Introduction to Software Architecture

CS6.401 Software Engineering

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Software Engineering Research Centre

Acknowledgements

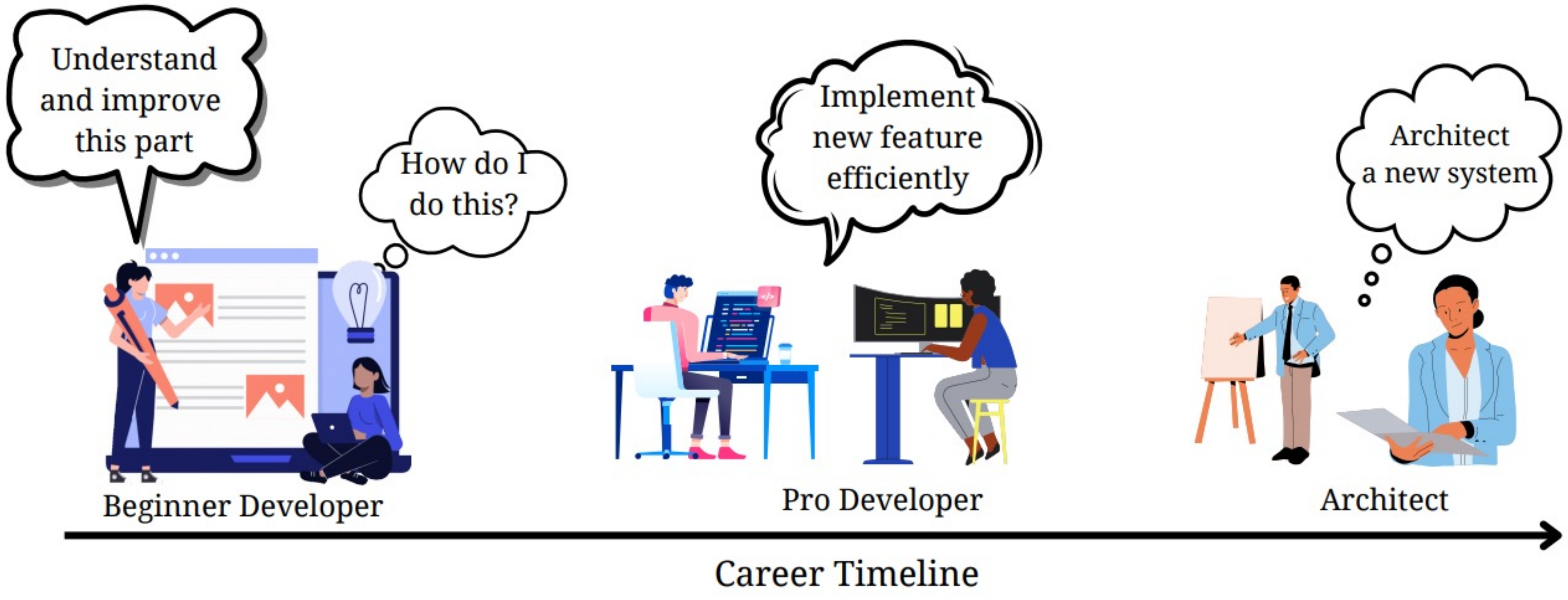
The materials used in this presentation have been gathered/adapted/generate from various sources as well as based on my own experiences and knowledge -- Karthik Vaidhyanathan

Sources:

1. Introduction to Software Architecture, Henry Muccini, University of L'Aquila
2. Software Architecture in Practice, Len Bass, 3rd edition
3. Software Architecture (SE Course), Alessio Gambi, Saaraland University, Germany
4. Software Architecture Design Reasoning Workshop, Antony Tang, ISAPS 2018

Source: Googe images

The Journey



This Course

Modeling	Design Principles	Architectural Framework
Refactoring	Design Patterns	Architectural Patterns

In your opinion what is Software Architecture?

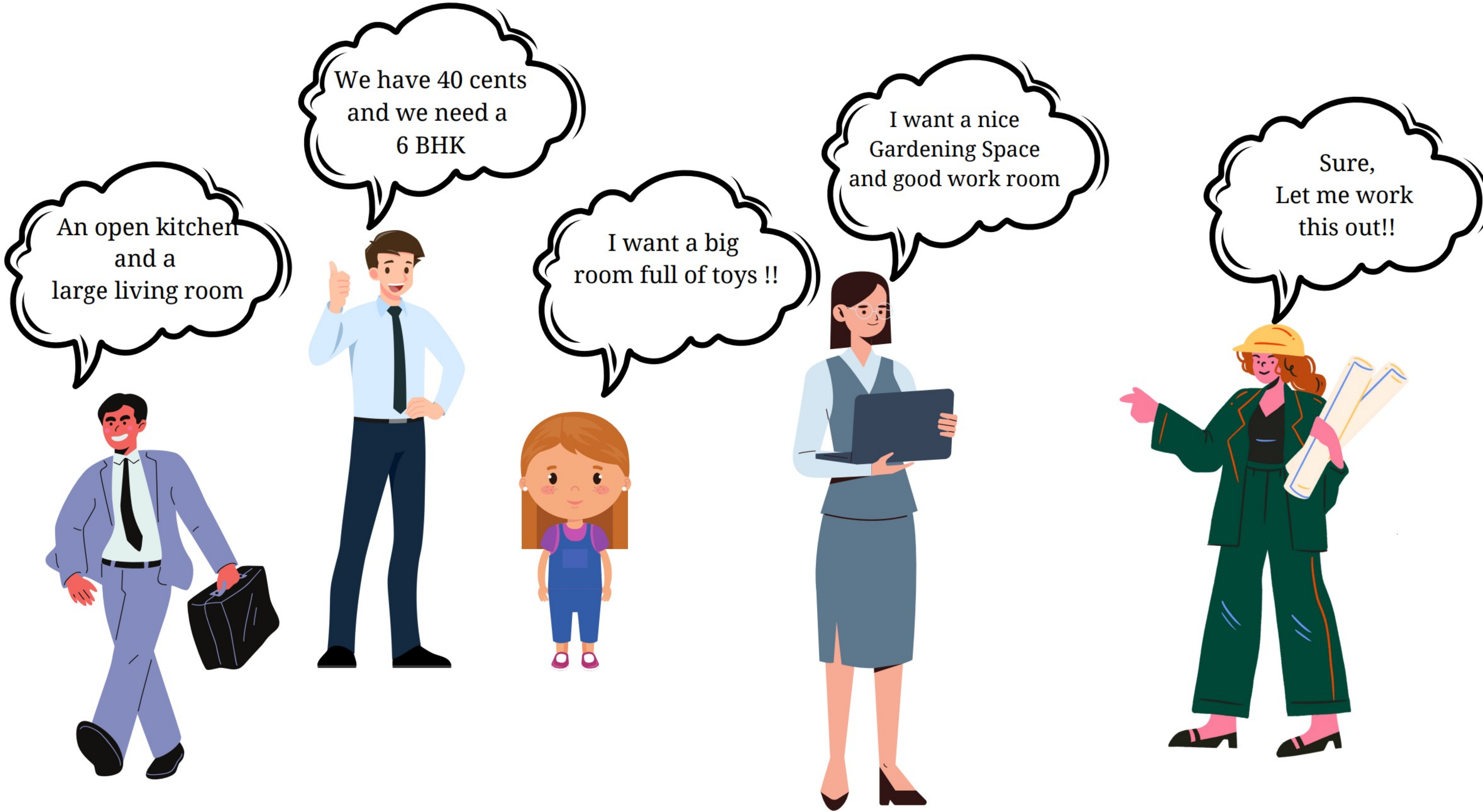
What will you do if you want to build a house?

- Family of 6
- Independent house
- Land of 40 cents
- Accommodate 6 + 2
- ……

Give the requirements!!

I want your help to build my dream home
Give me your requirements

Here you go!!! – There are always multiple Stakeholders


An open kitchen and a large living room
We have 40 cents and we need a 6 BHK
I want a big room full of toys !!
I want a nice Gardening Space and good work room
Sure, Let me work this out!!

Let me list all the requirements

6 BHK

House in 40 cents

Accommodate 2 More

Open Kitchen

Large Living Room

Kid friendly room

Gardening Space

Let me see Constraints and Significant Requirements

6 BHK

House in 40 cents

Accommodate 2 More

Open Kitchen

Large Living Room

Kid friendly room

Gardening Space

Time for Some Decisions

What material to be used?
- Budget
- Weather Condition
- …

How to balance size?
- Living room size
- Kitchen Size
- …

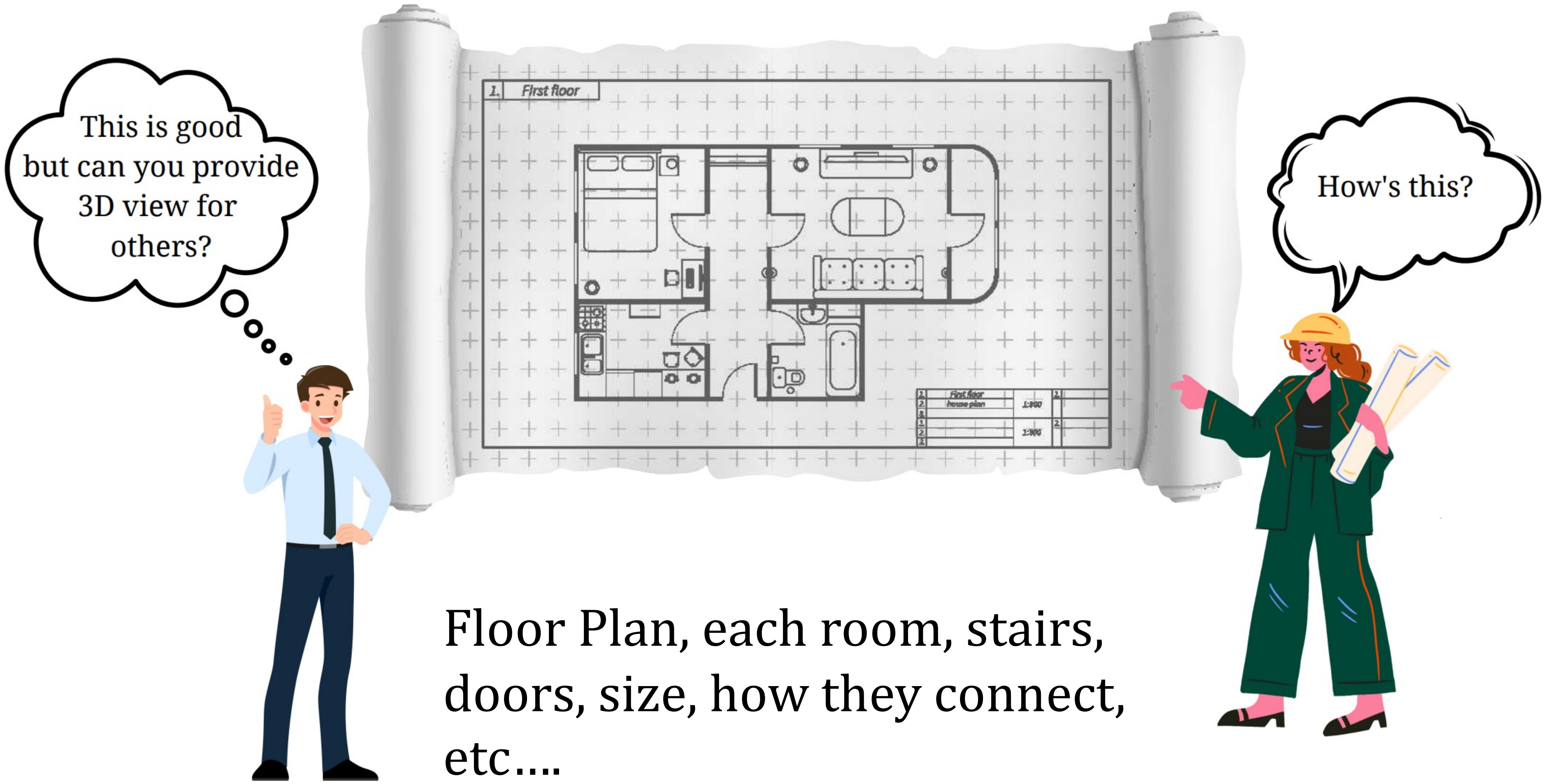
Design Decisions!!

