Semester Wrap-Up

CSCI 5828: Foundations of Software Engineering
Lecture 03 — 05/03/2012

Goals

- Present a review of the topics covered in class this semester

Four Main Topics

- Software Engineering Fundamentals
- Software Life Cycles
  - Agile philosophy and techniques
- Software Testing
  - Behavior and Test Driven Development
- Software Concurrency
  - Design and Implementation of Concurrent Software Systems

SE Fundamentals (I)

- What is Software Engineering
  - Software engineering is that form of engineering that applies…
    - a systematic, disciplined, quantifiable approach,
    - the principles of computer science, design, engineering, management, mathematics, psychology, sociology, and other disciplines…
  - to creating, developing, operating, and maintaining cost-effective, reliably correct, high-quality solutions to software problems. (Daniel M. Berry)
- Fred Brooks's No Silver Bullet
  - Progress will be made on software engineering in terms of our ability to be produce high quality software on time and under budget
    - But it will be hard work! No one technique is going to "save us"

SE Fundamentals (II)

- Overview of Software Life Cycles
  - In SE, Process is King!
    - Examined transition and differences between traditional waterfall methods and more recent agile approaches
- Overview of Software Testing
  - Errors, Faults, and Failures
  - Black box, gray box, and white box
  - Folding and Sampling
  - Test Driven Development

SE Fundamentals (III)

- Overview of Concurrency
  - Why the design of concurrent software systems is important
    - Chips are getting “wider” not faster
  - But concurrency is hard
    - race conditions, deadlock, etc.
  - It’s especially hard if you continue to do concurrency the way we’ve always done it
    - Shared mutability, low-level threading primitives, locks
  - We then examined higher-level abstractions that avoid these problems

Agile (I)

- A software development philosophy and a set of practices
  - that values
    - communication over process
    - communication over documents
    - communication over tools
    - <do you notice a pattern?>
    - and advocates a set of practices that help developers embrace the fact that change in software development is inevitable
      - Don’t hide from it!

Agile (II)

- Specific Techniques
  - Agile Inception Deck: Make sure the team and the customer are aligned
  - User Stories
  - Iteration Plan
  - Burn-Down Charts
  - Test Driven Development
  - Continuous Integration
  - Configuration Management

Software Testing

- Test Automation Frameworks
  - Cucumber as the example
    - How to get your customer to write tests
    - How to maintain separation between
      - test code and the system under test
  - Examined strategies for keeping test code abstract
    - while underneath via glue code the system under test could grow
      - from simple model code to full fledged system with UIs, web services, etc.

Concurrency

- Fairly broad coverage of concurrency techniques at the individual system level
  - Typical threading primitives and the problems associated with them
  - java.util.concurrent
    - notion of separation of thread and task
    - and the need for a thread allocation strategy
  - Styles of Concurrency: shared mutability, isolated mutability, ...
  - “New” concurrency models
    - Software Transactional Memory, Agent Model, Grand Central Dispatch

Two Aspects of Concurrency Not Explored

- A Multi-Process Approach to Concurrency
  - With this approach your “system” is a bunch of individual programs where
    - each individual program is single threaded and thus easier for developers to understand and maintain
    - concurrent operation comes from the fact that the operating system will run these processes at the same time on different cores
    - coordination occurs via inter-process communication or via the file system
- MapReduce
  - can be done in individual programs but also enables large scale distribution of computation across clusters of machines

MapReduce

MapReduce

- To understand MapReduce, we must first talk about functional programming
  - We encountered functional programming when we looked at Clojure in the context of STM and in our discussions of pure immutability
- Functional programming is an approach to programming language design in which functions are
  - first class values (with the same status as int or string)
    - you can pass functions as arguments, return them from functions and store them in variables (as we saw with blocks in GCD)
  - and have no side effects
    - they take input and produce output
    - this typically means that they operate on immutable values

Example (I)

- In python, strings are immutable
  - a = “Ken @@@”
  - b = a.replace(“@”, “!”)
  - b
    - 'Ken !!!'
  - a
    - 'Ken @@@'
- Replace is a function that takes an immutable value and produces a new immutable value with the desired transformation; it has no side effects

Example (II)

- Functions as values (in python)
  - def Foo(x, y):
    - return x + y
  - add = Foo
  - add(2, 2)
    - 4
- Here, we defined a function, stored it in a variable, and then used the “call syntax” with that variable to invoke the function that it pointed at

Example (III)

- continuing from previous example
  - def DoIt(fun, x, y): return fun(x,y)
  - DoIt(add, 2, 2)
    - 4
- Here, we defined a function that accepts three values, some other function and two arguments
  - We then invoked that function by passing our add function along with two arguments ;
  - DoIt() is an example of a **higher-order function**: functions that take functions as parameters
  - Higher-order functions are a common idiom in functional programming

Relationship to Concurrency?

