# Overview (and reorientation) of SE

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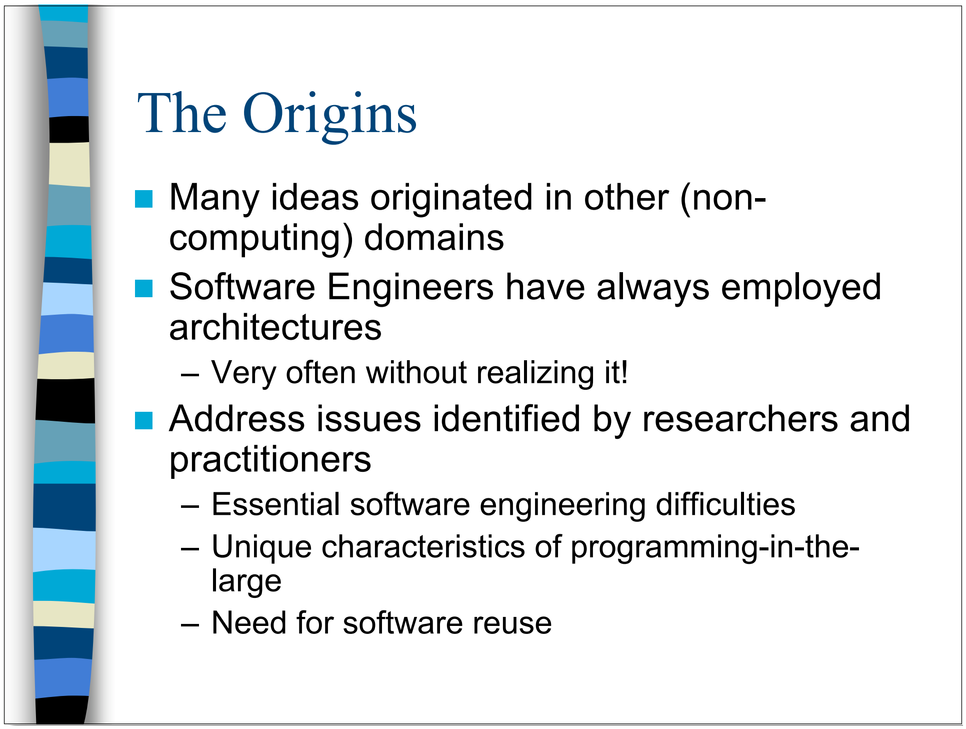
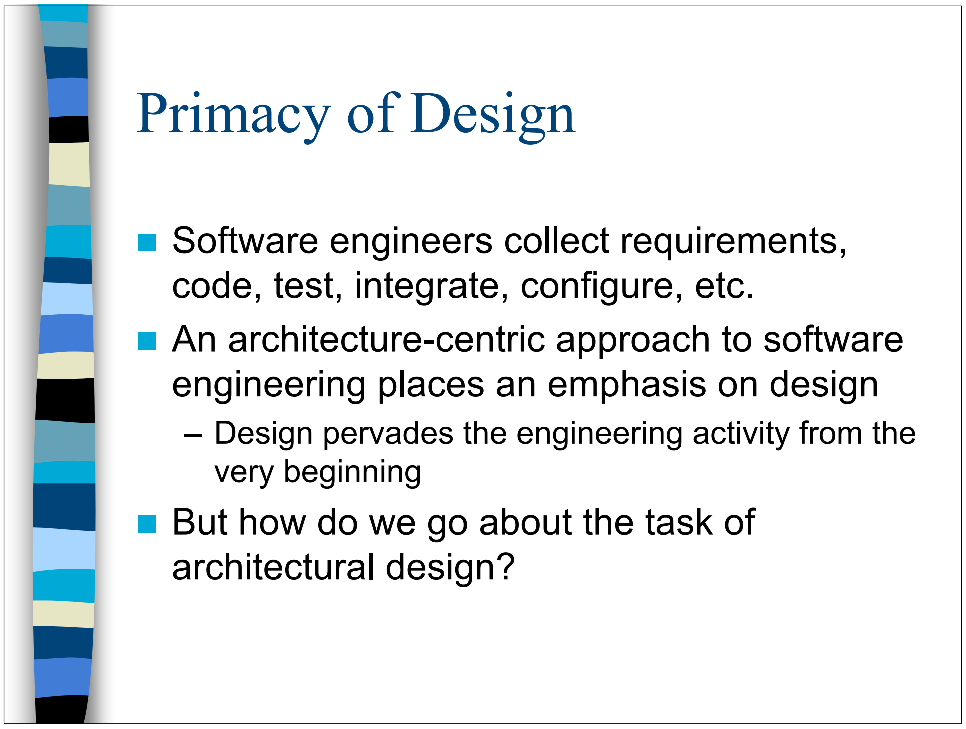


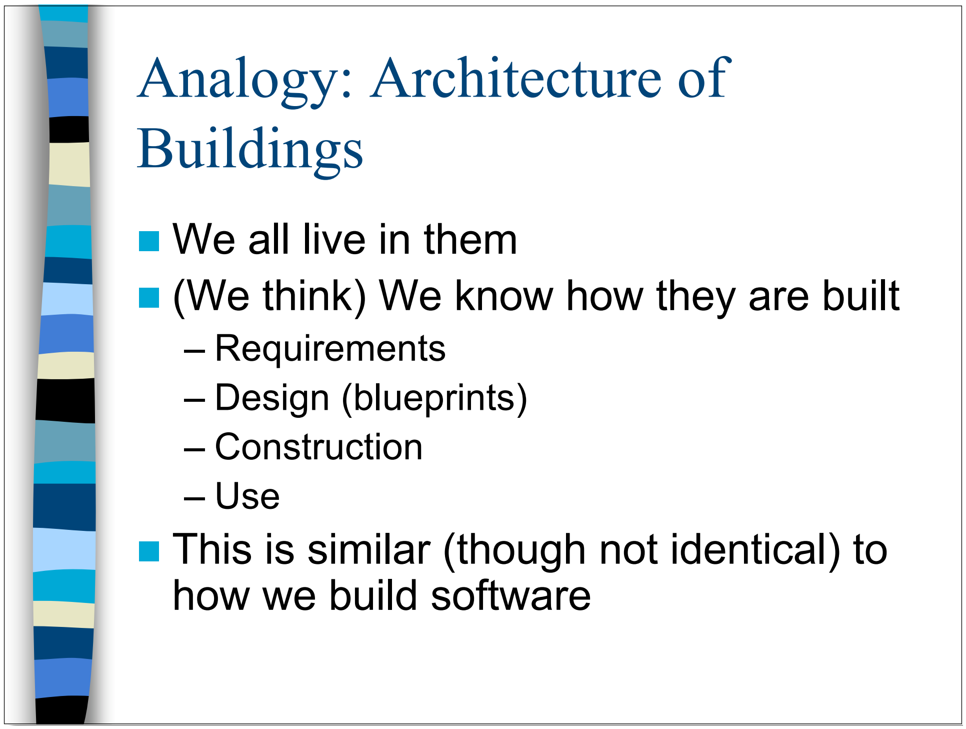
## The Origins

- Many ideas originated in other (non-computing) domains
- Software Engineers have always employed architectures
  - Very often without realizing it!
- Address issues identified by researchers and practitioners
  - Essential software engineering difficulties
  - Unique characteristics of programming-in-the-large
  - Need for software reuse



## Primacy of Design

- Software engineers collect requirements, code, test, integrate, configure, etc.
- An architecture-centric approach to software engineering places an emphasis on design
  - Design pervades the engineering activity from the very beginning
- But how do we go about the task of architectural design?



