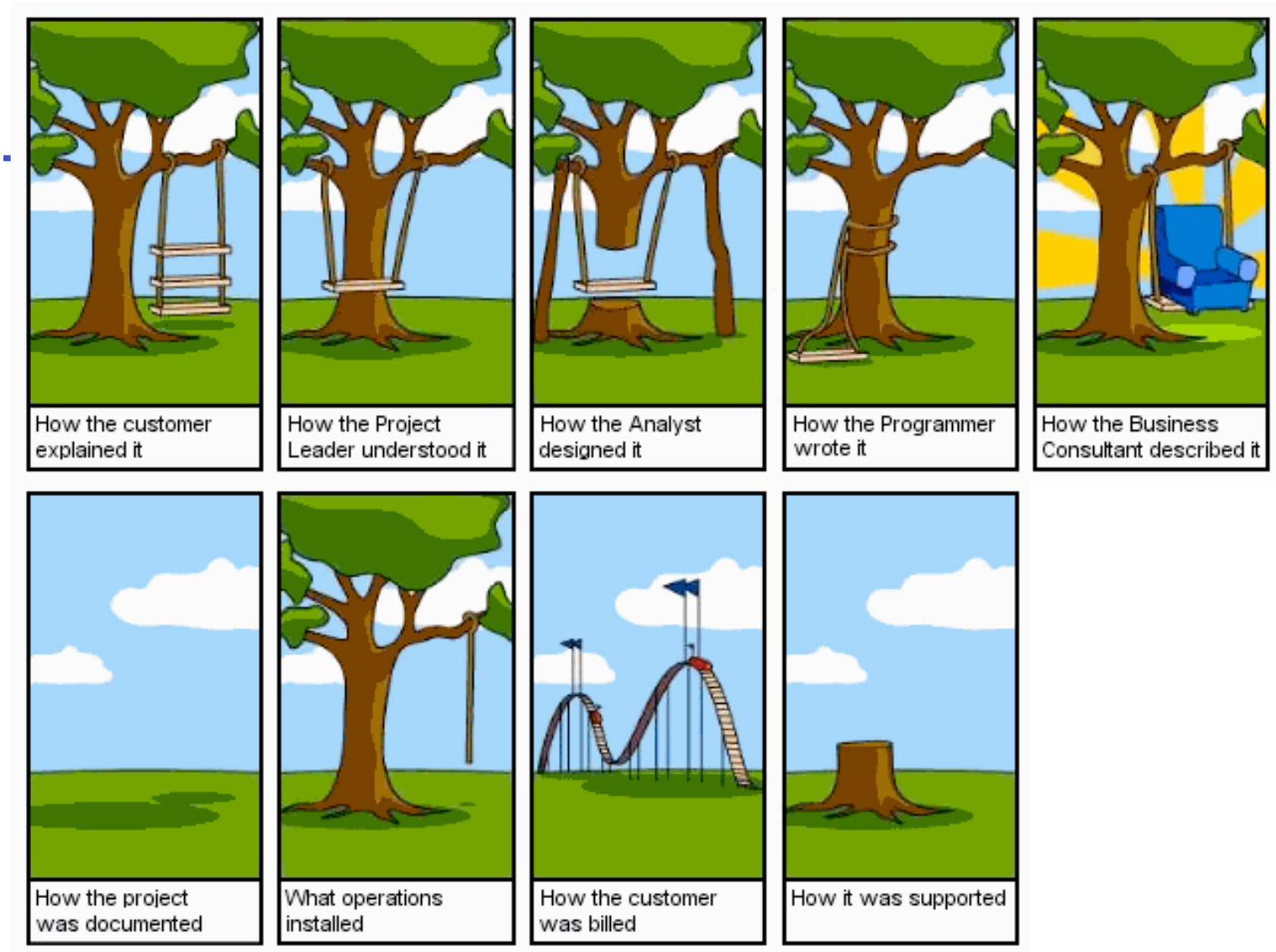
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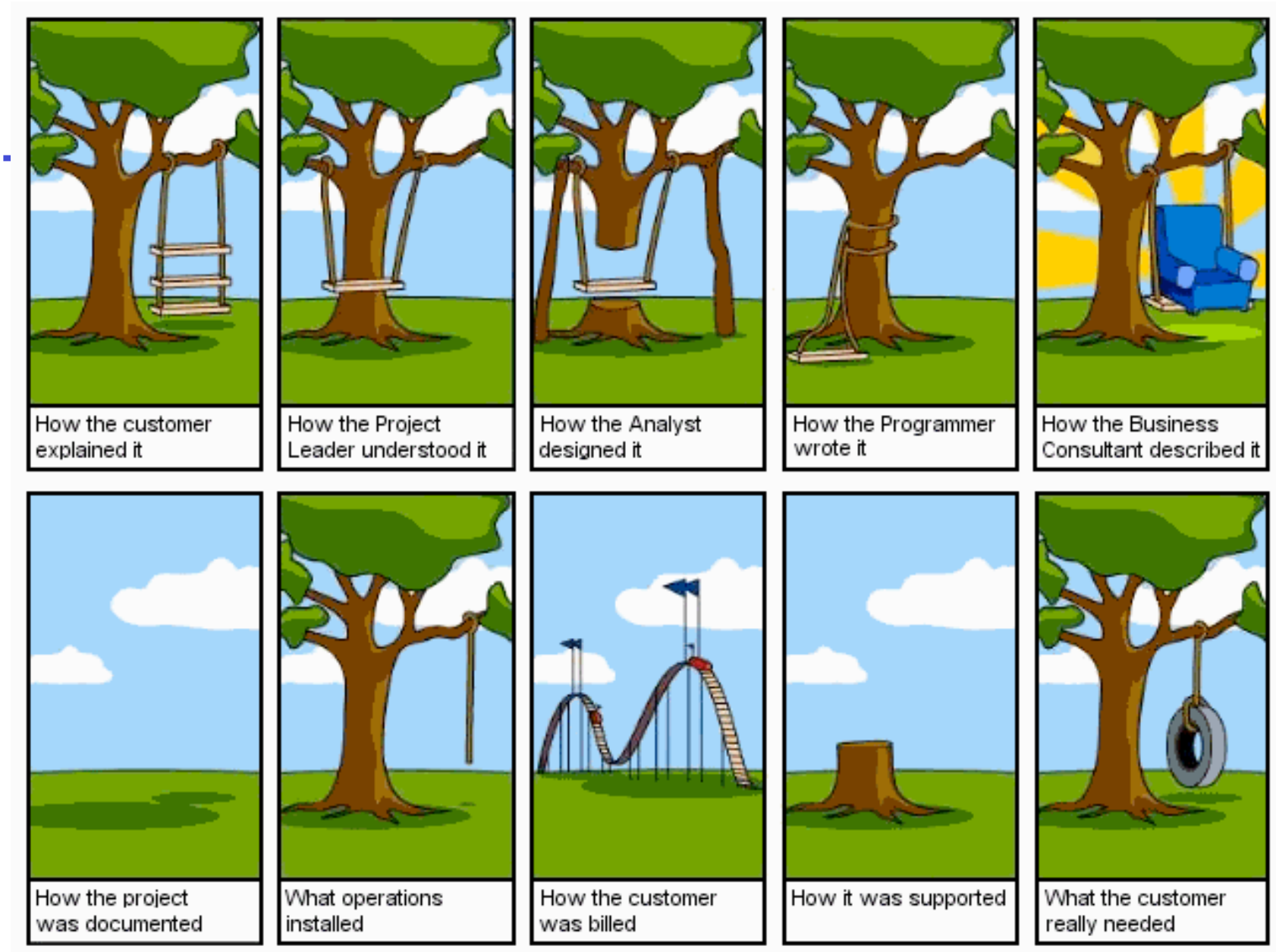
How it was supported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How the project was documented
What operations installed
How the customer was billed
How it was supported
What the customer really needed