- How does this relate to concurrency?
  - It leads naturally to the pure immutability style of concurrent design
    - Each thread operates on immutable data structures using functions with no side effects
    - A thread’s data structures are not shared with other threads
    - Work is performed by passing messages between threads
      - If one thread requires data from another, that data is copied and then sent
- As we’ve seen, such an approach allows each thread to act like a single-threaded program; no danger of interference

Map, Filter, Reduce

- Three common higher order functions are **map**, **filter**, **reduce**
- map(fun, list) -> list
  - Applies fun() to each element of list; returns results in new list
- filter(fun, list) -> list
  - Applies boolean fun() to each element of list; returns new list containing those members of list for which fun() returns True
- reduce(fun, list) -> value
  - Returns a value by applying fun() to successive members of list (total = fun(list[0], list[1]); total = fun(total, list[2]); …)

Examples

- list = [10, 20, 30, 40, 50]

- def double(x): return 2 * x
- def limit(x): return x > 30
- def add(x,y): return x + y

- map(double, list) returns [20, 40, 60, 80, 100]
- filter(limit, list) returns [40, 50]
- reduce(add, list) returns 150

Implications

- map is very powerful
  - especially when you consider that you can pass a list of functions to it and then pass a higher-order function as the function to be applied
    - for example
      - def DoIt(x): return x()
      - map(DoIt, [f(), g(), h(), i(), j(), k()])
- But the real power, with respect to concurrency is that map is simply an abstraction that can, in turn, be implemented in a number of ways

Single Threaded Map

- We could for instance implement map() like this:
    - def map(fun, list):
        - results = []
        - for item in list:
            - results.append(fun(item))
- This would implement map in a single threaded fashion

Multi-threaded Map

- We could also implement map like this (pseudocode):
  - def Mapper(Thread):
    - def __init__(… fun, list): …
    - def run():
      - self.results = map(fun, list)
  - def xmap(fun, list):
    - split list into N parts where N = number of cores
    - create N instances of Mapper(fn, list_i)
    - wait for each thread to end (in order) and grab results
    - append thread results to xmap results
    - return xmap results

Note: threads can complete in any order since each computation is independent

Super Powerful Map

- We could also implement map like this:
  - def supermap(fun, list):
    - divide list into N parts where N equals # of machines
    - send list_i to machine i which then invokes xmap
    - wait for results from each machine
    - combine into single list and return
- Given this implementation, you can apply a very complicated function to a very large list and have (potentially) thousands of machines leap into action to compute the answer

Google

- Indeed, this is what Google does when you submit a search query:
  - def aboveThreshold(x): return x > 0.5 <-- just making this up
  - def probabilityDocumentRelatedToSearchTerm(doc): …
  - searchResults =
    - filter(aboveThreshold,
      - map(probabilityDocumentRelatedToSearchTerm,
        - [<entire contents of the Internet]))