What about window type?
- French Window
- Normal window
- Consider window location
- …

What about stair elevation?

- Roof length
- Type of people
- …

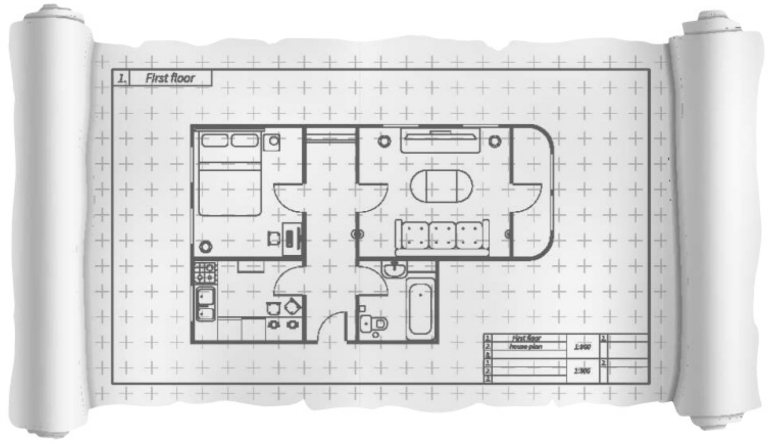
High level Plan Ready



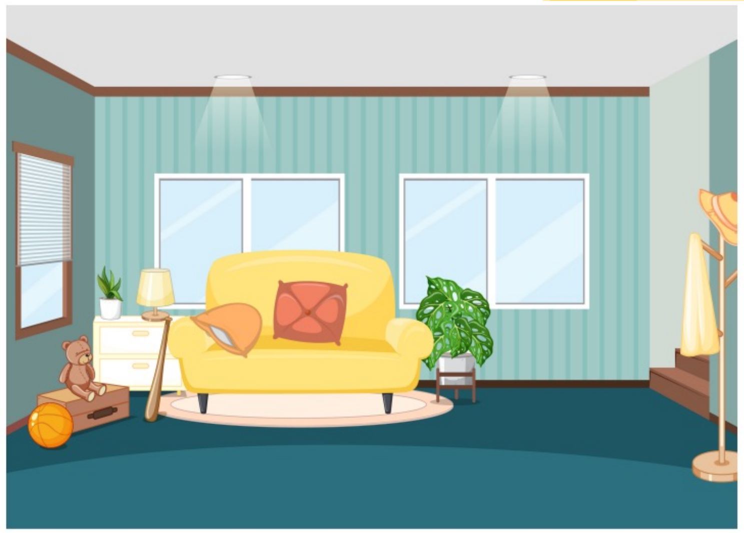
Floor Plan, each room, stairs, doors, size, how they connect, etc….

Multiple Views for different set of people

3D View



2D View

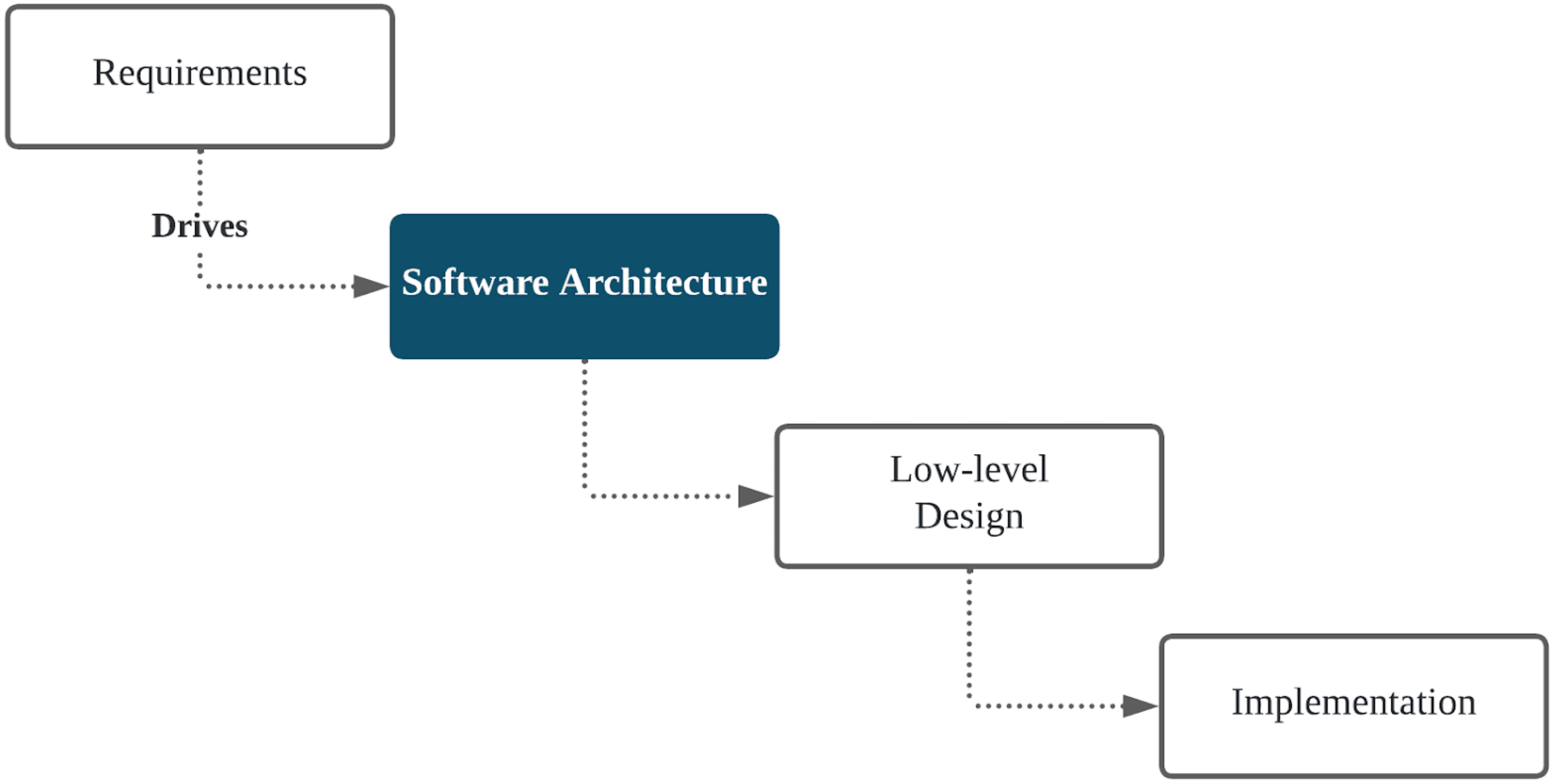

Interior View

Views and Viewpoints

Construction happens and the house is ready!

Let’s take this to Software

Where does Software Architecture come into Picture?



Software Architecture: Is that it?

*"Software is **not limited by physics**, like buildings are. It is **limited by imagination**, by design, by organization. In short, it is limited by properties of people, not by properties of the world. We have **met the enemy, and he is us**"*

Ralph Jhonson

Martin Fowler, ***Who needs an Architect?*** IEEE Software, 2003

Source: Googe images

What is Software Architecture?

Software Architecture Definitions

Many different definitions exist for software architecture!

Check: https://sei.cmu.edu/architecture/definitions.html

Software Architecture Definitions

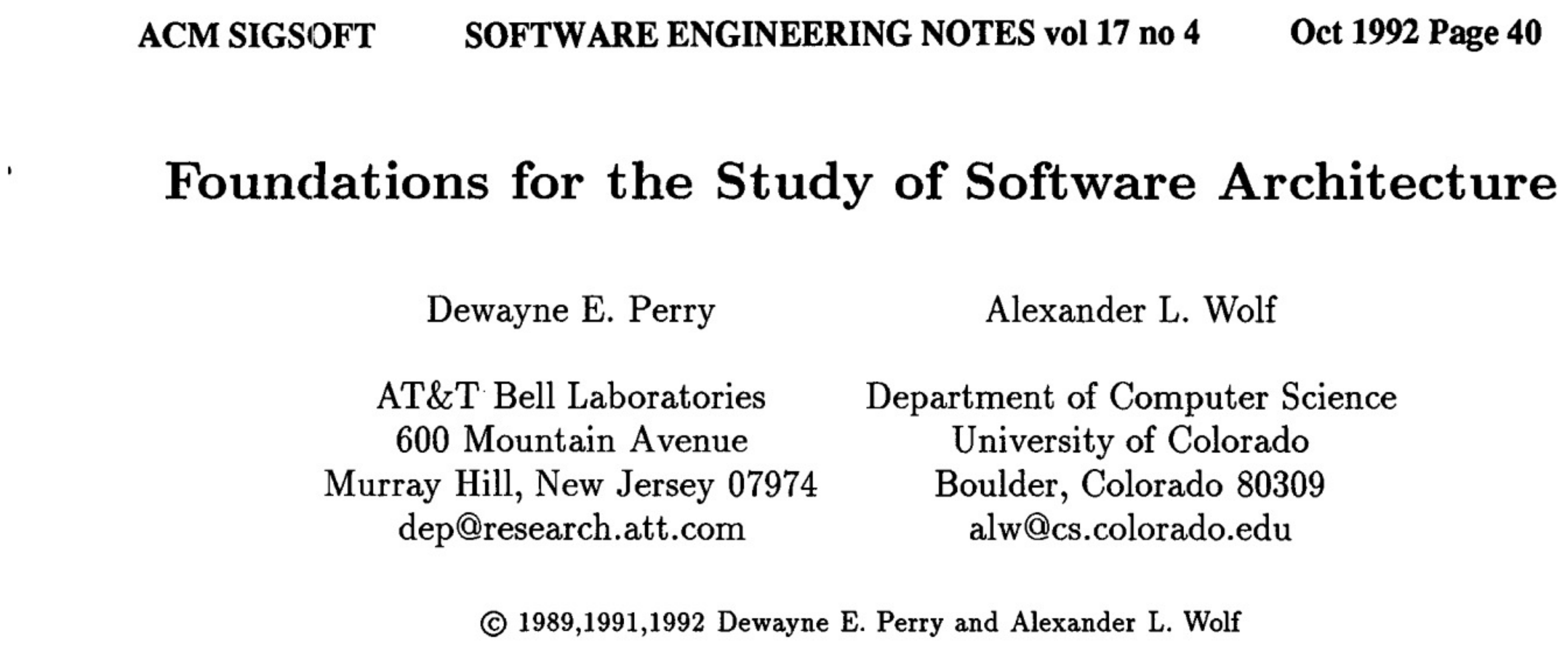
- Garlan and Shaw, ’93:

  Architecture for a specific system may be captured as “**a collection of** computational **components** - or simply components - together with a description of the interactions between these components - the **connectors** ”

- Bass et al.:

"The software architecture of a program or computing system is the **structure or structures** of the system, which comprise **software elements**, the **externally visible properties** of those elements, and the **relationships** between them."

Software Architecture


ACM SIGSOFT SOFTWARE ENGINEERING NOTES vol 17 no 4 Oct 1992 Page 40

Foundations for the Study of Software Architecture

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Murray Hill, New Jersey 07974
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Alexander L. Wolf
Department of Computer Science
University of Colorado
Boulder, Colorado 80309
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Software Architecture = {Elements, Form, Rationale}

Elements, Form and Rationale

Elements (Components and Connectors)

1. Three types: data, processing and connecting elements
2. They form the foundational pieces of a software architefctre

Form (Architectural Patterns/Styles)

1. Weighted properties and relationships
2. Properties indicate the properties of the elements and weight indicates relevence/preference
3. Relationships constrain the placements of elements (how they interact, how they are organized, etc.)

Rationale (Design Decisions)

1. Captures the motivation for choice of architectural style, elements and form

Software Architecture

The Software Architecture is the **earliest model** of the **whole software system** created along the software lifecycle

- A set of **components and connectors** communicating through interface
- A set of **architecture design decisions**
- Focus on set of **views and viewpoints**
- Developed according to **architectural styles**

Why Software Architecture?