## Analogy: Architecture of Buildings

- We all live in them
- (We think) We know how they are built
  - Requirements
  - Design (blueprints)
  - Construction
  - Use
- This is similar (though not identical) to how we build software

## Some Obvious Parallels

- Satisfaction of customers' needs
- Specialization of labor
- Multiple perspectives of the final product
- Intermediate points where plans and progress are reviewed

## Deeper Parallels

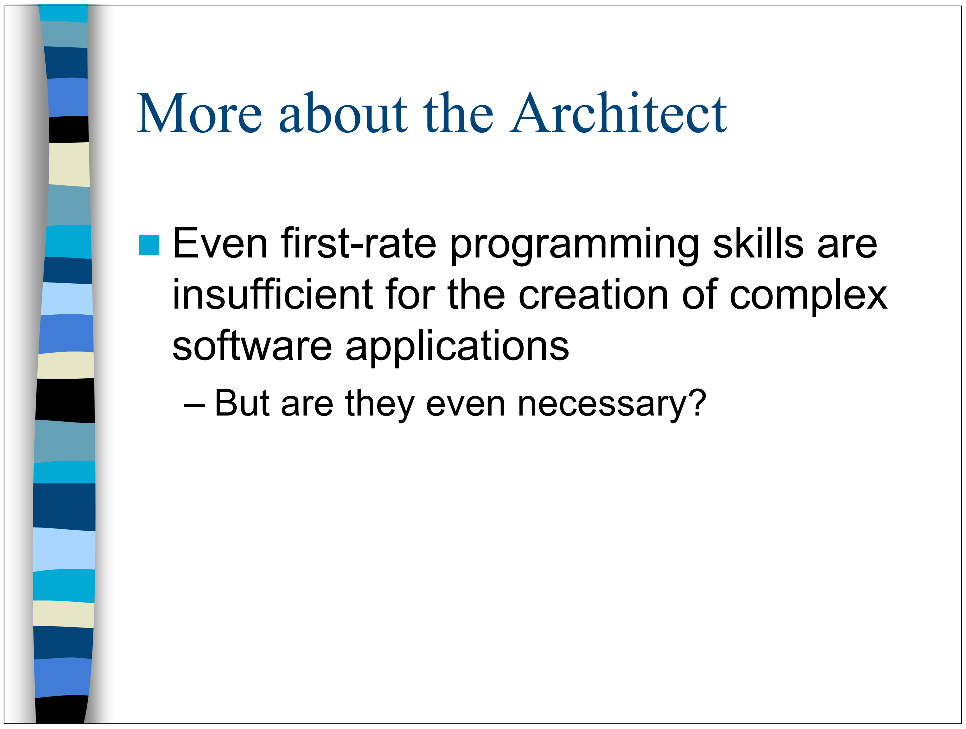
- Architecture is different from, but linked with the product/structure
- Properties of structures are induced by the design of the architecture
- The architect has a distinctive role and character

## Deeper Parallels (cont'd)

- Process is not as important as architecture
  - Design and resulting qualities are at the forefront
  - Process is a means, not an end
- Architecture has matured over time into a discipline
  - Architectural styles as sets of constraints
  - Styles also as wide range of solutions, techniques and palettes of compatible materials, colors, and sizes

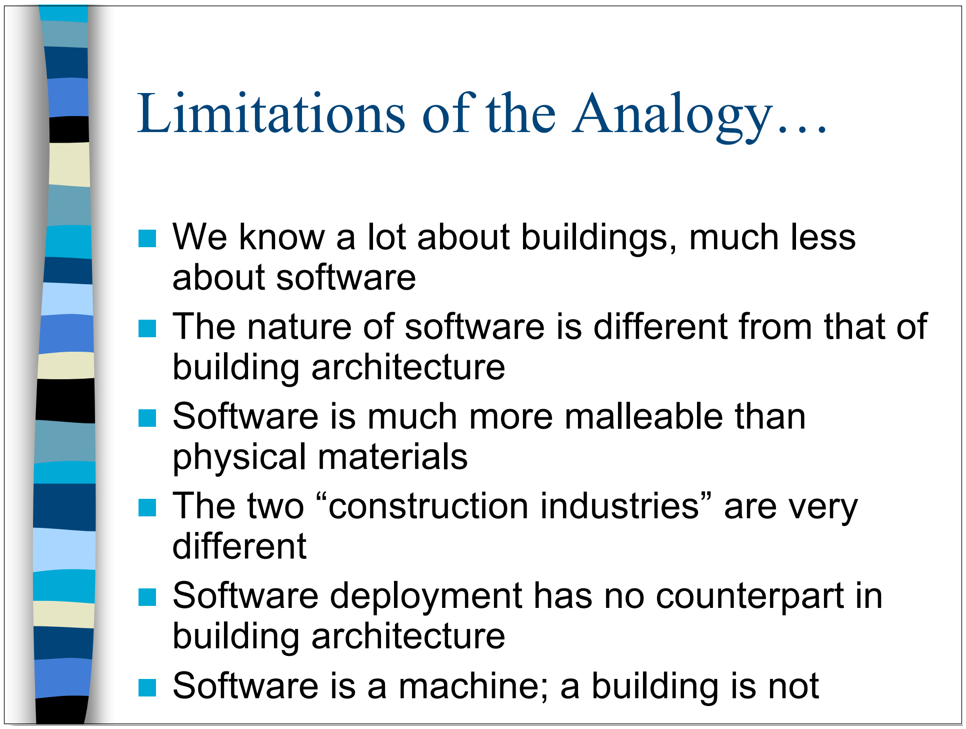
## About the Architect

- A distinctive role and character in a project
- Very broad training
- Amasses and leverages extensive experience
- A keen sense of aesthetics
- Deep understanding of the domain
  - Properties of structures, materials, and environments
  - Needs of customers



## More about the Architect

- Even first-rate programming skills are insufficient for the creation of complex software applications
  - But are they even necessary?



## Limitations of the Analogy…

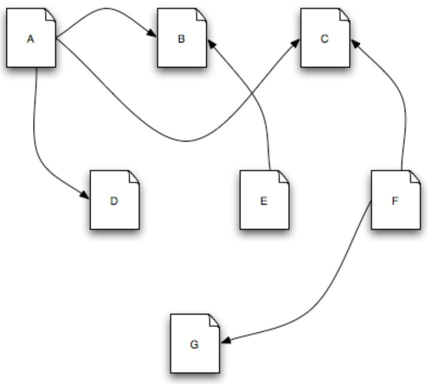
- We know a lot about buildings, much less about software
- The nature of software is different from that of building architecture
- Software is much more malleable than physical materials
- The two “construction industries” are very different
- Software deployment has no counterpart in building architecture
- Software is a machine; a building is not

## …But Still Very Real Power of Architecture

- Giving preeminence to architecture offers the potential for
  - Intellectual control
  - Conceptual integrity
  - Effective basis for knowledge reuse
  - Realizing experience, designs, and code
  - Effective project communication
  - Management of a set of variant systems
- Limited-term focus on architecture will not yield significant benefits!

## Architecture in Action: WWW

- This is the Web



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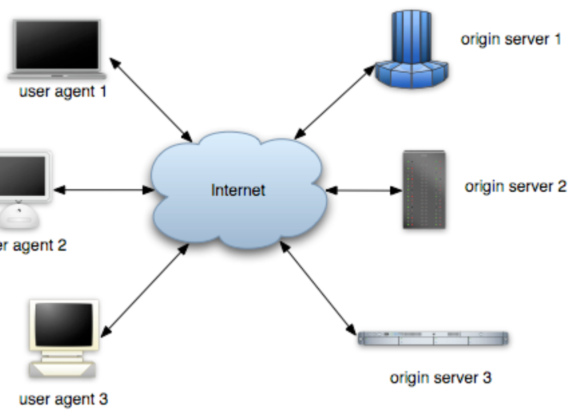
## Architecture in Action: WWW

- So is this



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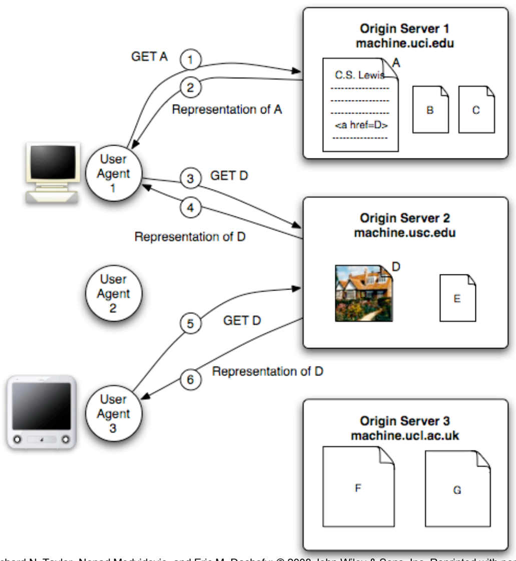
## Architecture in Action: WWW