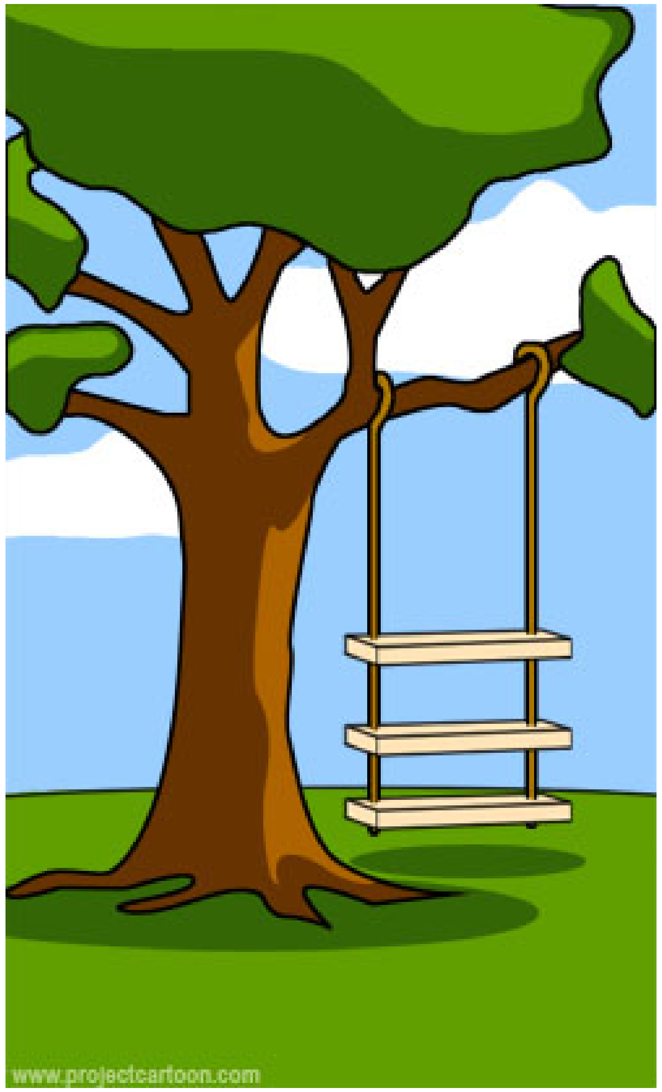
Difference between map and xmap?

- The team behind Erlang published results concerning the difference between map and xmap
  - They make a distinction between
    - CPU-bound computations with little message passing vs.
    - lightweight computations with lots of message passing
- With the former, xmap provides linear speed-up (10 CPUs provides a 10x speed-up, then declining) over map
  - the latter less so (10 CPUs provided 4x speed-up)
  - Indeed, xmap’s performance in the latter case tends to max out at 4x no matter how many CPUs were added

How Projects Really Work

- Our last lesson for the semester involves insight into how software development projects **REALLY** work
  - Taken from www.projectcartoon.com

How Projects Really Work



How the customer explained it

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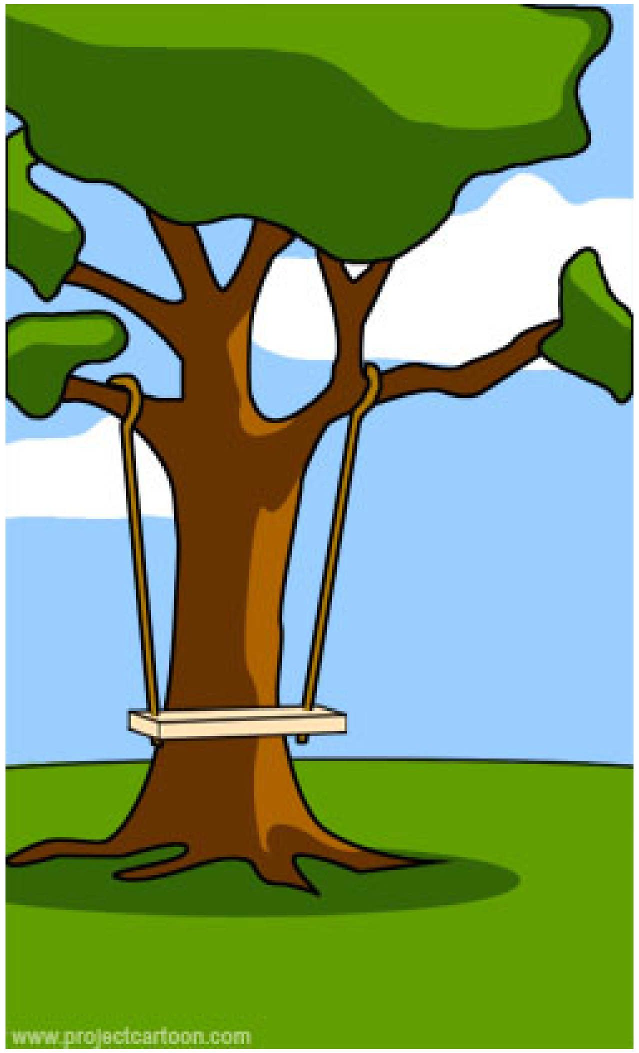
cartoon.com

