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Software Architecture and High-Level Design

Foundations of Software Engineering

FSE v2020.1, Block 1 Module 4

Alexey Artemov, Fall 2020

Lecture Outline

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§1. Why software architecture [15 min]

1.1. Partitioning, knowledge, and abstraction

1.2. Example architecture of a logging system

1.3. What is architecture?

1.4. When/why is architecture important?

Lecture Outline

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§2. Some principles of software architecture [10 min]

2.1. Prioritizing quality attributes

2.2. Architecture drivers, tradeoffs, and design decisions

§3. Software architecture notation [15 min]

3.1. Canonical model of software design

3.2. Component and connector

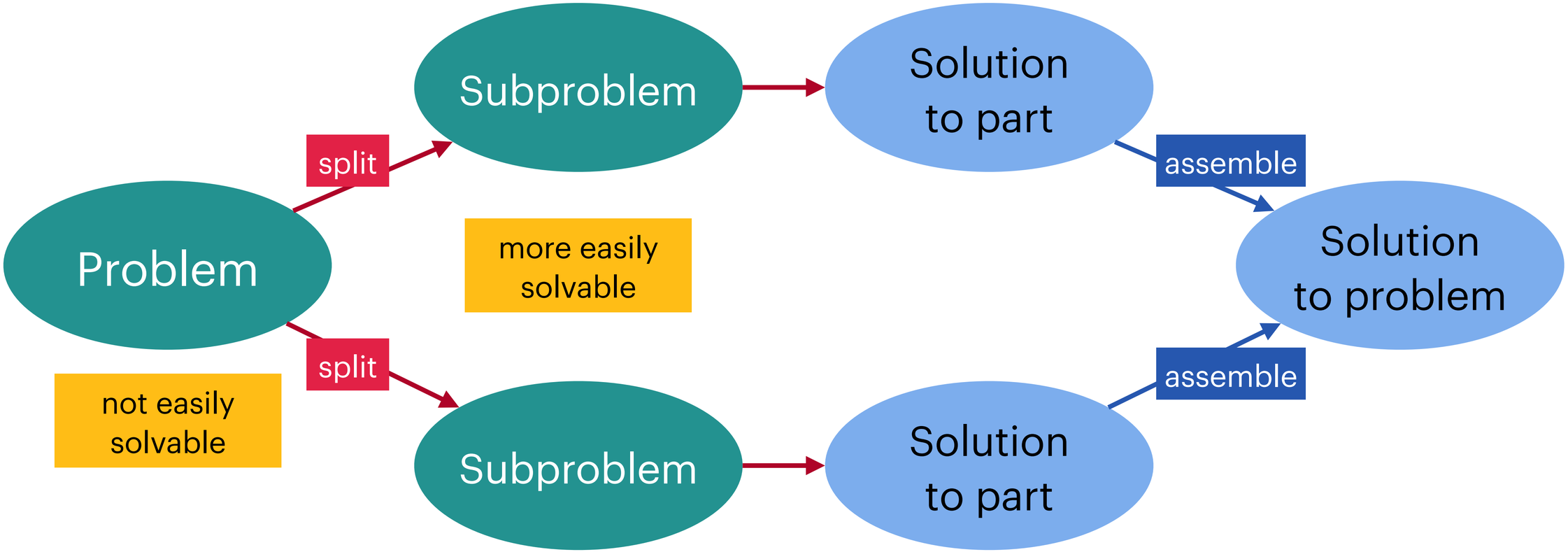
The Goal:
Think Before You Code

§1. Why software architecture?

Partitioning, knowledge, abstraction

§1. Why software architecture?

1.1. Partitioning, knowledge, and abstraction



§1. Why software architecture?