- And this



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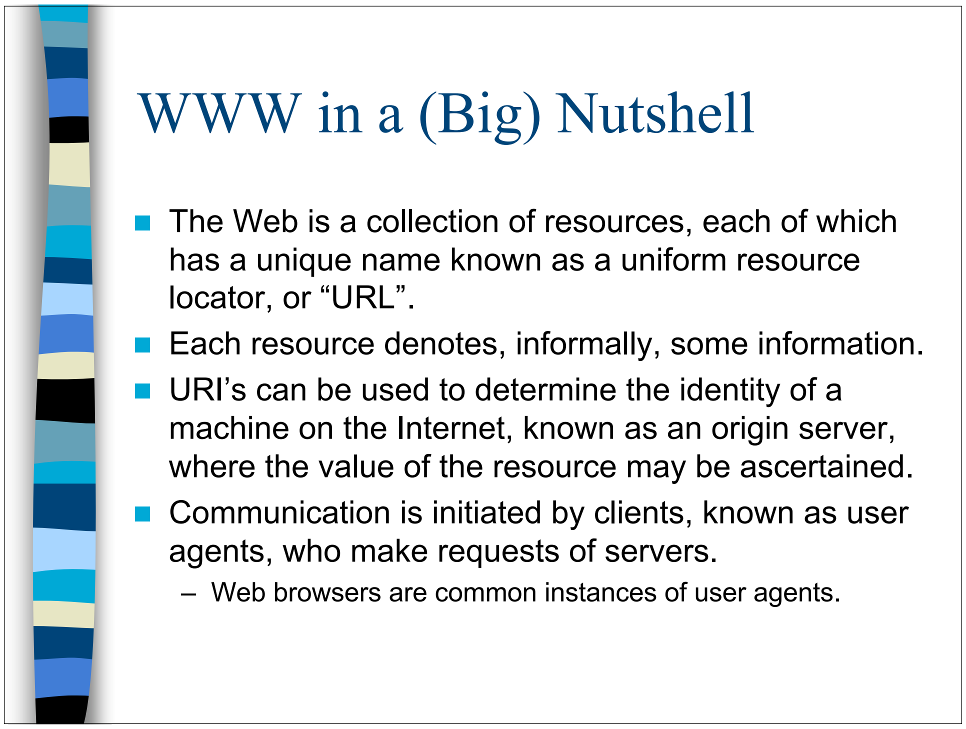
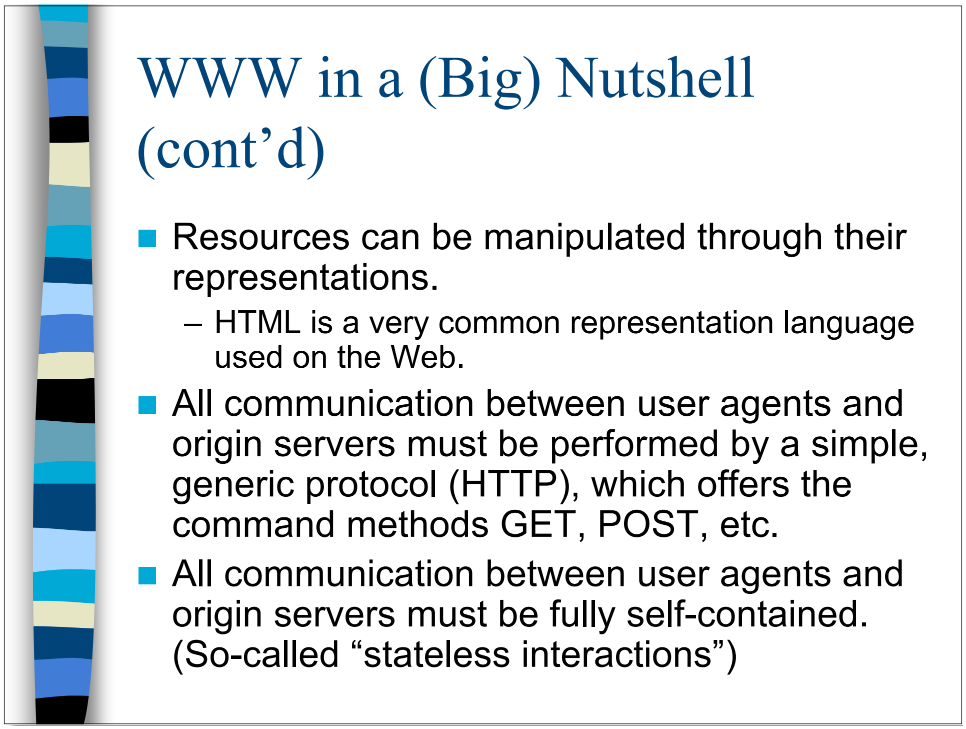


## WWW in a (Big) Nutshell

- The Web is a collection of resources, each of which has a unique name known as a uniform resource locator, or “URL”.
- Each resource denotes, informally, some information.
- URI’s can be used to determine the identity of a machine on the Internet, known as an origin server, where the value of the resource may be ascertained.
- Communication is initiated by clients, known as user agents, who make requests of servers.
  - Web browsers are common instances of user agents.



## WWW in a (Big) Nutshell (cont’d)

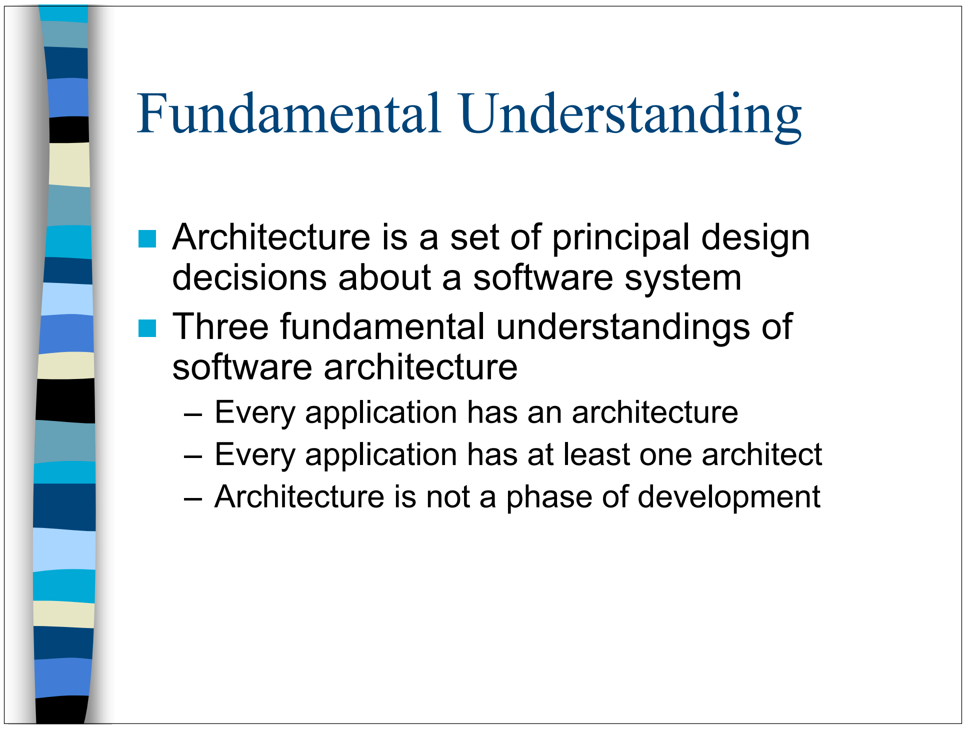
- Resources can be manipulated through their representations.
  - HTML is a very common representation language used on the Web.
- All communication between user agents and origin servers must be performed by a simple, generic protocol (HTTP), which offers the command methods GET, POST, etc.
- All communication between user agents and origin servers must be fully self-contained. (So-called “stateless interactions”)