How Projects Really Work



How the project leader understood it

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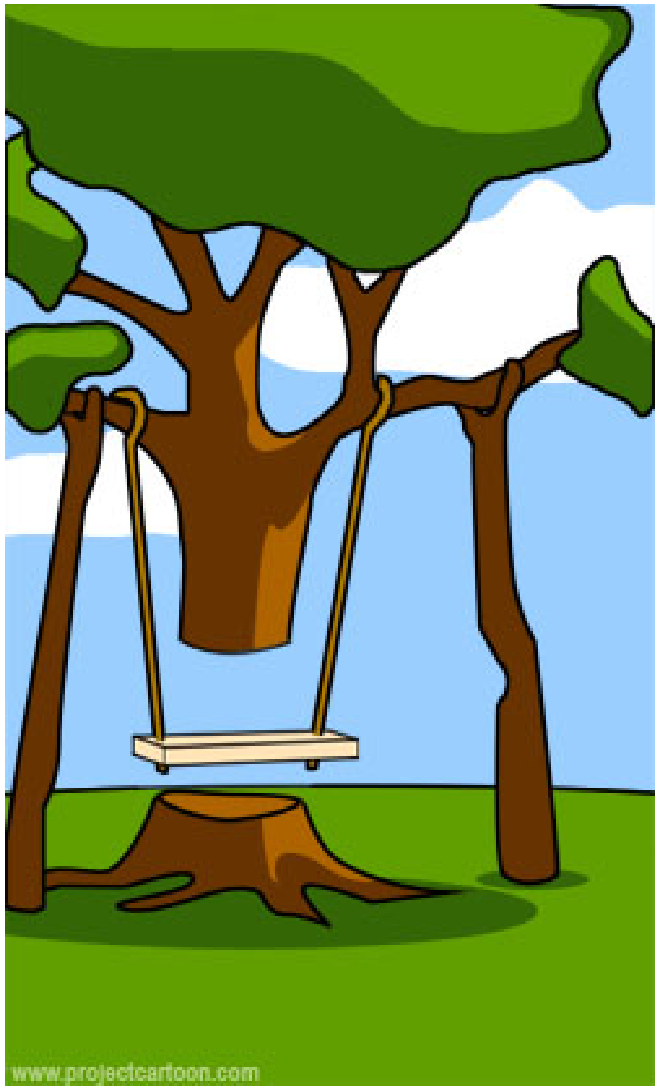
How Projects Really Work



How the analyst designed it

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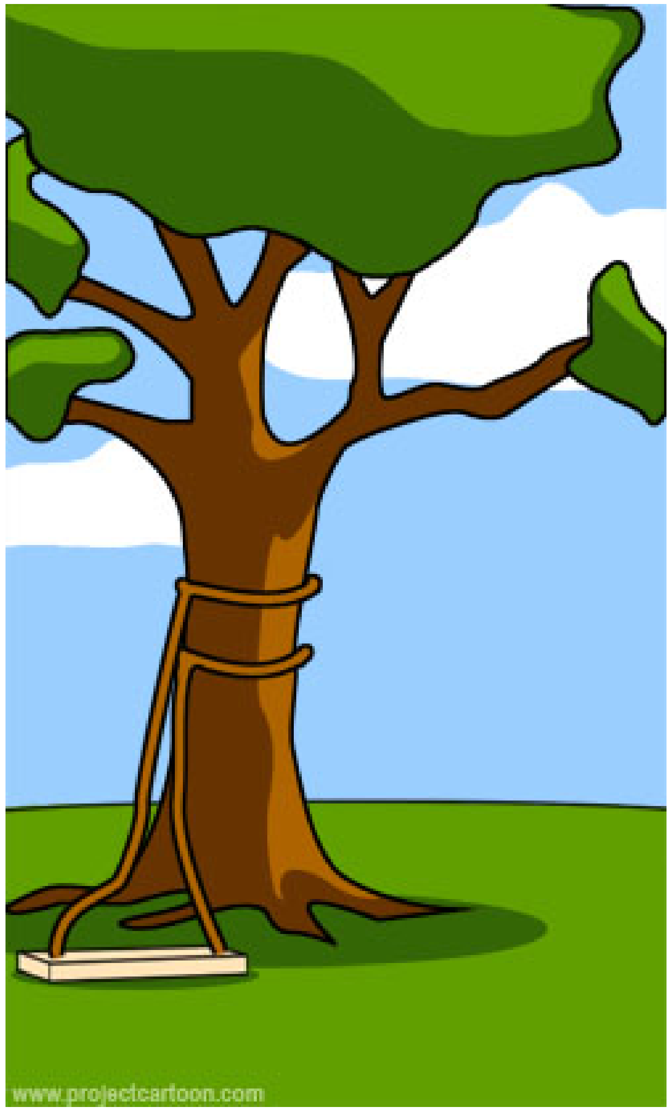
How Projects Really Work