Interesting Rather Relevant Definitions

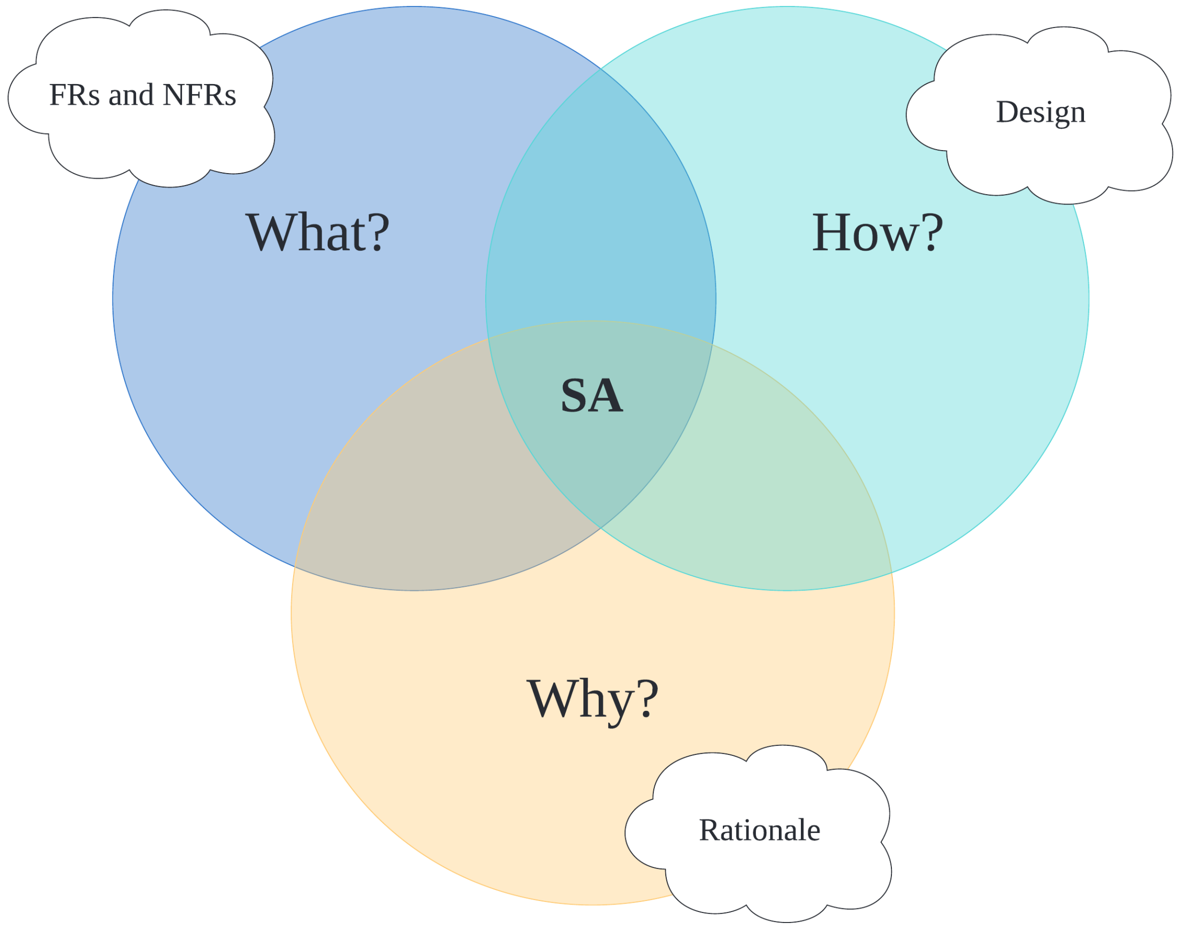
“The shared understanding that the expert developers have of the system design”

”The decisions you wish you could get right early in a project”

*“Software Architecture is about **all the important stuff**, whatever that is”*

Martin Fowler, ***Who needs an Architect?*** IEEE Software, 2003

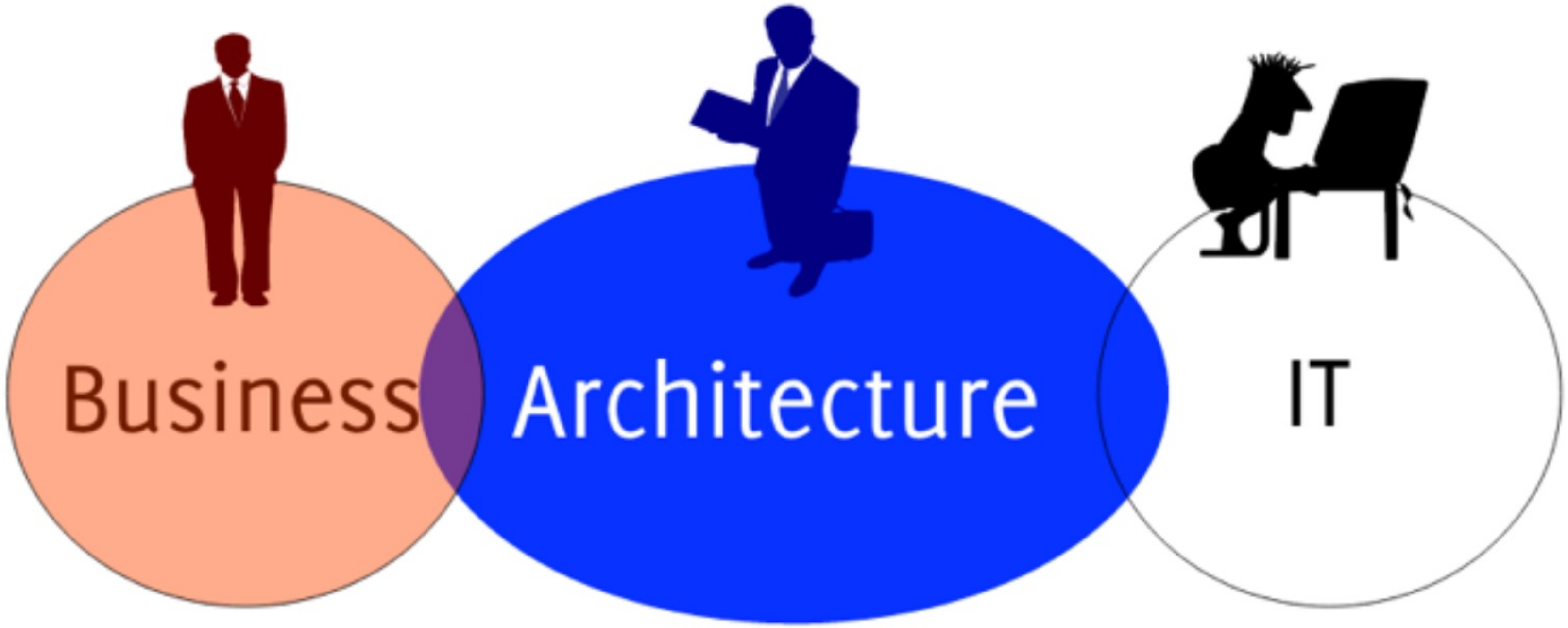
Abstraction



Manage complexity in the design (Transferable abstraction, promotes reuse)

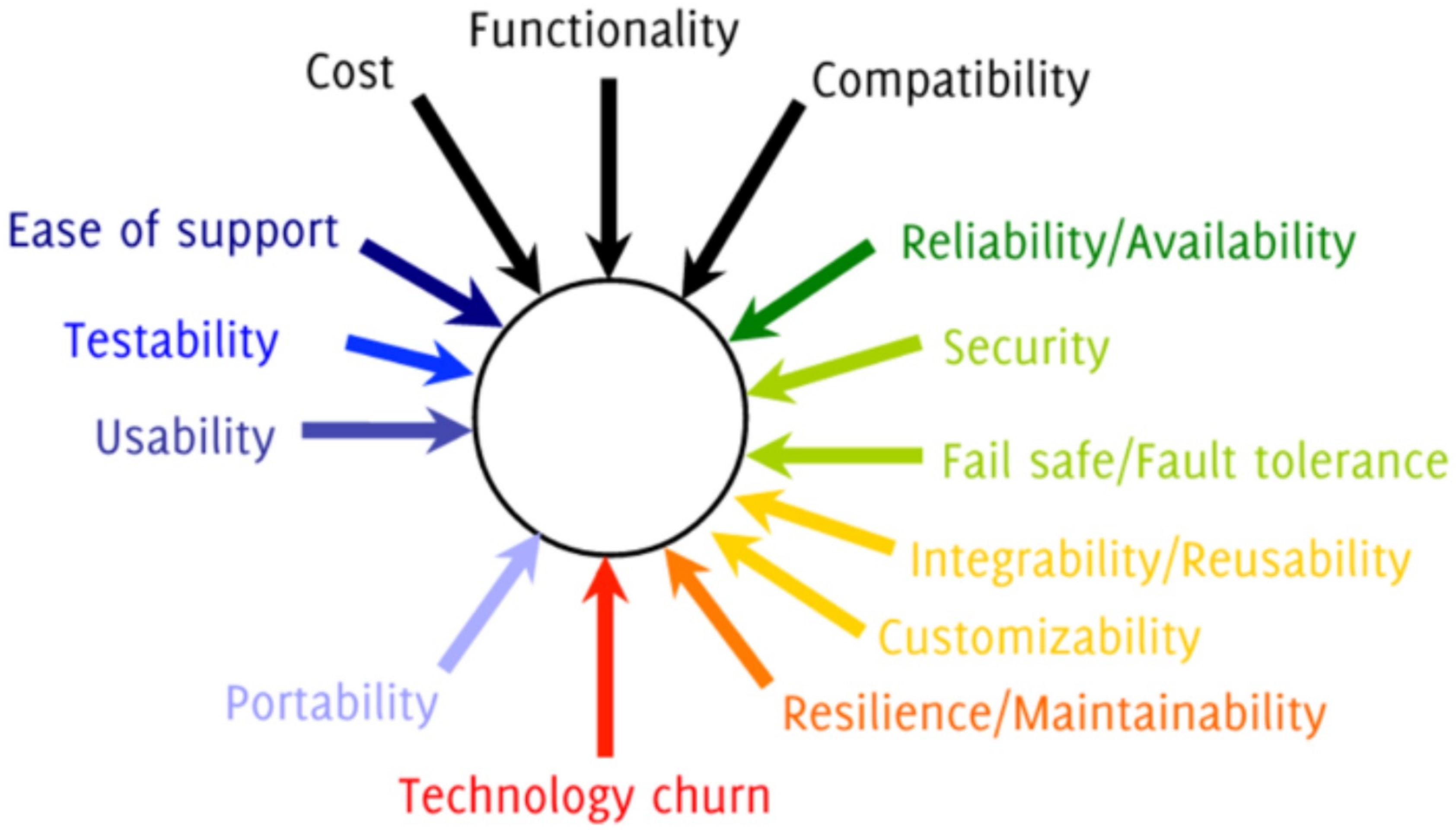
Communication

“Good architects are grown not born”