## WWW’s Architecture

- Architecture of the Web is wholly separate from the code
- There is no single piece of code that implements the architecture.
- There are multiple pieces of code that implement the various components of the architecture.
  - E.g., different Web browsers

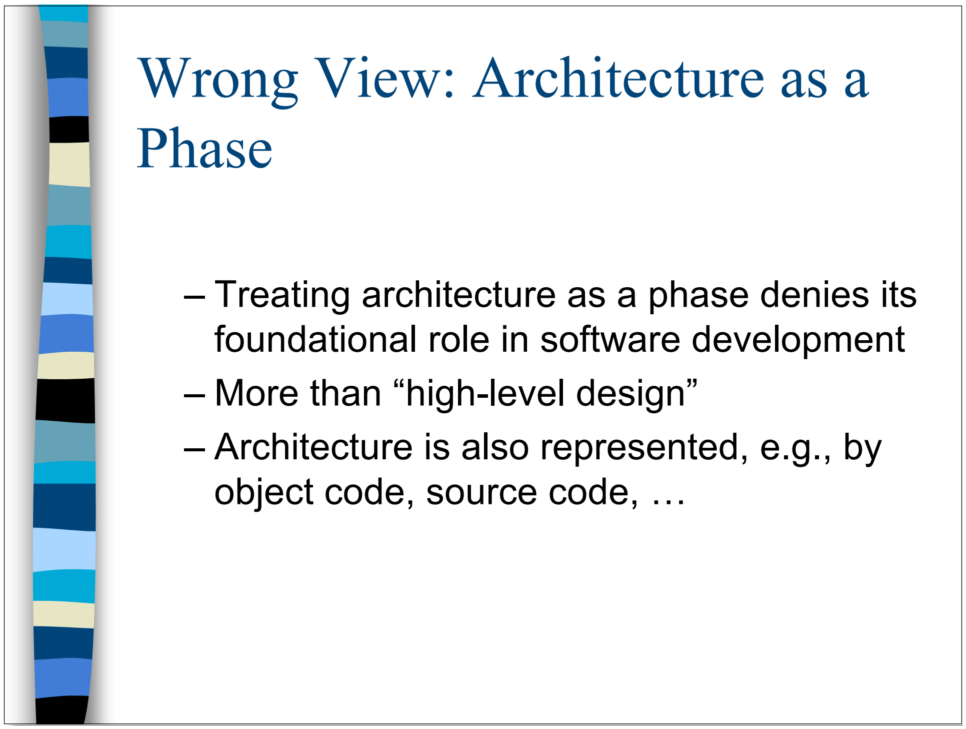
## WWW’s Architecture (cont’d)

- Stylistic constraints of the Web’s architectural style are not apparent in the code
  - The effects of the constraints are evident in the Web
- One of the world’s most successful applications is only understood adequately from an architectural vantage point.



## Fundamental Understanding

- Architecture is a set of principal design decisions about a software system
- Three fundamental understandings of software architecture
  - – Every application has an architecture
  - – Every application has at least one architect
  - – Architecture is not a phase of development



## Wrong View: Architecture as a Phase

- – Treating architecture as a phase denies its foundational role in software development
- – More than “high-level design”
- – Architecture is also represented, e.g., by object code, source code, …

## Context of Software Architecture

- Requirements
- Design
- Implementation
- Analysis and Testing
- Evolution
- Development Process

## Requirements Analysis

- Traditional SE suggests requirements analysis should remain unsullied by any consideration for a design
- However, without reference to existing architectures it becomes difficult to assess practicality, schedules, or costs
  - In building architecture we talk about specific rooms…
  - …rather than the abstract concept “means for providing shelter”
- In engineering new products come from the observation of existing solution and their limitations

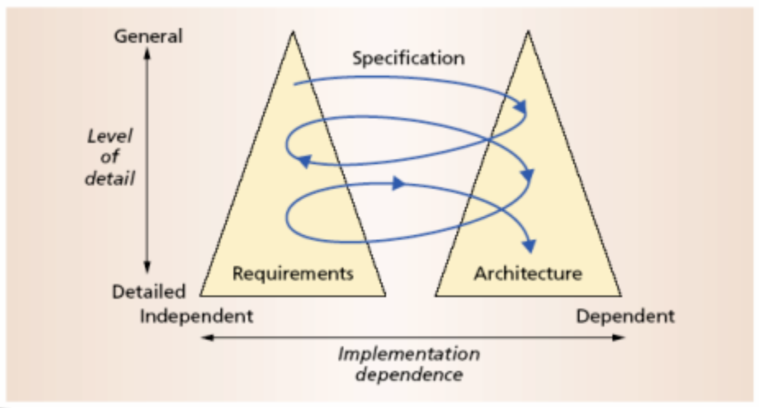
## New Perspective on Requirements Analysis

- Existing designs and architectures provide the solution vocabulary
- Our understanding of what works now, and how it works, affects our wants and perceived needs
- The insights from our experiences with existing systems
  - helps us imagine what might work and
  - enables us to assess development time and costs
- → Requirements analysis and consideration of design must be pursued at the same time

## Non-Functional Properties (NFP)

- NFPs are the result of architectural choices
- NFP questions are raised as the result of architectural choices
- Specification of NFP might require an architectural framework to even enable their statement
- An architectural framework will be required for assessment of whether the properties are achievable

## The Twin Peaks Model



## Design and Architecture

- Design is an activity that pervades software development
- It is an activity that creates part of a system's architecture
- Typically in the traditional Design Phase decisions concern
  - A system's structure
  - Identification of its primary components
  - Their interconnections
- Architecture denotes the set of principal design decisions about a system
  - That is more than just structure

## Architecture-Centric Design

- Traditional design phase suggests translating the requirements into algorithms, so a programmer can implement them
- Architecture-centric design
  - stakeholder issues
  - decision about use of COTS component
  - overarching style and structure
  - package and primary class structure
  - deployment issues
  - post implementation/deployment issues

## Design Techniques

- Basic conceptual tools
  - Separation of concerns
  - Abstraction
  - Modularity
- Two illustrative widely adapted strategies
  - Object-oriented design
  - Domain-specific software architectures (DSSA)

## Object-Oriented Design (OOD)

- Objects
  - Main abstraction entity in OOD
  - Encapsulations of state with functions for accessing and manipulating that state

## Pros and Cons of OOD

- Pros
  - UML modeling notation
  - Design patterns
- Cons
  - Provides only
    - One level of encapsulation (the object)
    - One notion of interface
    - One type of explicit connector (procedure call)
      - Even message passing is realized via procedure calls
  - OO programming language might dictate important design decisions
  - OOD assumes a shared address space

## DSSA

- Capturing and characterizing the best solutions and best practices from past projects within a domain
- Production of new applications can focus on the points of novel variation
- Reuse applicable parts of the architecture and implementation
- Applicable for product lines
  - Philips Koala example

## Implementation

- The objective is to create machine-executable source code
  - That code should be faithful to the architecture
    - Alternatively, it may adapt the architecture
    - How much adaptation is allowed?
    - Architecturally-relevant vs. -unimportant adaptations
  - It must fully develop all outstanding details of the application

## Faithful Implementation

- All of the structural elements found in the architecture are implemented in the source code
- Source code must not utilize major new computational elements that have no corresponding elements in the architecture
- Source code must not contain new connections between architectural elements that are not found in the architecture
- Is this realistic?
  Overly constraining?
  What if we deviate from this?