How the programmer wrote it

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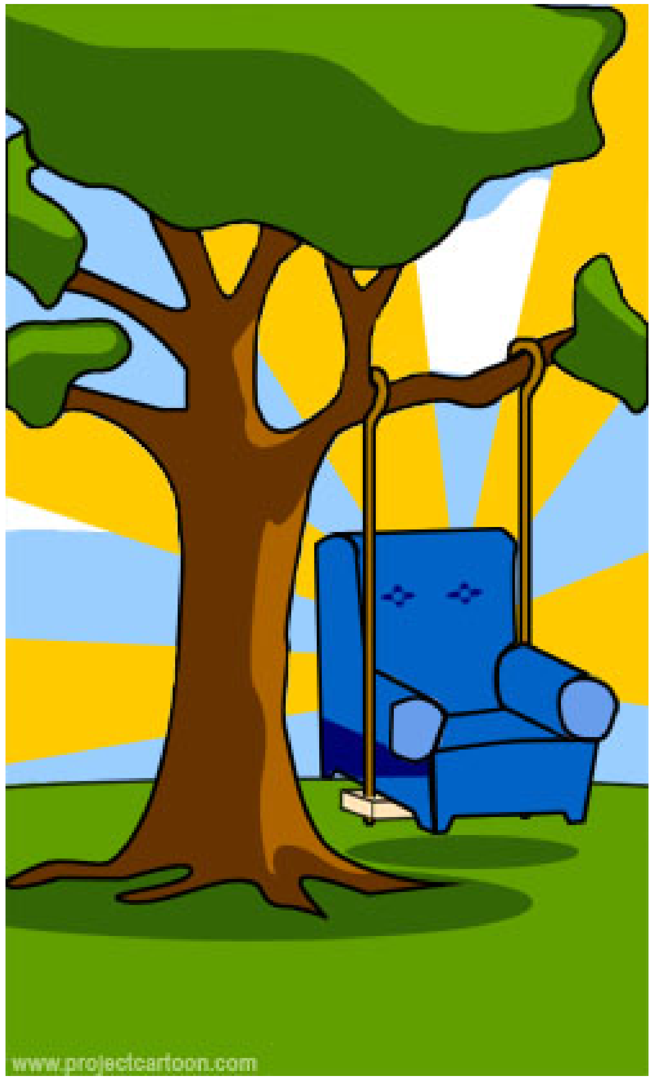
How Projects Really Work



How the business consultant described it

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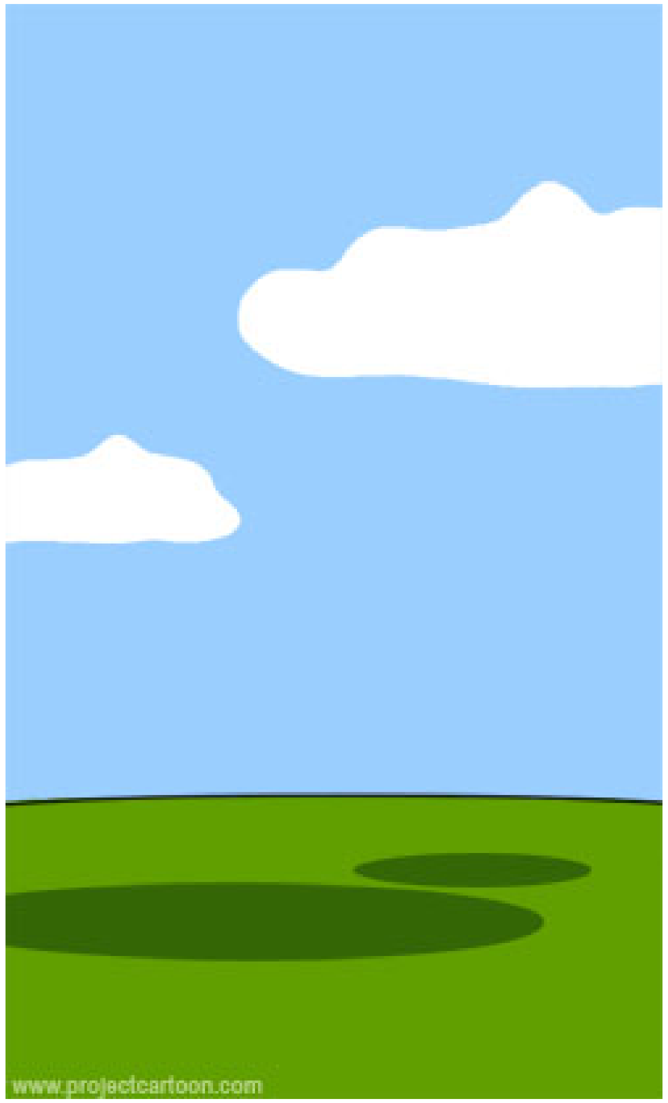
How Projects Really Work