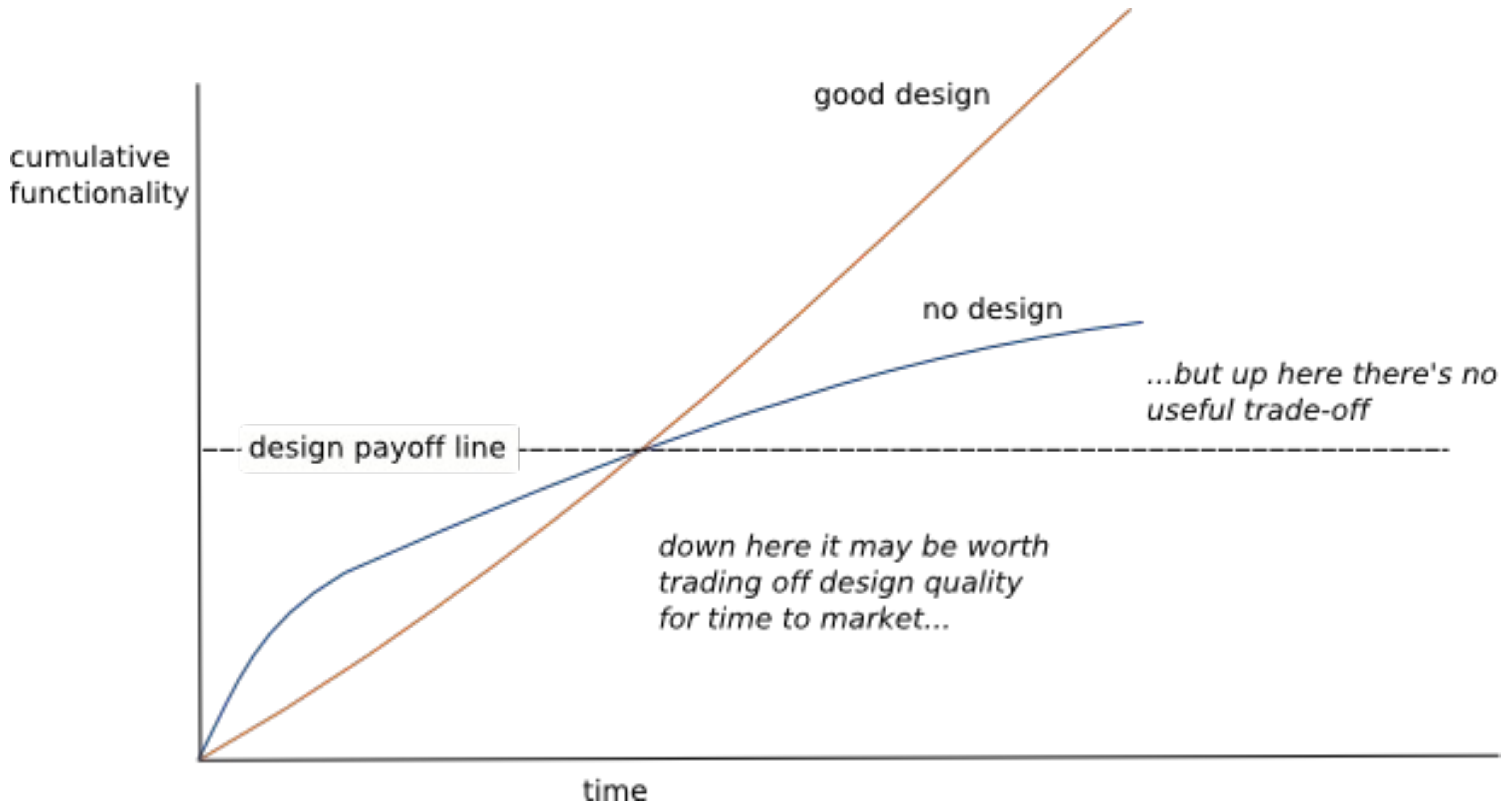
1. Document, remember and commmunicate among stakeholders
2. Manifest early design decisions

Quality Analysis



Understand, Predict and Control

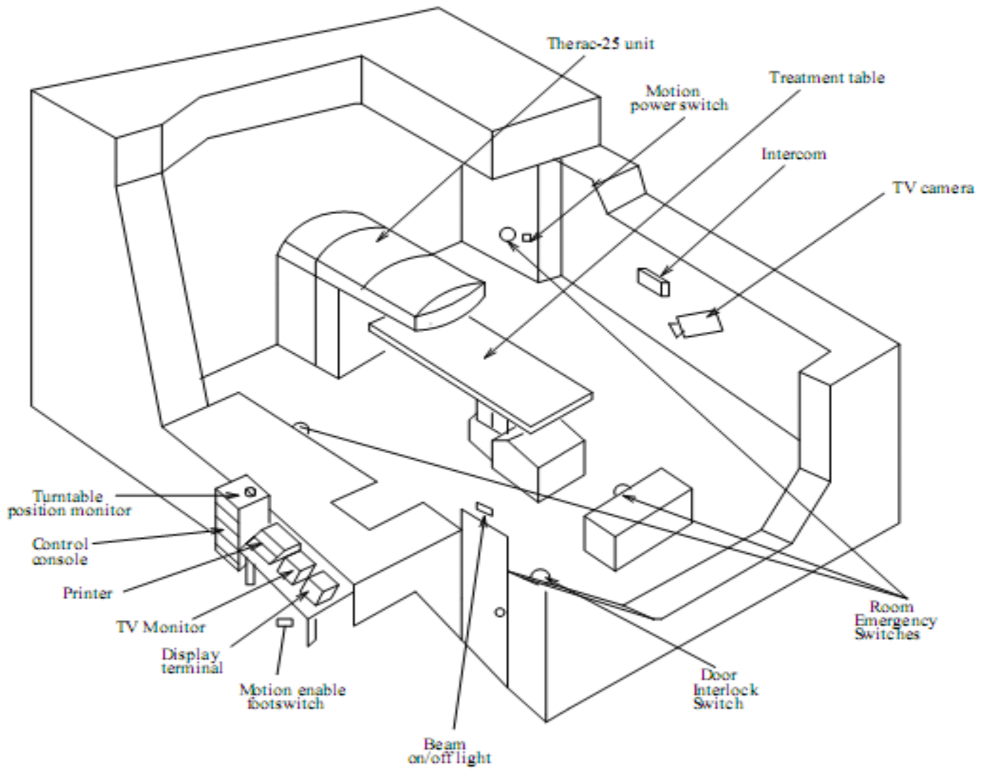
Design Stamina Hypothesis



https://martinfowler.com/bliki/DesignStaminaHypothesis.html

Why to Care? - The Case of Therac 25

- approximately 100 times the intended dose of radiation
- 3 people died, and 6 got injured



1. **Overconfidence in software!!**
2. In adequate software engineering practices
3. Design failure – No defensive approach (0 error handling or verification)

For more info: http://sunnyday.mit.edu/papers/therac.pdf
https://www.computer.org/csdl/magazine/co/2017/11/mco2017110008/13rRUxAStVR

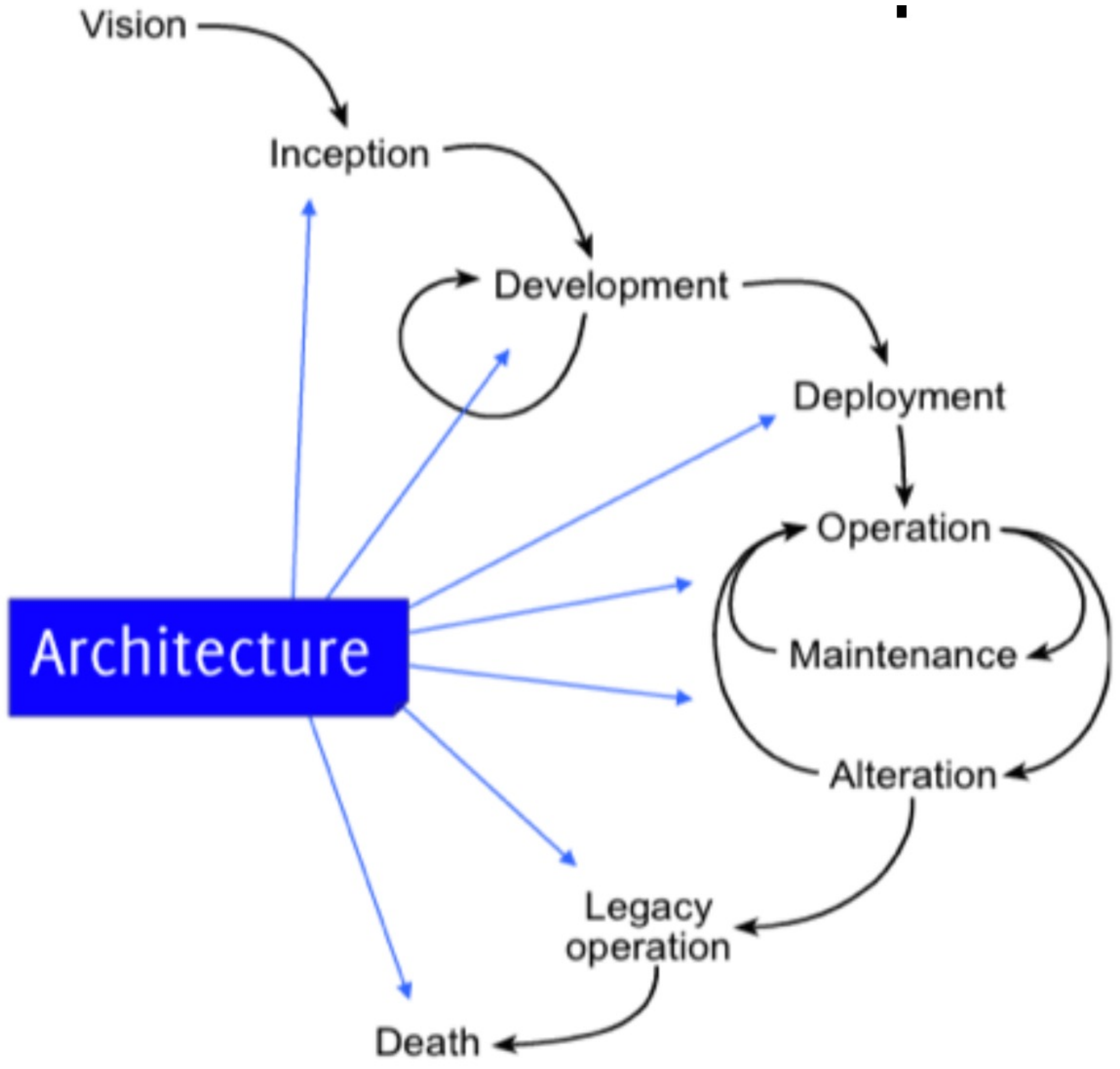
Why to Care?

- All the software systems have an architecture
  - All the critical/complex systems must have it carefully and explicitly specified

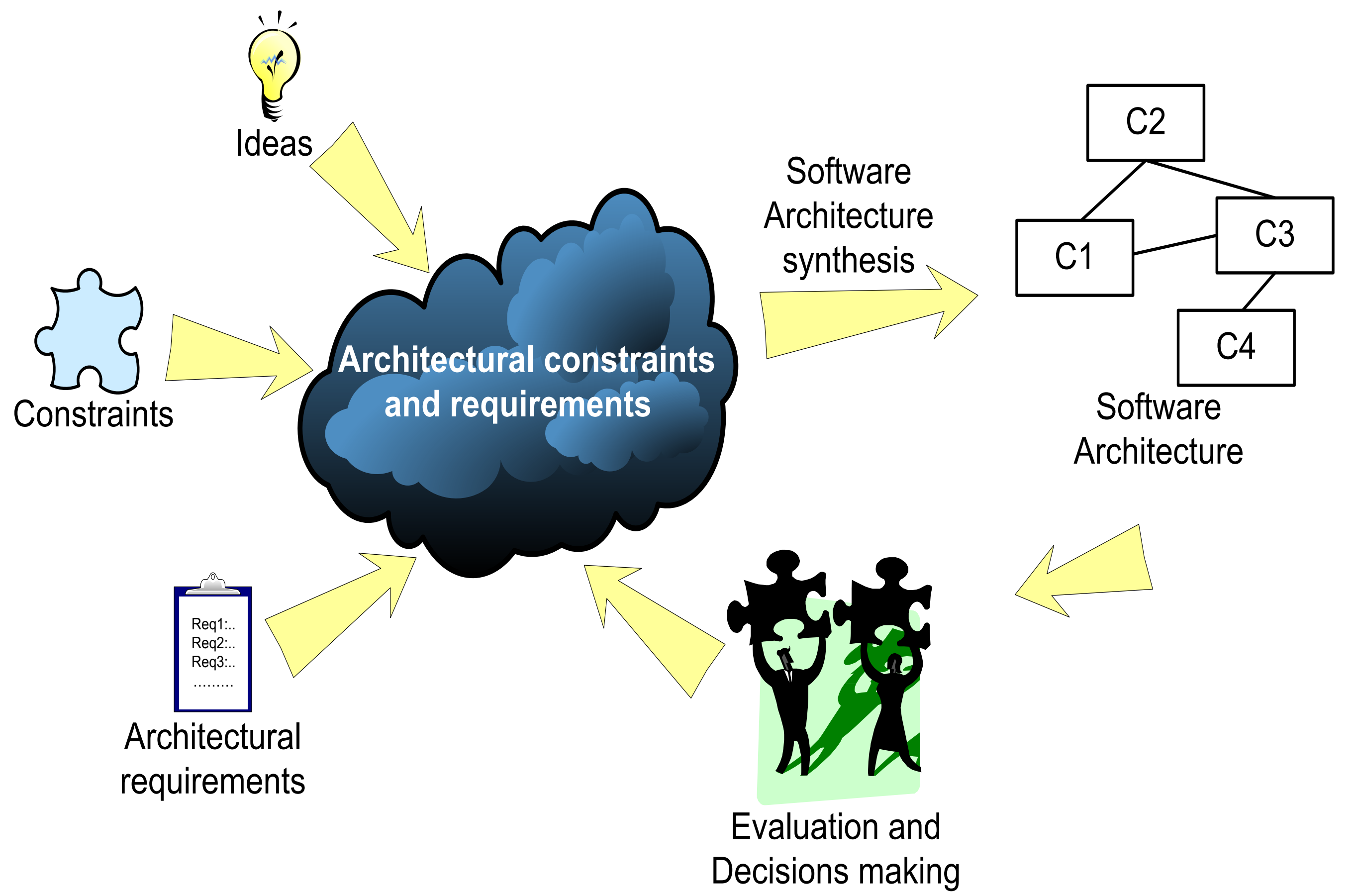
- Architecture-level decisions impact the scalability, performance, testability, functioning of the produced system

- Even if the code is perfectly written, a wrong architecture produces a wrong system

When does SA end?