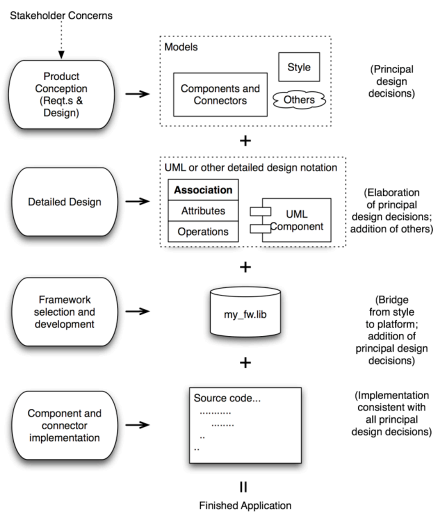
## Unfaithful Implementation

- The implementation does have an architecture
  - It is latent, as opposed to what is documented.
- Failure to recognize the distinction between planned and implemented architecture
  - robs one of the ability to reason about the application's architecture in the future
  - misleads all stakeholders regarding what they believe they have as opposed to what they really have
  - makes any development or evolution strategy that is based on the documented (but inaccurate) architecture doomed to failure

## Implementation Strategies

- Generative techniques
  - e.g. parser generators
- Frameworks
  - collections of source code with identified places where the engineer must "fill in the blanks"
- Middleware
  - CORBA, DCOM, RPC, …
- Reuse-based techniques
  - COTS, open-source, in-house
- Writing all code manually

## How It All Fits Together


Stakeholder Concerns
Product Conception (Reqt.s & Design)
Models
Components and Connectors
Style
Others
(Principal design decisions)
+
Detailed Design
UML or other detailed design notation
Association
Attributes
Operations
UML Component
(Elaboration of principal design decisions; addition of others)
+
Framework selection and development
my_fw.lib
(Bridge from style to platform; addition of principal design decisions)
+
Component and connector implementation
Source code...
(Implementation consistent with all principal design decisions)
=
Finished Application

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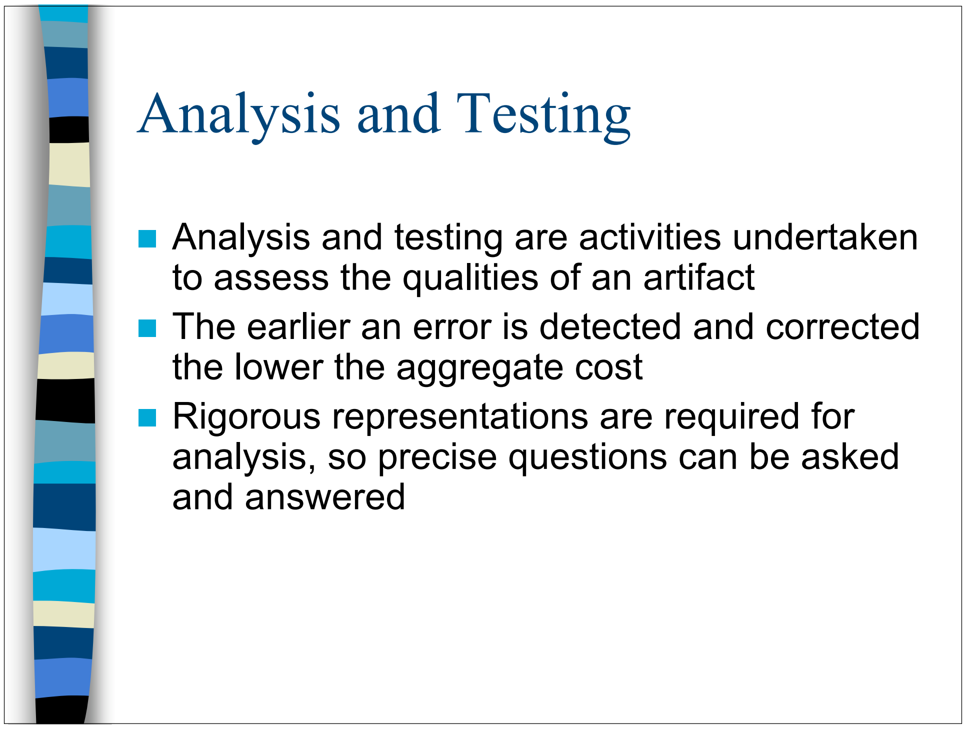
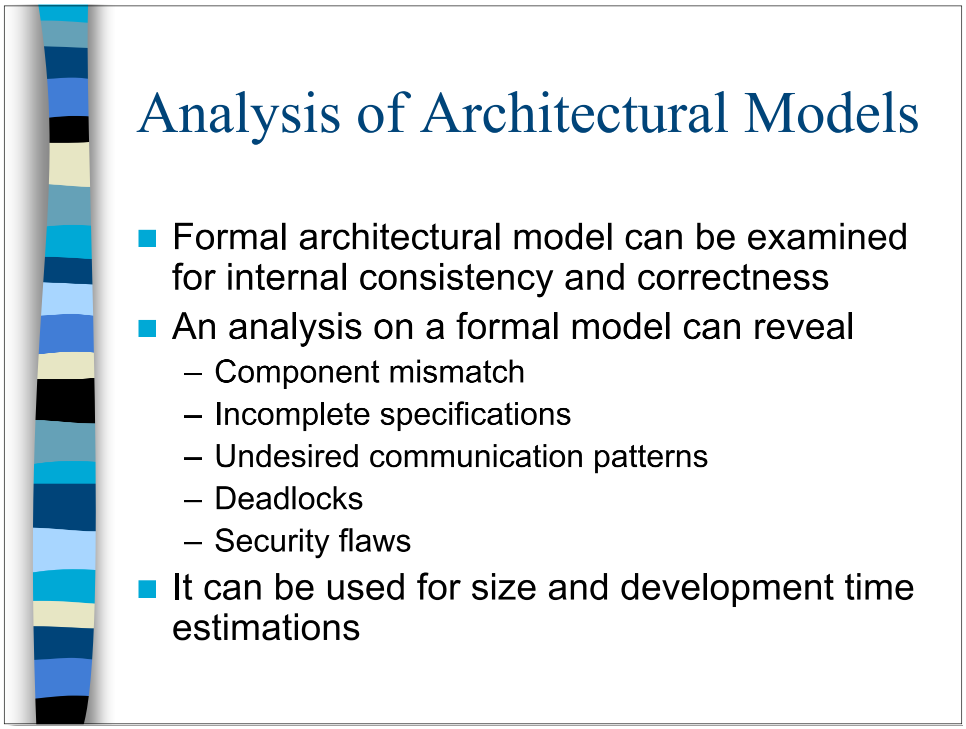


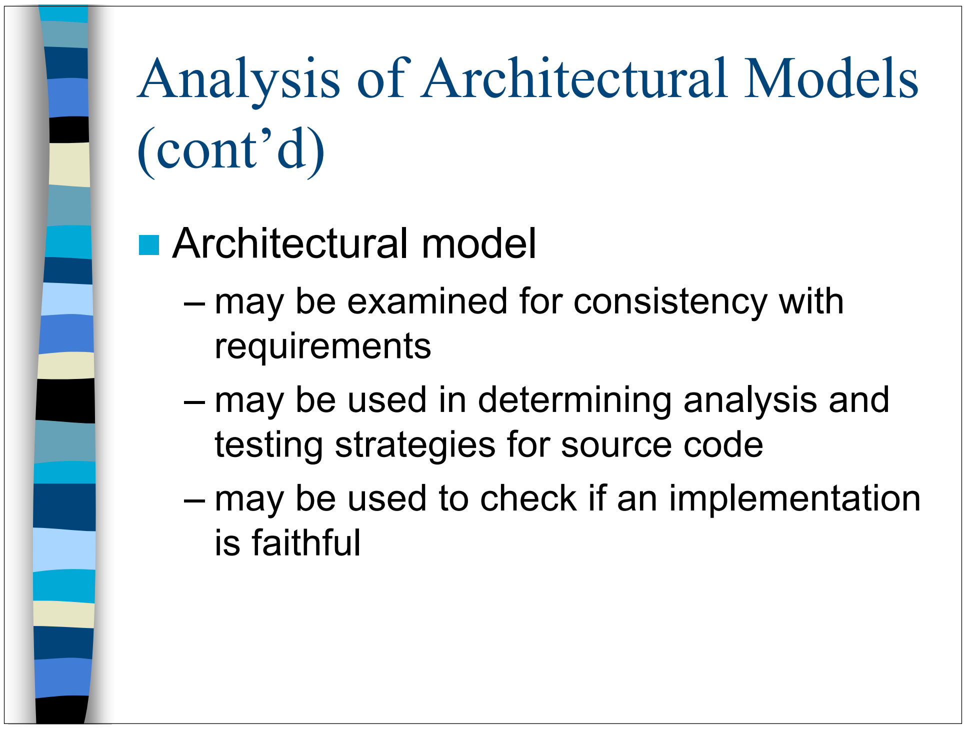
## Analysis and Testing

- Analysis and testing are activities undertaken to assess the qualities of an artifact
- The earlier an error is detected and corrected the lower the aggregate cost
- Rigorous representations are required for analysis, so precise questions can be asked and answered