How the project was documented

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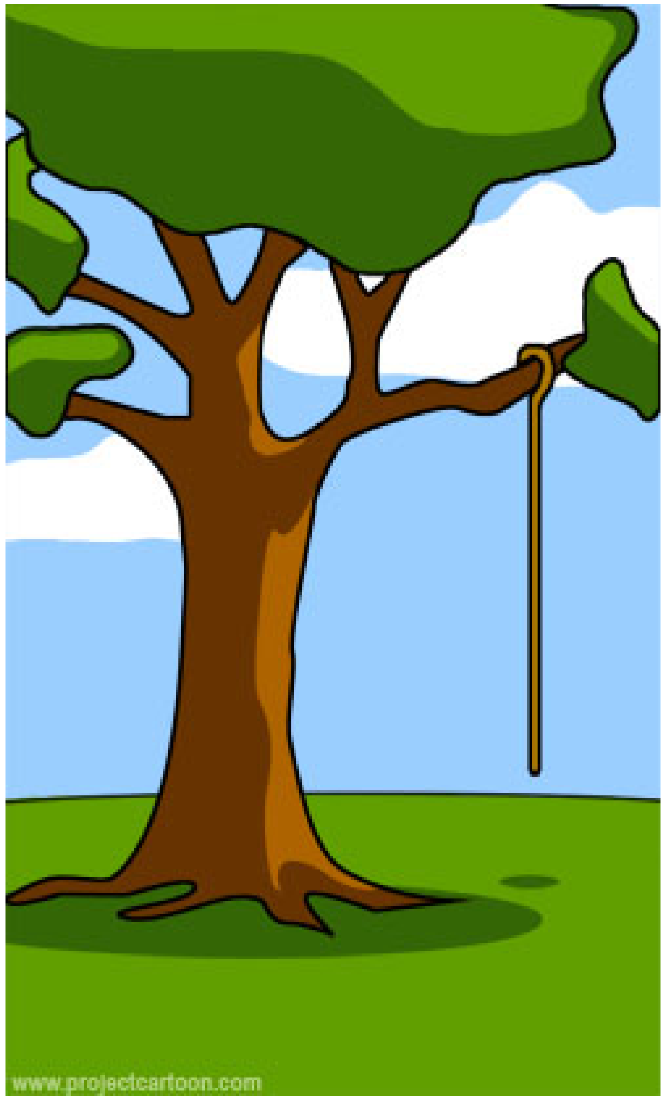
How Projects Really Work