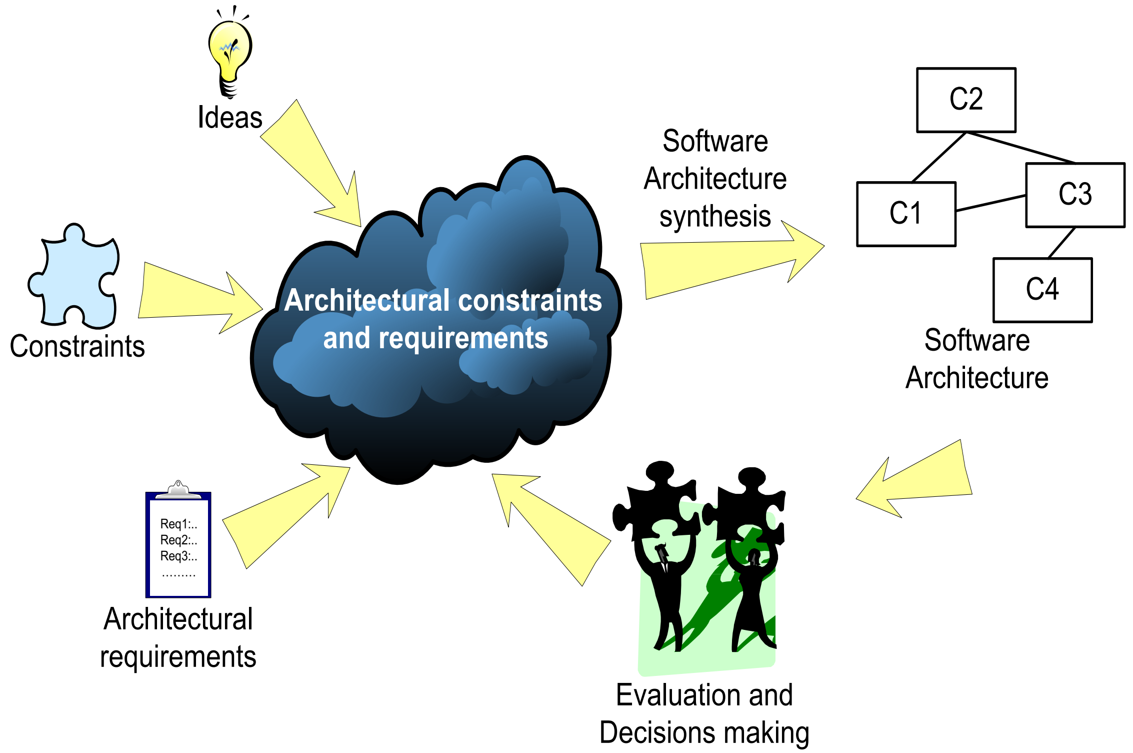


The Overall Architecting Process


Ideas
Constraints
Architectural constraints and requirements
Req1:..
Req2:..
Req3:..
....
Architectural requirements
Software Architecture synthesis
C2
C1
C3
C4
Software Architecture
Evaluation and Decisions making

So which is the right architecture?

- There is not one that is the best – tradeoff’s
- The one that satisfies at best the requirements and constraints
- The "less" risky one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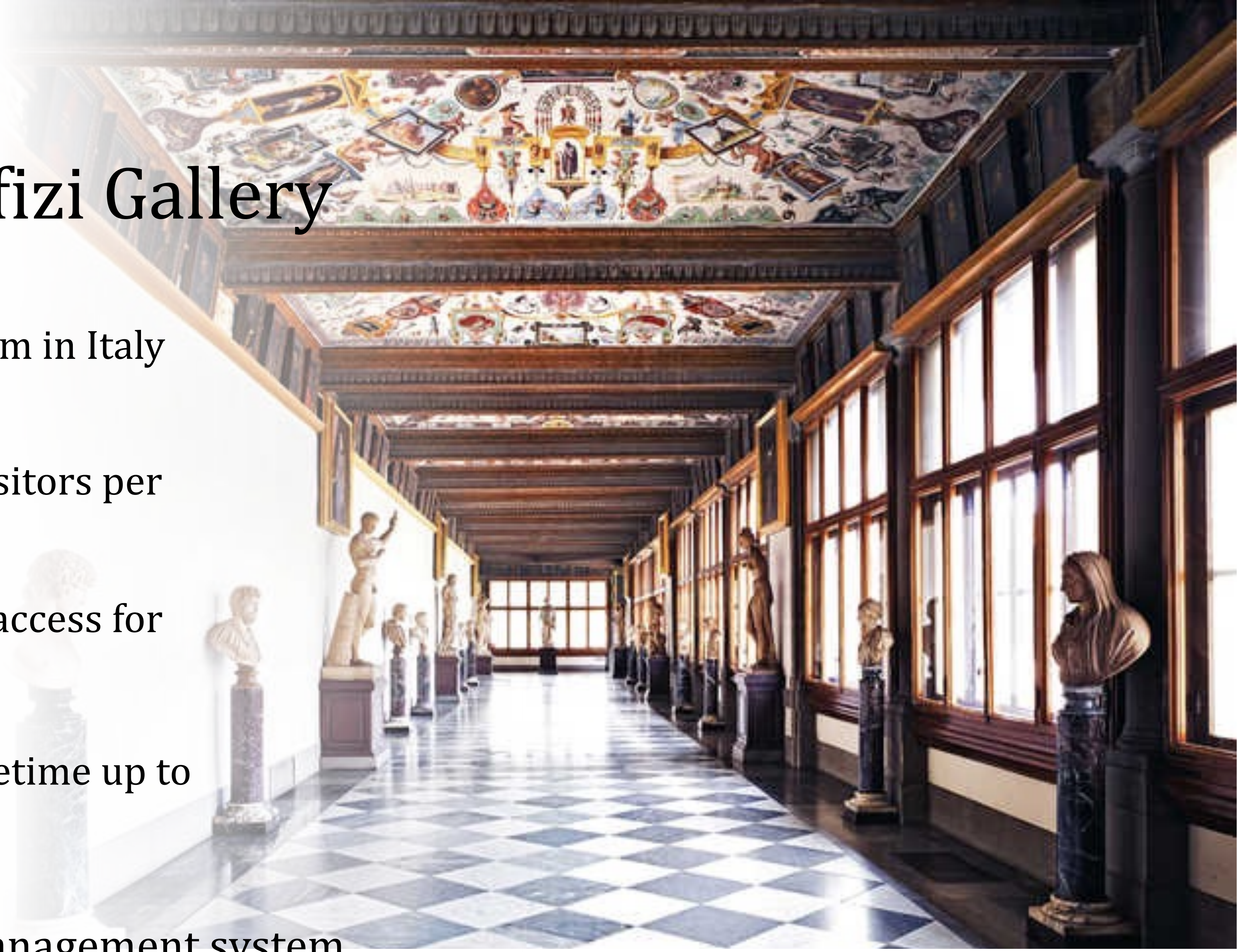
Software Architecture
Evaluation and Decisions making

Concrete Example

The Case of Uffizi Gallery



- 3rd most visited museum in Italy in 2018
- More than 2.200.000 visitors per year
- Limited contemporary access for safety reasons
- Waiting time went sometime up to **4 hours!!**

Goal: Build a crowd management system

Requirements for the System

Functional Requirements:

1. FR1: User Registration
2. FR2: Check Availability
3. FR3: Entry booking
4. FR4: Recommendations

…..

Non-Functional or Extra Functional Requirements:

1. EFR1: Performance – Latency/request < 0.1 sec
2. EFR2: Security – Prevent unauthorized access
3. EFR3: Availability – 99.999%
4. EFR4: Scalability – 1000 users/second
5. **…**

Let the key requirements drive the high-level design of the system!!!

Software Architecture

The Software Architecture is the **earliest model** of the **whole software system** created along the software lifecycle

- A set of **components and connectors** communicating through interface
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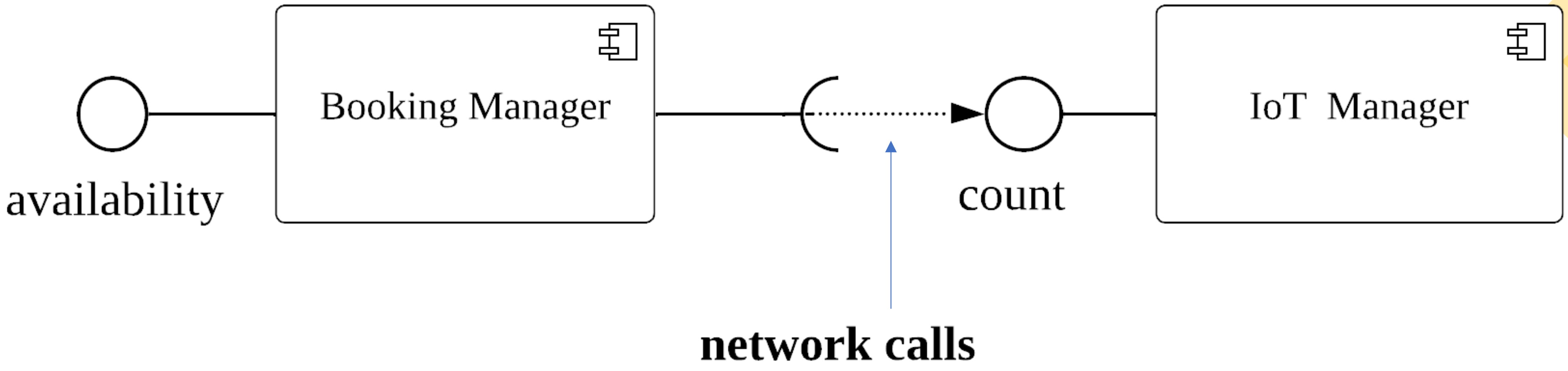
- Focus on set of **views and viewpoints**
- Developed according to **architectural styles**

Components and Connectors

Components and Connectors



Components:

- Data or processing element
- Has a **provided** and **required** interface

Eg: database, client, server, etc.

Connectors:

- Enables interaction among components
- Can be implicit or explict

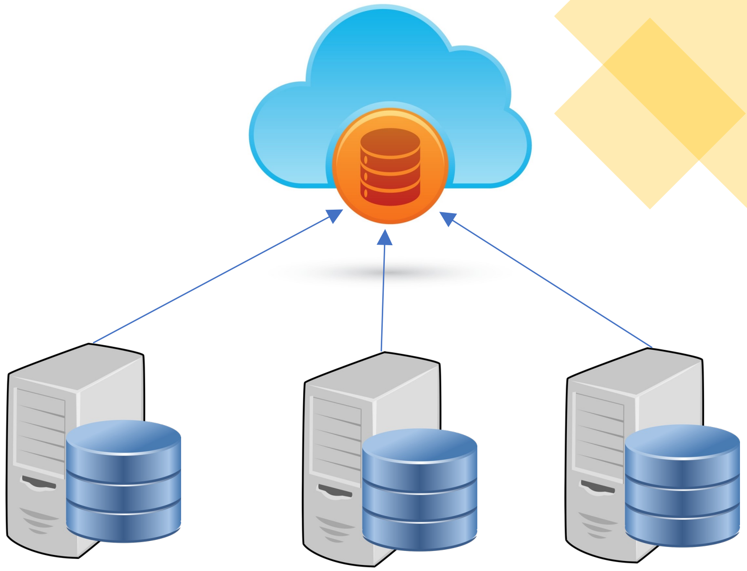
Eg: HTTP events, proceduce calls, etc.