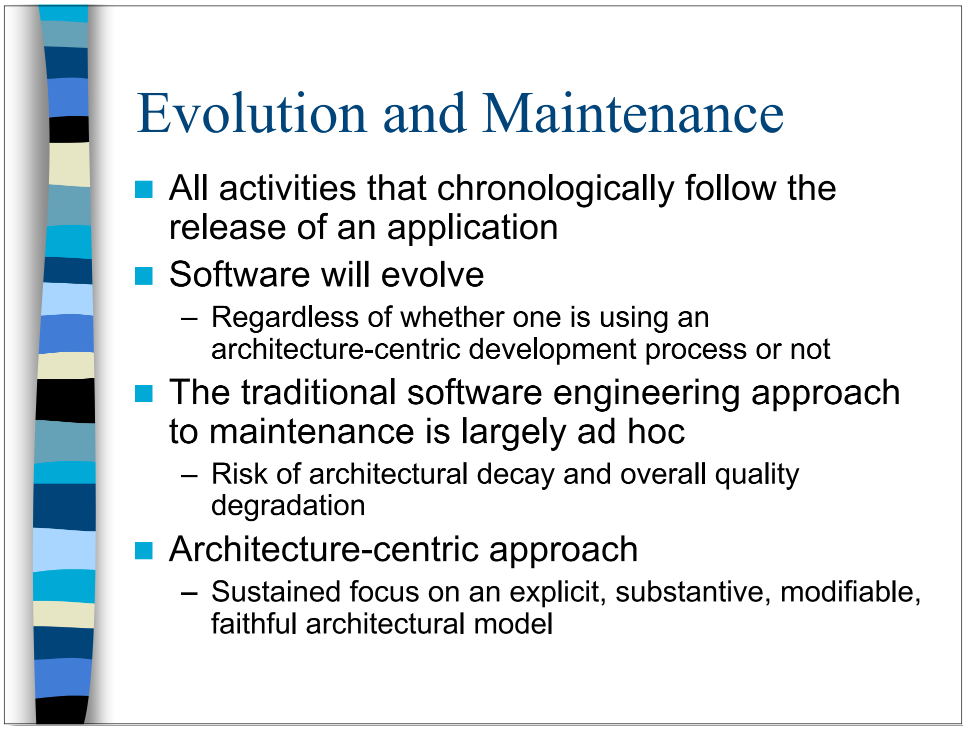
## Analysis of Architectural Models

- Formal architectural model can be examined for internal consistency and correctness
- An analysis on a formal model can reveal
  - Component mismatch
  - Incomplete specifications
  - Undesired communication patterns
  - Deadlocks
  - Security flaws
- It can be used for size and development time estimations



## Analysis of Architectural Models (cont’d)

- Architectural model
  - may be examined for consistency with requirements
  - may be used in determining analysis and testing strategies for source code
  - may be used to check if an implementation is faithful



## Evolution and Maintenance

- All activities that chronologically follow the release of an application
- Software will evolve
  - Regardless of whether one is using an architecture-centric development process or not
- The traditional software engineering approach to maintenance is largely ad hoc
  - Risk of architectural decay and overall quality degradation
- Architecture-centric approach
  - Sustained focus on an explicit, substantive, modifiable, faithful architectural model

## Architecture-Centric Evolution Process

- Motivation
- Evaluation or assessment
- Design and choice of approach
- Action
  – includes preparation for the next round of adaptation

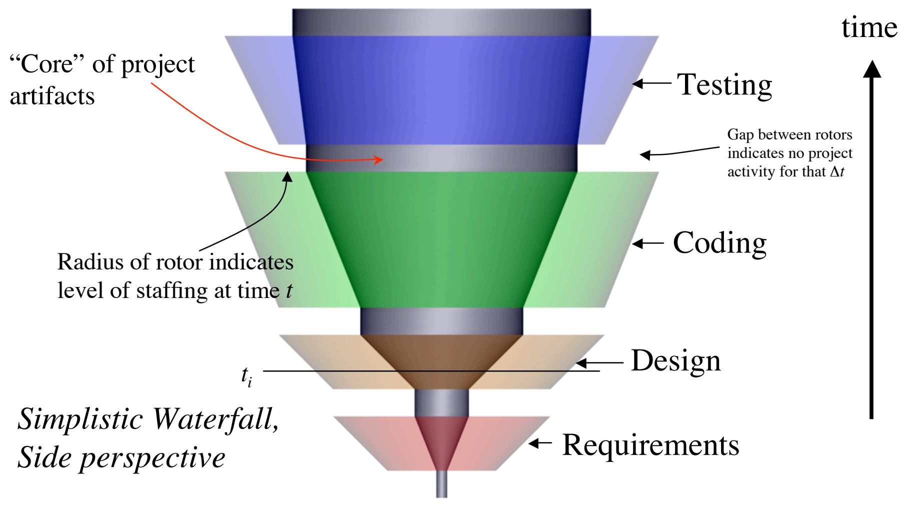
## Processes

- Traditional software process discussions make the process activities the focal point
- In architecture-centric software engineering the product becomes the focal point
- No single “right” software process for architecture-centric software engineering exists

## Turbine – A New Visualization Model

- Goals of the visualization
  - Provide an intuitive sense of
    - Project activities at any given time
      - Including concurrency of types of development activities
    - The “information space” of the project
  - Show centrality of the products
    - (Hopefully) Growing body of artifacts
    - Allow for the centrality of architecture
      - But work equally well for other approaches, including “dysfunctional” ones
  - Effective for indicating time, gaps, duration of activities
  - Investment (cost) indicators

## The Turbine Model


“Core” of project artifacts
Testing
time
Gap between rotors indicates no project activity for that Δ*t*
Coding
Radius of rotor indicates level of staffing at time *t*
$t_i$
Design
Requirements
*Simplistic Waterfall, Side perspective*