What Can We Do?

- Write specifications
  - Write down what it is supposed to do
  - Make sure everyone understands it
  - Keep the specification up to date

- This does not solve the problem completely
  - There are always ambiguities, contradictions
  - These lead to bugs
  - But the problem is reduced to manageable size

Summary of Problem #1

- A specification allows us to:
  - Check whether software works
  - Build software in teams at all
- Actually checking that software works is hard
  - Code reviews
  - Static analysis tools
  - Testing and more testing
  - We will examine this problem closely

Problem #2: How Do We Code Efficiently?

- Assume we want to minimize time
  - Usually the case
  - Time-to-market exerts great pressure in software
- How can we code faster?
  - Obvious answer: Hire more programmers!

Parallel Development

- How many programmers can we keep busy?
  - As many as there are independent tasks
- People can work on different modules
  - Thus we get parallelism
  - And save time
- What are the pitfalls?

Pitfalls of Parallel Development

- The problems are the same as in parallel computing
- More people = more communication
  - Which is hard
- Individual tasks must not be too fine-grain
  - Increases communication overhead further
- Inherent sequential constraints
  - E.g., pipeline architecture

Interfaces

- The chunks of work must be independent
  - But work together in the final system
- We need interfaces between the components
  - To isolate them from one another
  - To ensure that the final system works
- The interfaces must not change (much)!

Defining Interfaces

- What are interfaces?
- They are just specifications!
- But of a special kind
  - Interfaces are the boundaries between components
    - And people

Defining Interfaces

- Specifying interfaces is most important
  - Interfaces should not change a lot
  - Effort must be spent ensuring everyone understands the interfaces
  - Both things require preplanning and time
- But often we can stop at specifying interfaces
  - Let individual programmers handle the internals themselves

Software Architecture

- To define interfaces, we must decompose a system into separate pieces with boundaries
- How do we do this?
- Your thoughts

My Opinions

The decomposition of a system is driven by:

- What it does
- How we build it
- Who builds it

Decomposition: What the System Does

- The application itself often dictates natural decomposition

- A compiler is a pipeline consisting of
  - Lexer
  - Parser
  - Type checker
  - Optimizer
  - Etc.

Decomposition: How We Build It

- Buildings need scaffolding during construction
- So does software!

- Two areas in particular:
  - Lots of extra code that is not really part of the final product
  - Influence of third-party subsystems

- Test harnesses, stubs, ways of building and running partial systems

Decomposition: Who Builds It

- Software architecture reflects the structure of the organization that builds it

- Often, 5 developers = 5 components

Summary of Problem #2

- Efficient development requires
  - Decomposing system into pieces
  - Good interfaces between pieces
- The pieces should be large
  - Don't try to break up into too many pieces
- Interfaces are specifications of boundaries
  - Must be well thought-out and well communicated

Conclusions

- Software engineering boils down to several issues:
  - Specification: Know what you want to do
  - Design: Develop an efficient plan for doing it
  - Programming: Do it
  - Validation: Check that you have got what you wanted
- Specifications are important
  - To even define what you want to do
  - To ensure everyone understands the plan

Conclusions (Cont.)

- Is that all?
- NO!
- Why?
  - Because specifications do change!
  - Because you were wrong about what you wanted
  - Because the world changes
  - We'll talk about this next time . . .

Caveats in This Course

- CS Professors usually good at well-defined technical problems
- May not be great at ill-defined non-technical problems
- Take everything in this class with a pinch of salt
  - Ultimately, the most important things you learn are those you learn through experience

Acknowledgements

- Many slides courtesy of Rupak Majumdar