What operations installed

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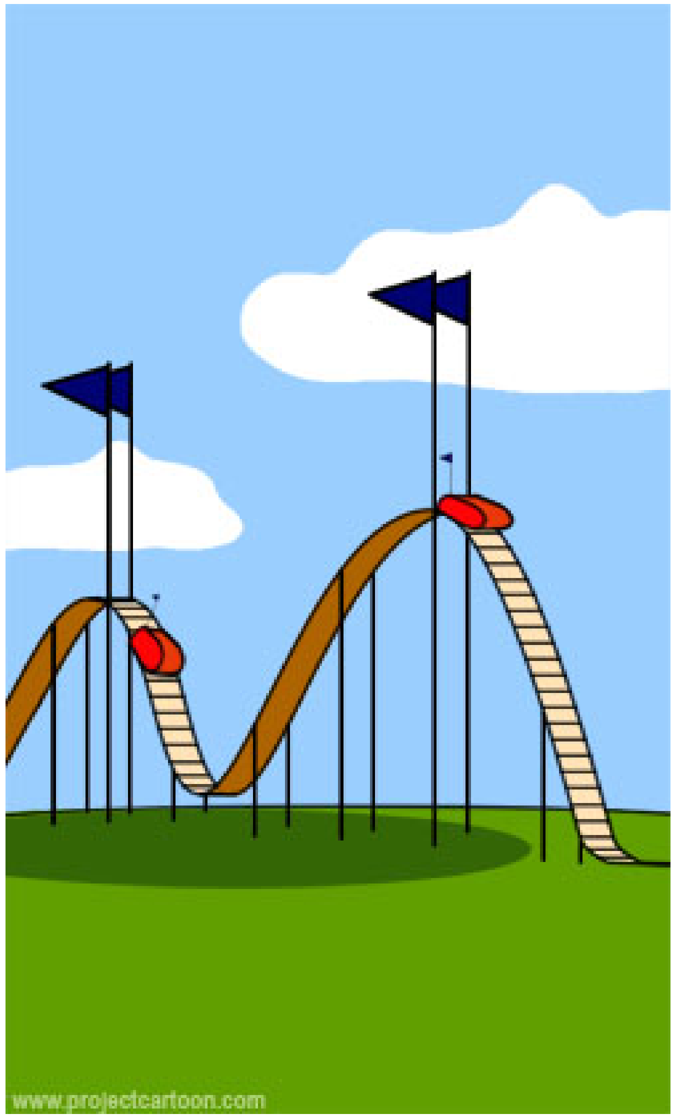
How Projects Really Work



How the customer was billed

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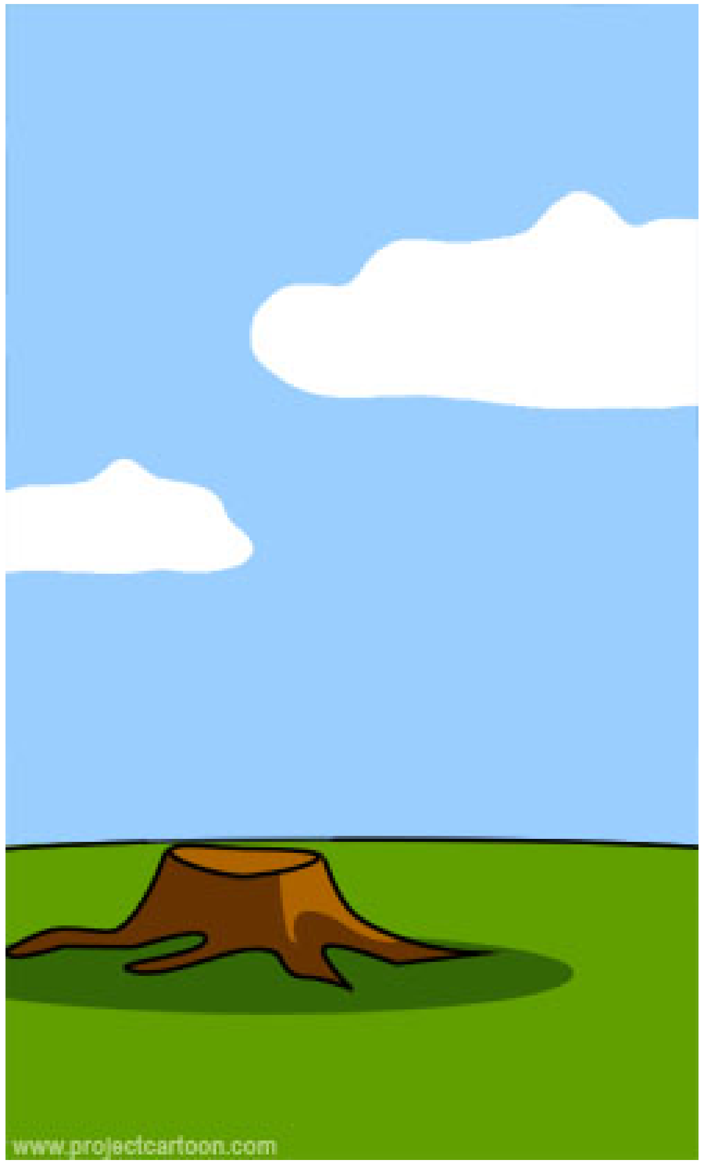
How Projects Really Work



How it was supported

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How Projects Really Work

What the customer really needed

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Coming Up Next

- Summer! Have a good one!