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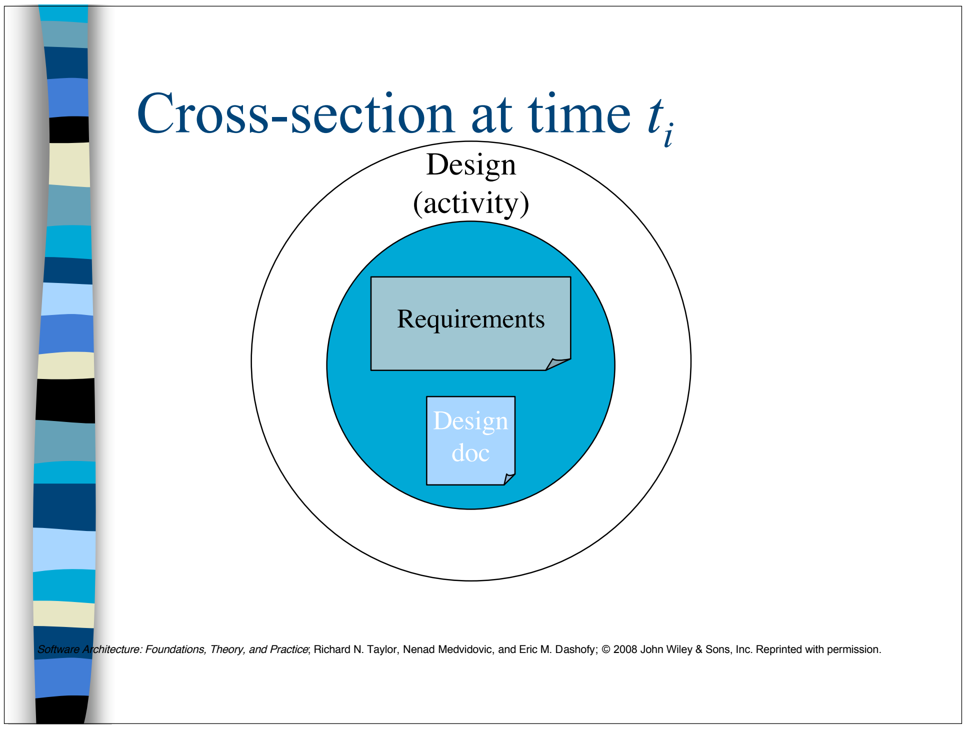
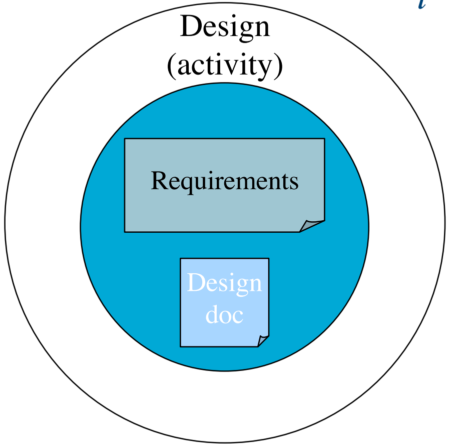
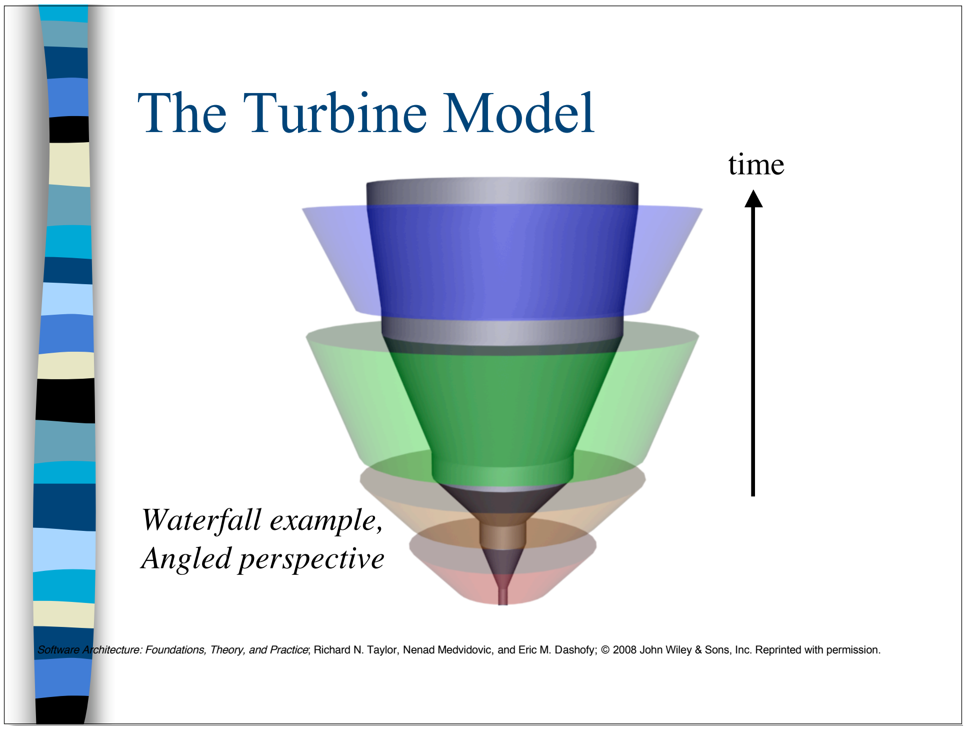
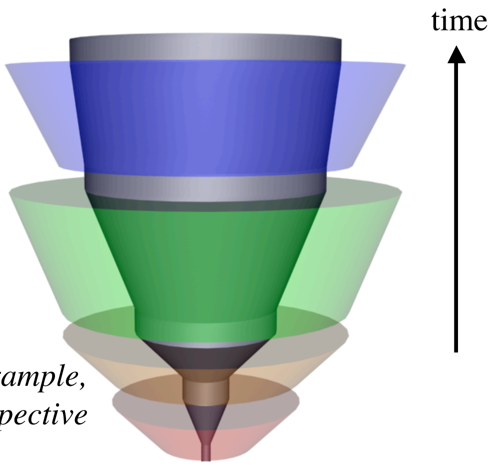


## Cross-section at time $t_i$



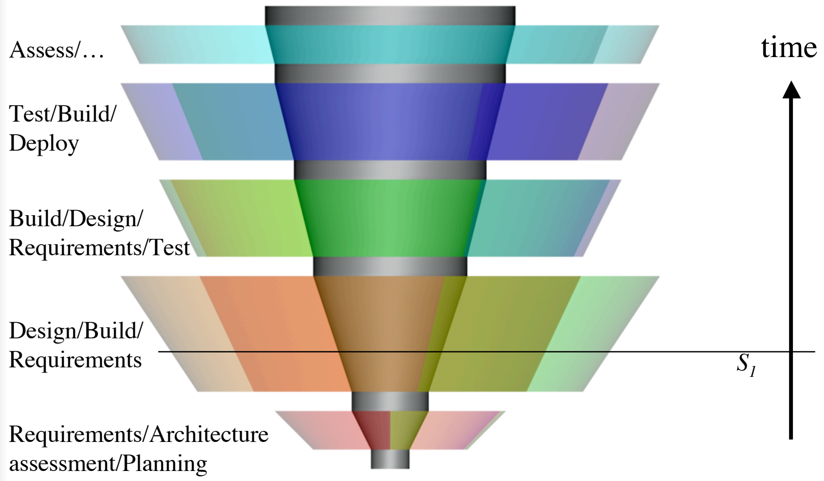


## The Turbine Model



*Waterfall example,*
*Angled perspective*

## A Richer Example



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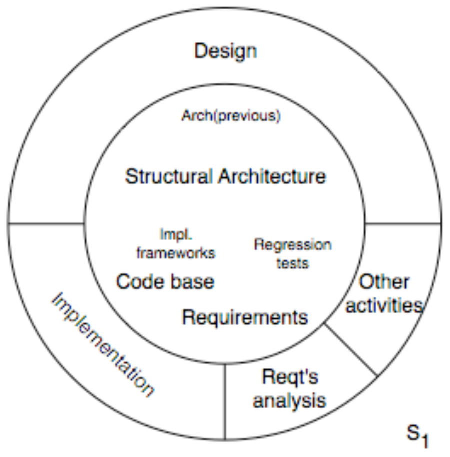
## A Sample Cross-Section



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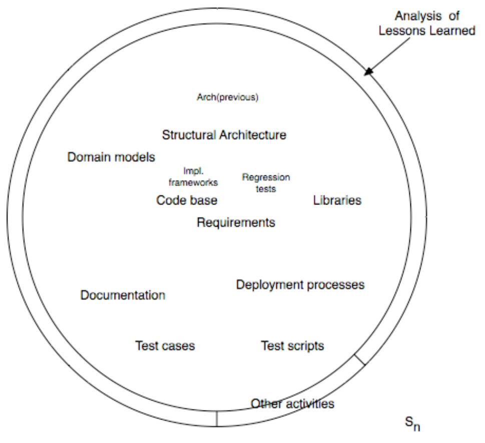
## A Cross-Section at Proiect End



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## Volume Indicates Where Time was Spent