Design Decisions

Let us revisit our case – What to Choose?

Centralize data in cloud

Store data in Fog


Each museum can have its own data

Implications on performance, privacy, security, etc.

Reasoning with Simple Logic may not work!

- Oracle is more scalable than MySQL
- MySQL is more scalable than Informix

Therefore Oracle is more scalable than Informix

Q: I need a scalable RDBMS, Shall I got with Oracle?

A: It depends!!!

Architectural Design Decisions

Decisions about:

Selected components/interfaces/connectors
Distribution/Configuration of components/connectors
Expected behavior
SA Styles, Patterns and Tactics
HW/SW/Deployment and other views
Components' Nesting and sub-systems
NF attributes

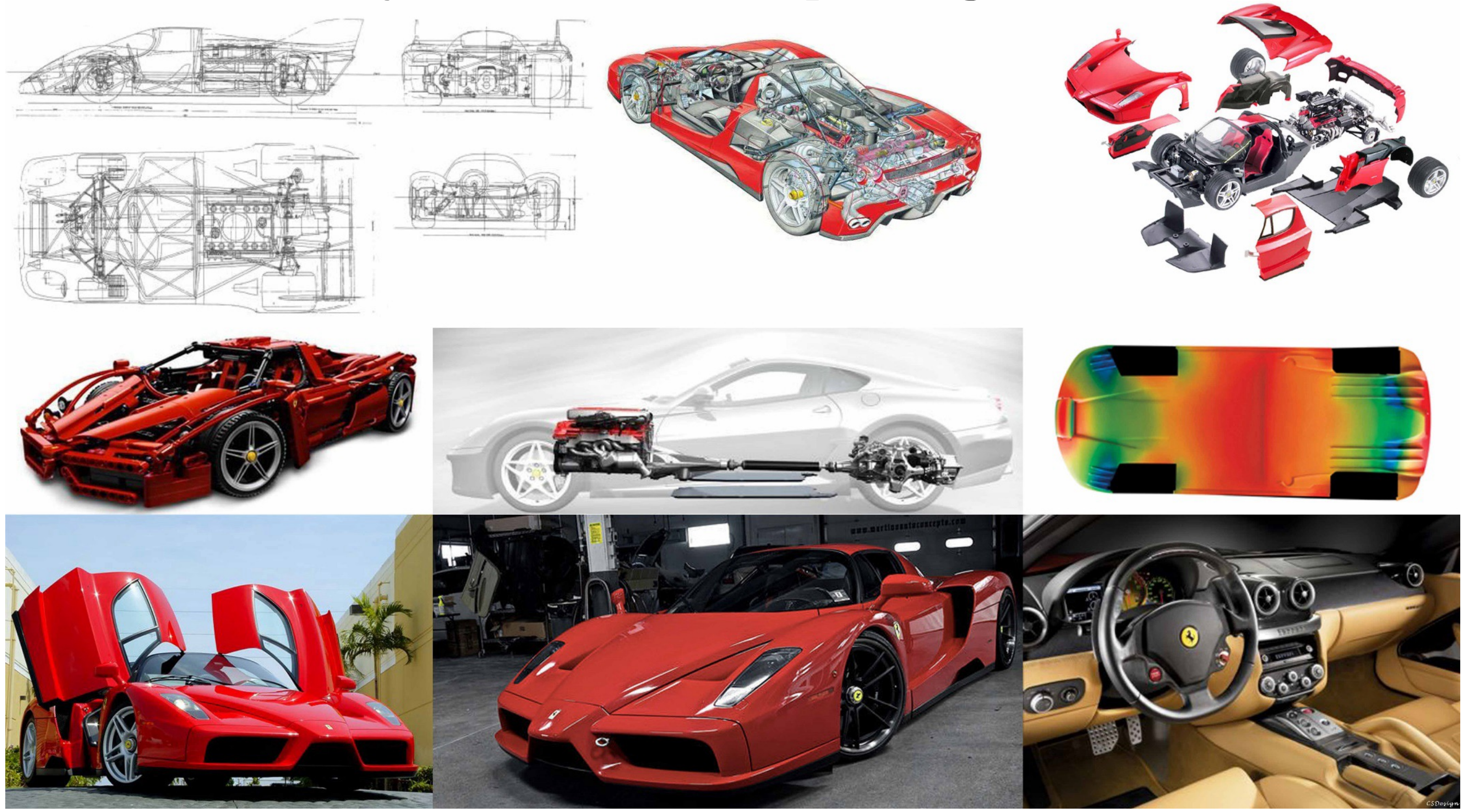
Consequences of Design Decisions

- Defines constraints on implementation
- Dictates organizational structure
- Inhibits or enables system's quality attribute
- System qualities may be predicted
- Easier to manage change
- Helps in evolutionary prototyping
- Enables cost and schedule estimates

Views and Viewpoints

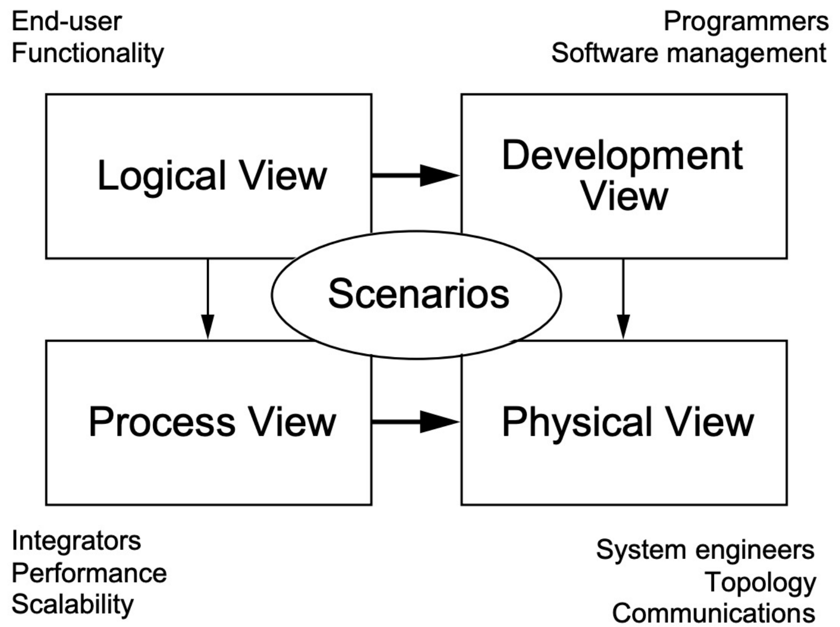
Architecture View and Viewpoints

- Viewpoint is about where you see from
- View is what you see!! – Viewpoint governs the view

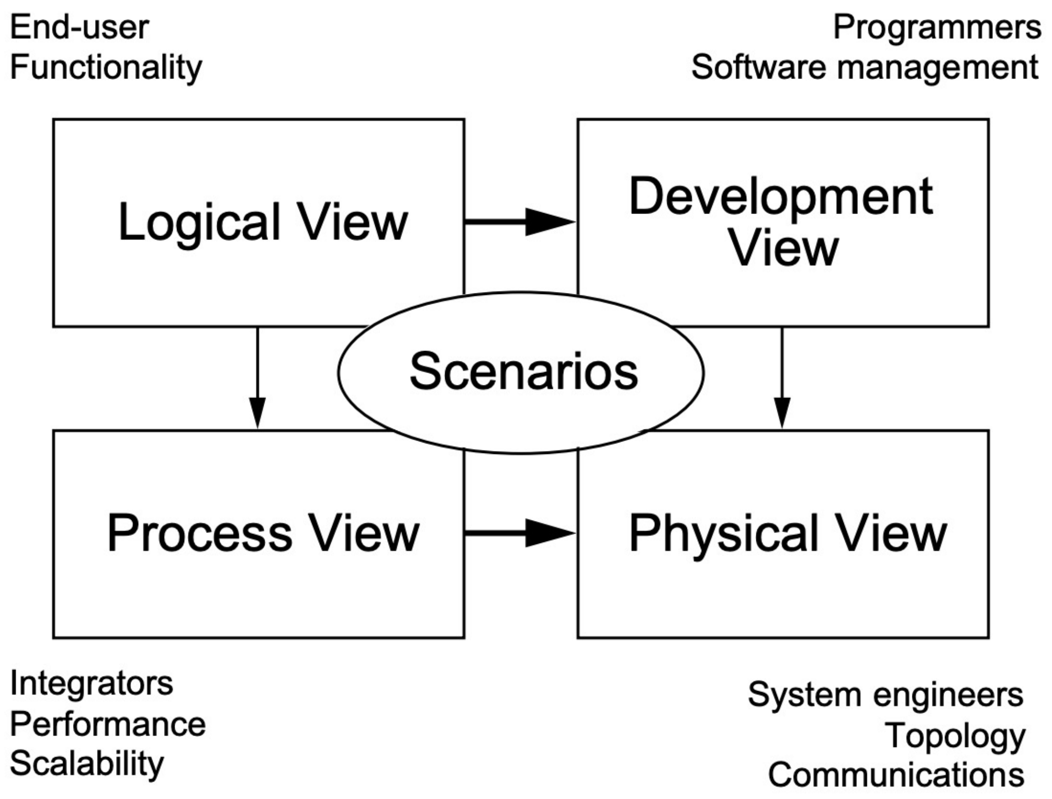


Architectural Views – How Many?

- View represents a collection of architectural elements and relations among them
- Two fundamental views – Structural and Behavioral
- Many models have been proposed – eg: 4+1 view model



4+1 View Model of Software Architecture

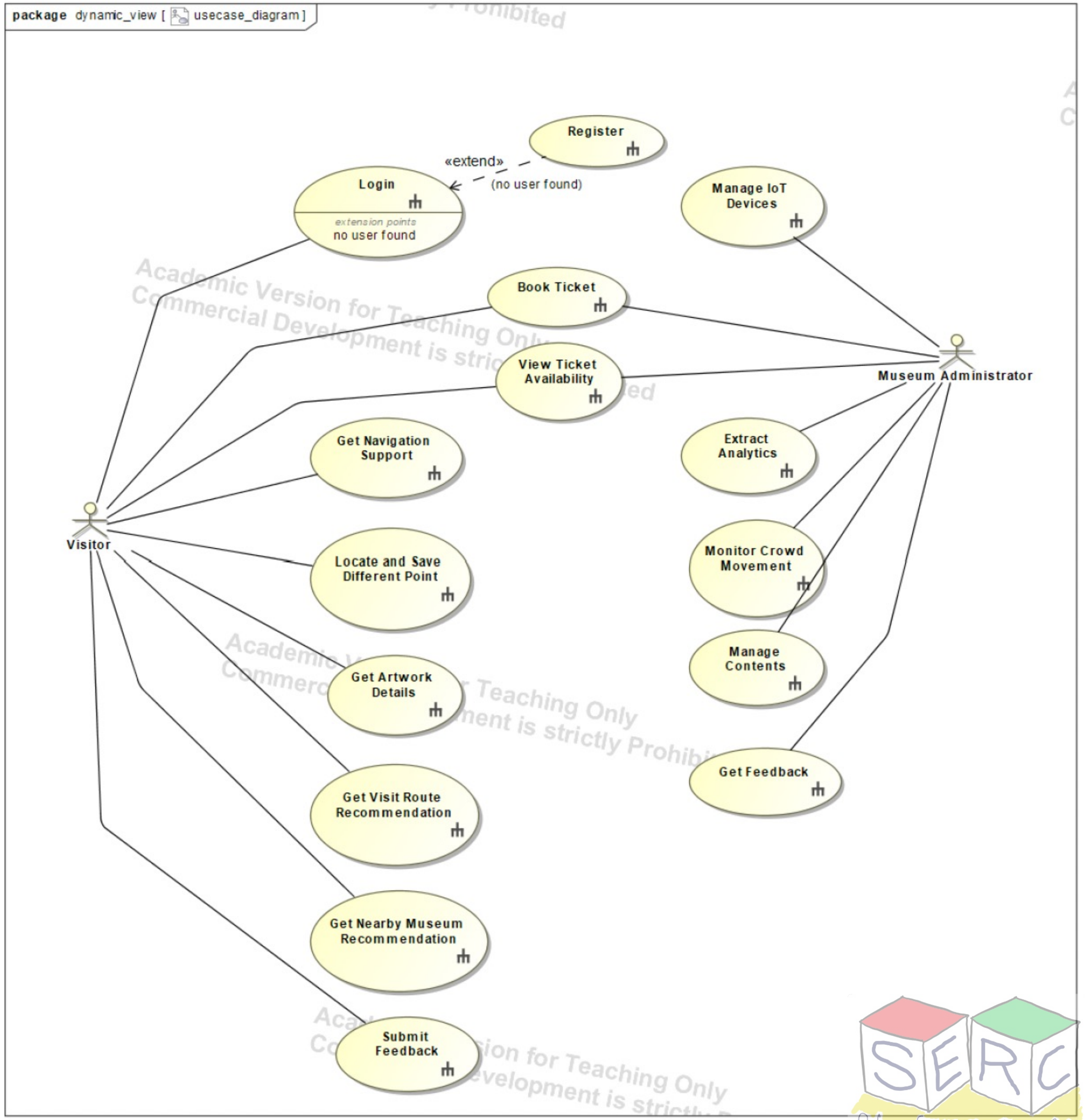


The "4+1" view model is rather "generic": other notations and tools can be used, other design methods can be used, especially for the logical and process decompositions, but we have indicated the ones we have used with success.