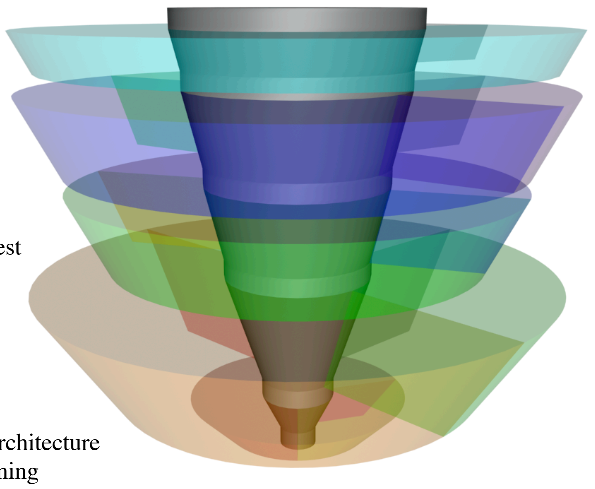
Assess/…

Test/Build/
Deploy

Build/Design/
Requirements/Test

Design/Build/
Requirements

Requirements/Architecture
assessment/Planning



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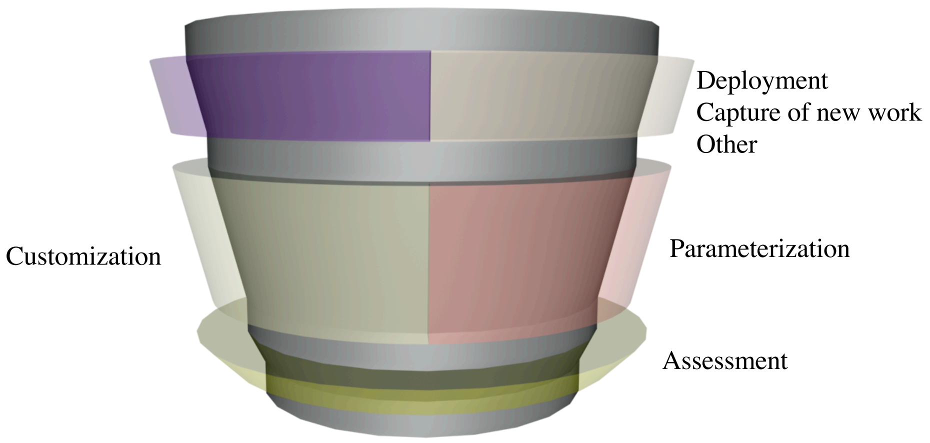
## A Technically Strong Product



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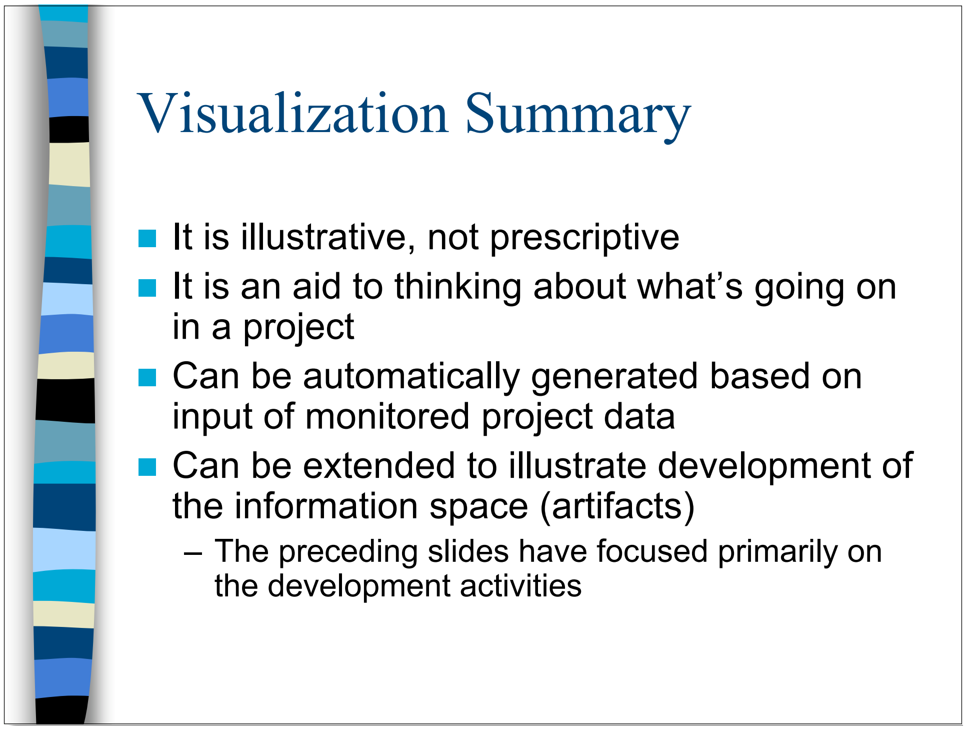


## Visualization Summary

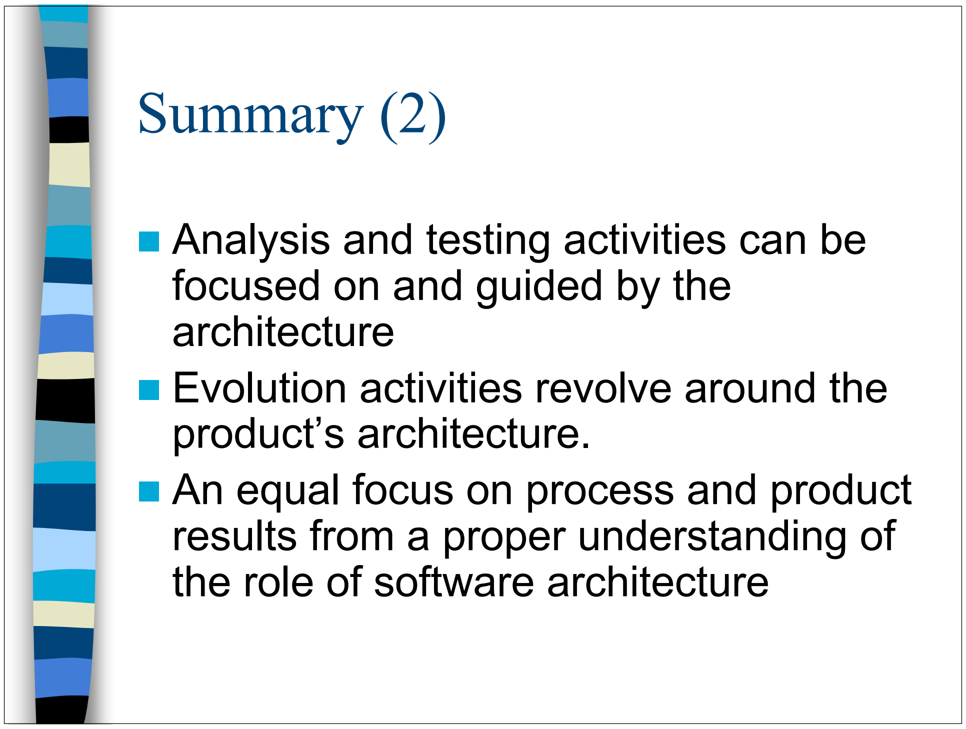
- It is illustrative, not prescriptive
- It is an aid to thinking about what's going on in a project
- Can be automatically generated based on input of monitored project data
- Can be extended to illustrate development of the information space (artifacts)
  - The preceding slides have focused primarily on the development activities

## Processes Possible in this Model

- Traditional, straight-line waterfall
- Architecture-centric development
- DSSA-based project
- Agile development
- Dysfunctional process

## Summary (1)

- A proper view of software architecture affects every aspect of the classical software engineering activities
- The requirements activity is a co-equal partner with design activities
- The design activity is enriched by techniques that exploit knowledge gained in previous product developments
- The implementation activity
  - is centered on creating a faithful implementation of the architecture
  - utilizes a variety of techniques to achieve this in a cost-effective manner



## Summary (2)

- Analysis and testing activities can be focused on and guided by the architecture
- Evolution activities revolve around the product's architecture.
- An equal focus on process and product results from a proper understanding of the role of software architecture