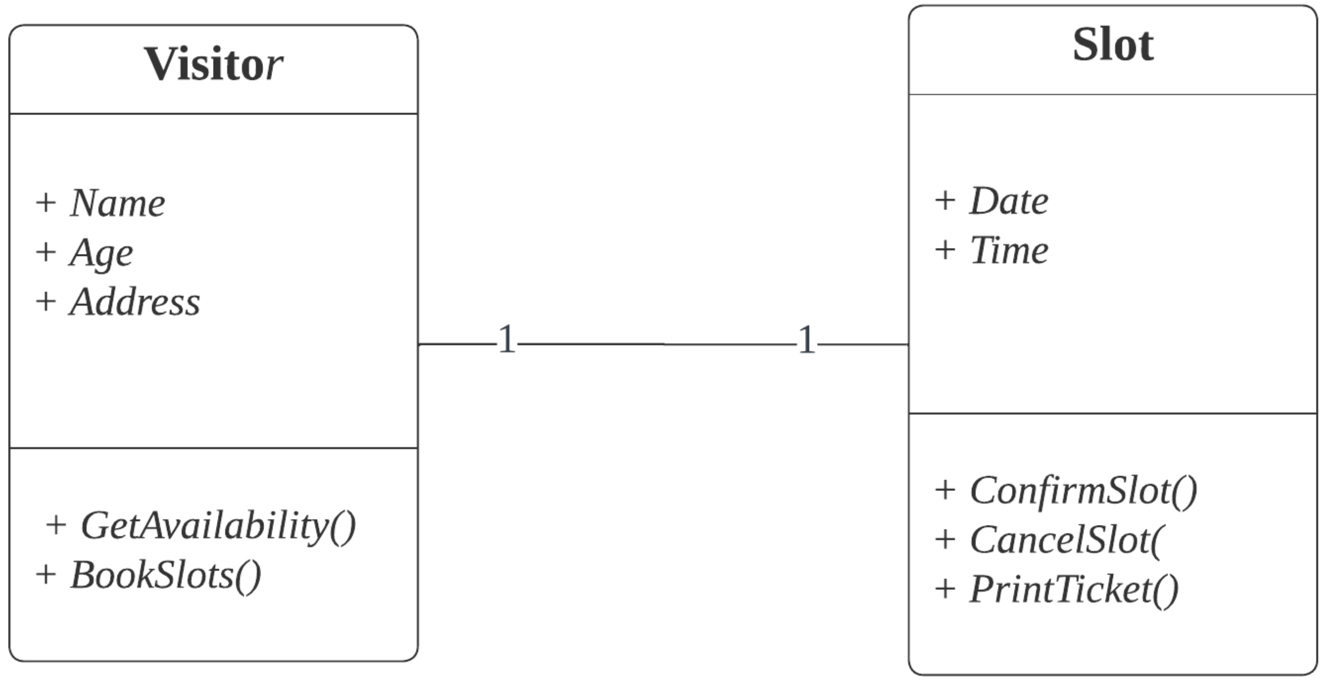
- Philippe Kruchten, Architectural Blueprints—The "4+1" View Model of Software Architecture

Scenarios

- Represent the different use cases
- **Stakeholders:** End-user, developer
- **Concerns:** Understandability
- **Diagram:** Use case diagrams



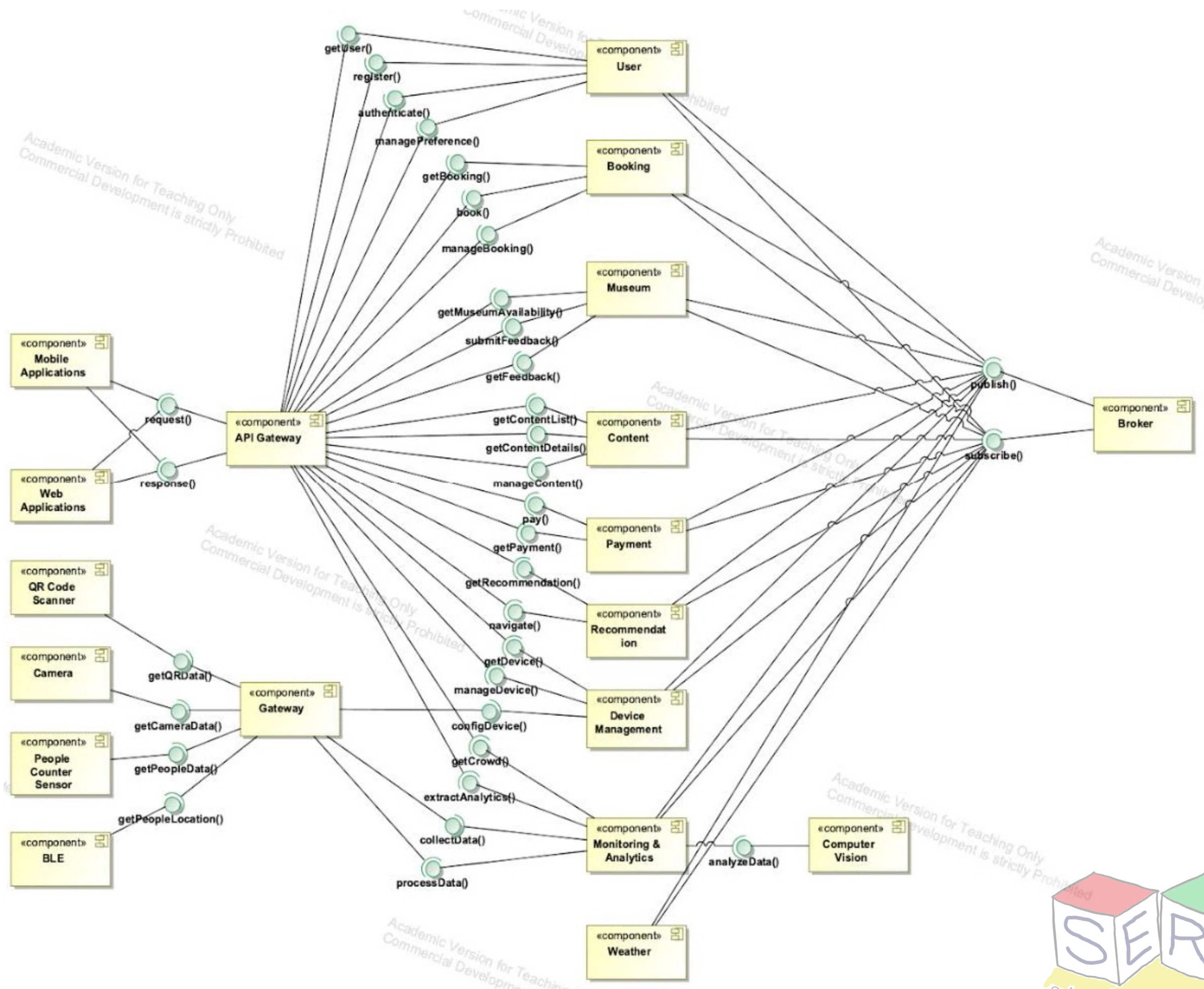
Logical View



- System decomposed into a set of abstractions (objects or object classes)
- **Stakeholders:** Developer
- **Concerns:** Functionality
- **Diagrams:** UML Class diagrams, logical connection diagrams

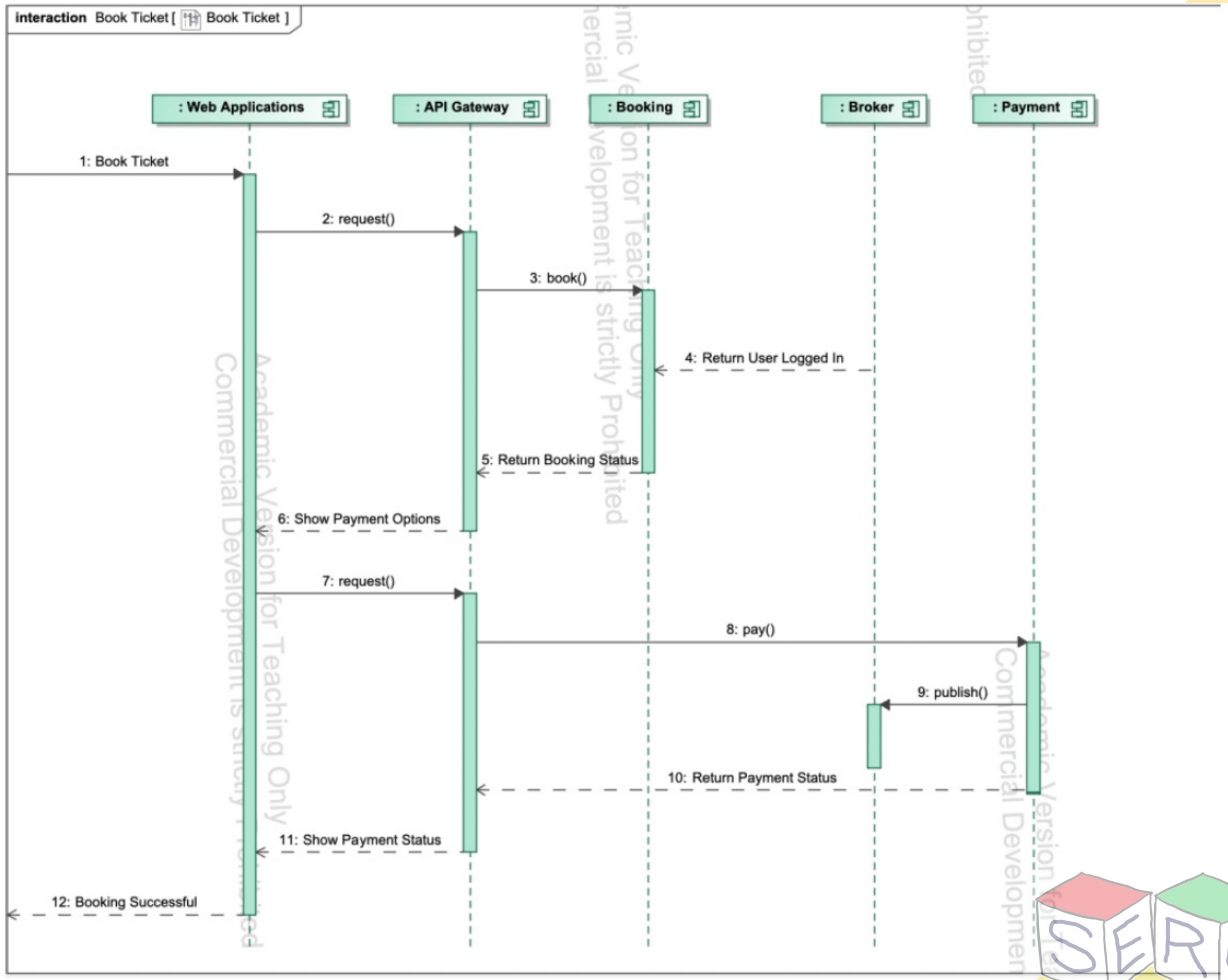
Development View

- Organization of software into subsystems/modules
- **Stakeholders:** Developer, manager
- **Concerns:** Organization, reuse, portability
- **Diagram:** UML Component diagram



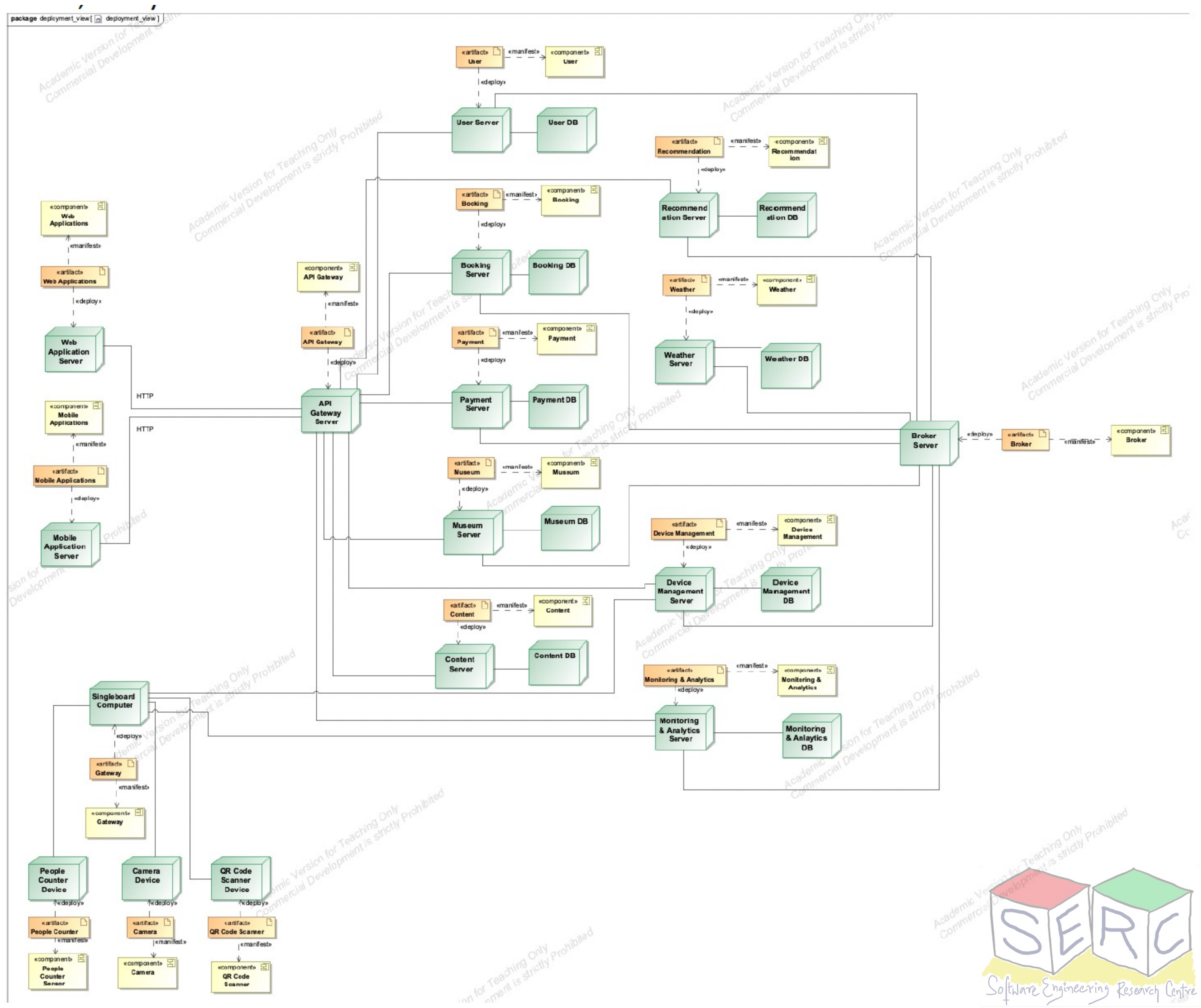
Process View

- Model dynamic aspects of softtware architecture
- **Stakeholders:** System designer, integrator
- **Concerns:** Performance, fault tolerance
- **Diagram:** UML Sequence diagram, Process diagram, Data flow



Physical View

- Mapping of SW elements into deployment nodes
- **Stakeholders:** System designer, Admin
- **Concerns:** Performance,Scalability, Availability
- **Diagram:** UML Deployment diagram, Network diagram, etc.



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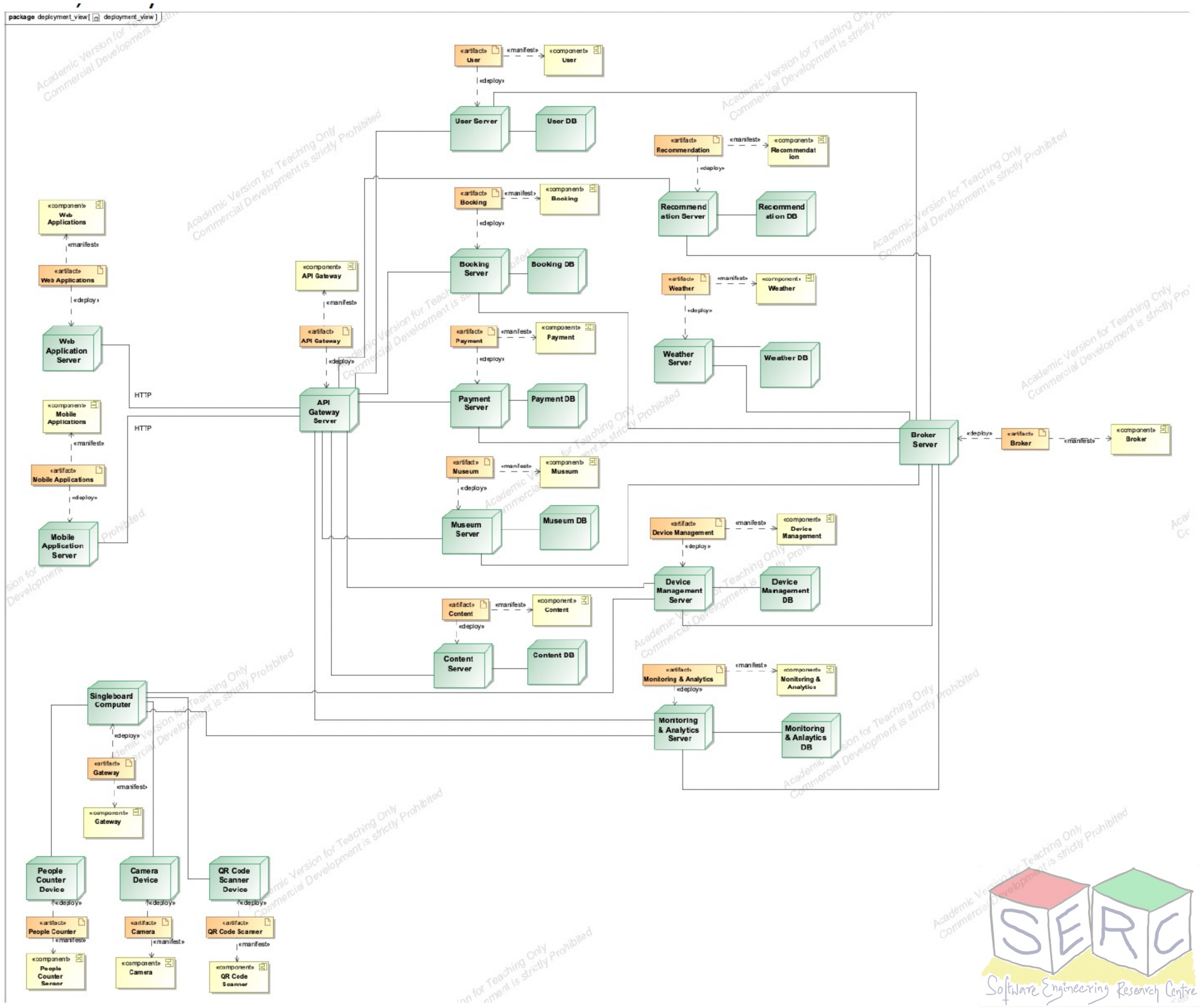

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Architecture Description

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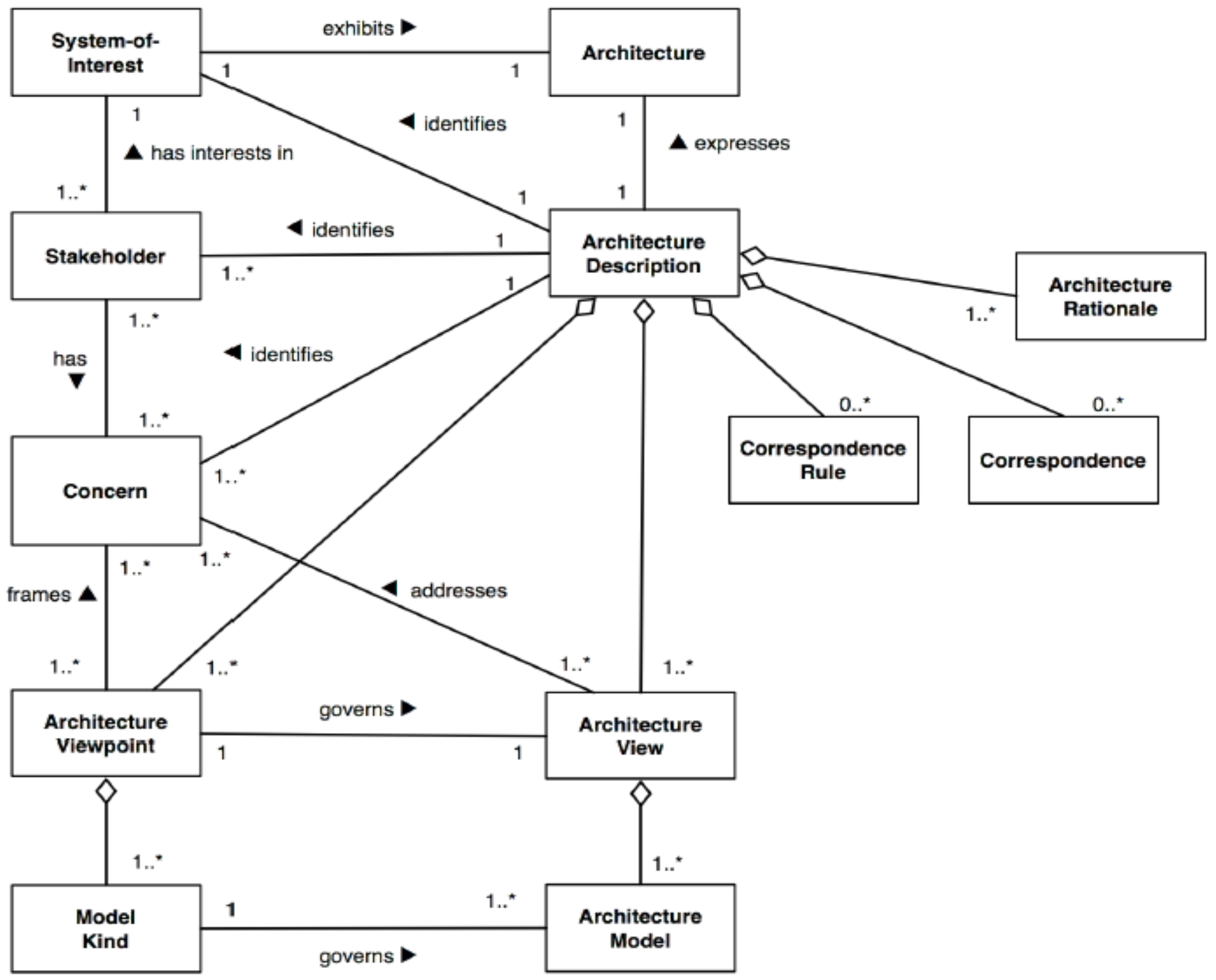

Thank You

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