1.1. Partitioning, knowledge, and abstract

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Design Google Maps

- Choose map style
- Choose controls style
- Design info panels

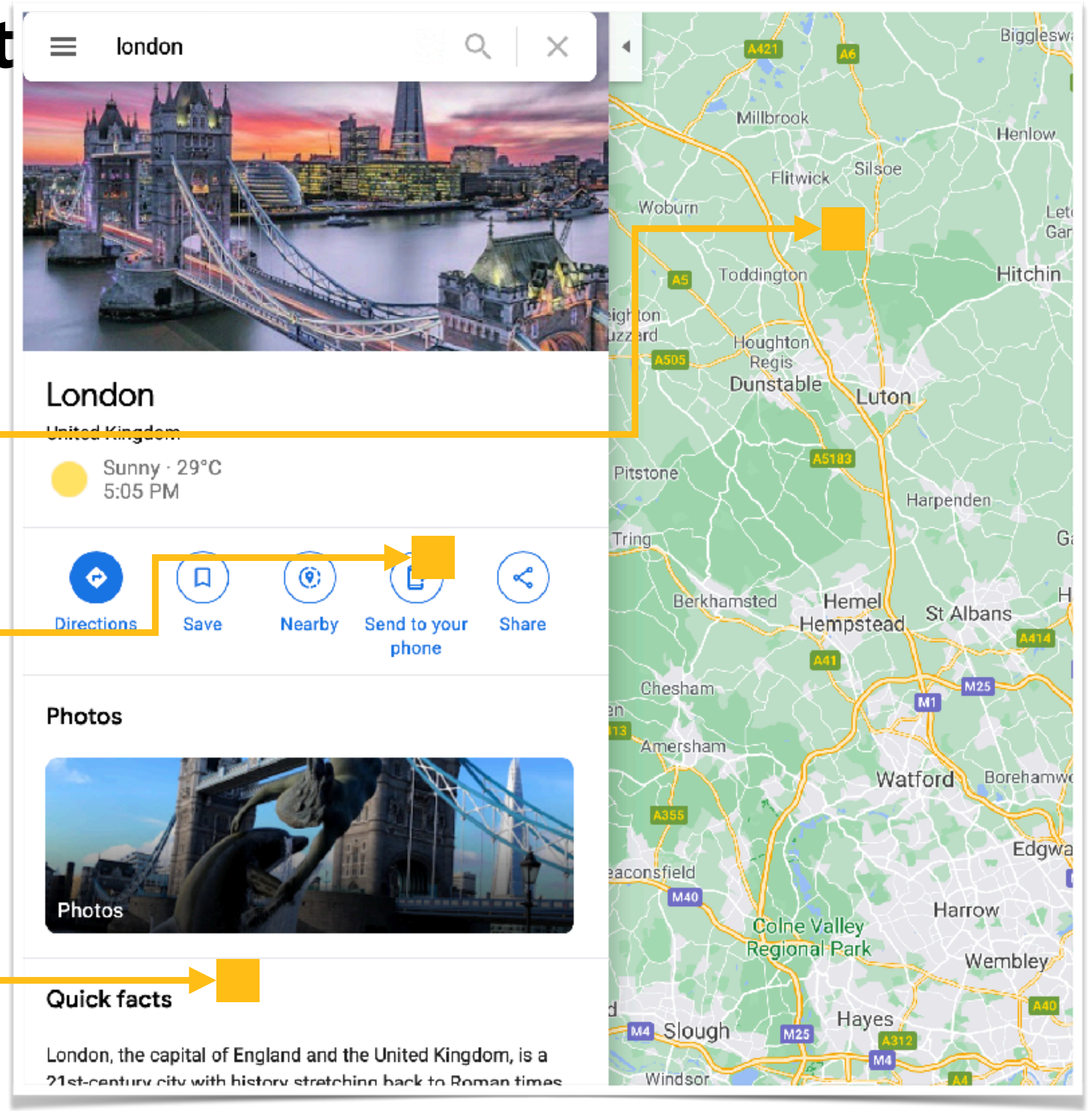
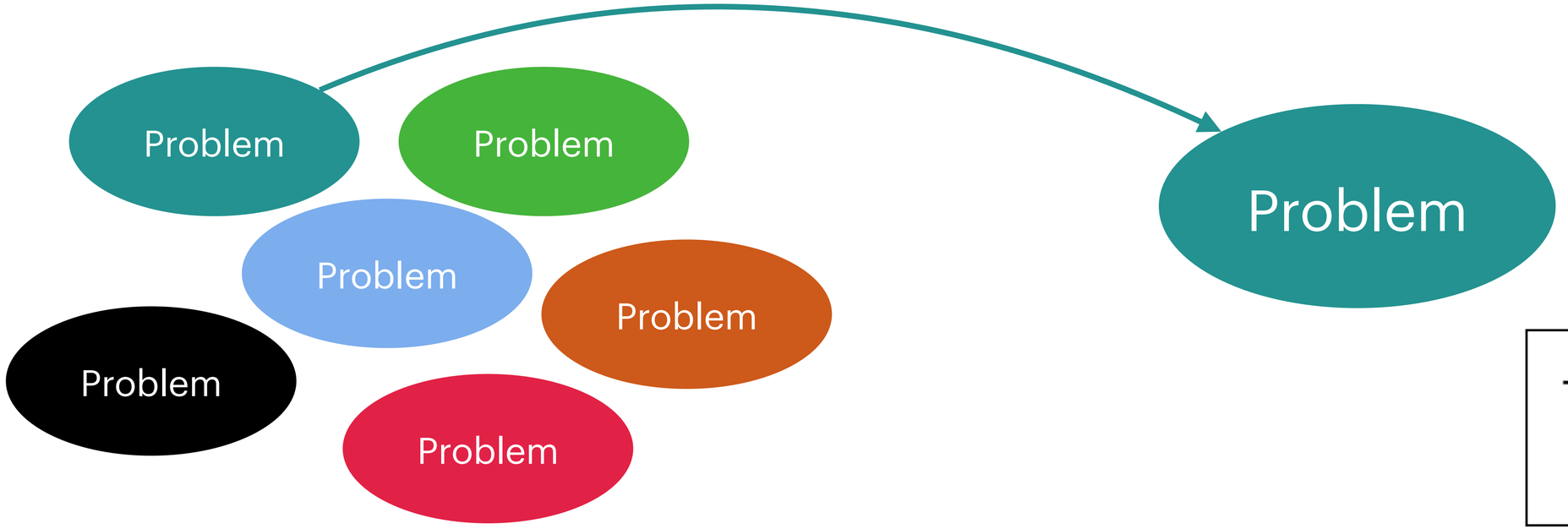
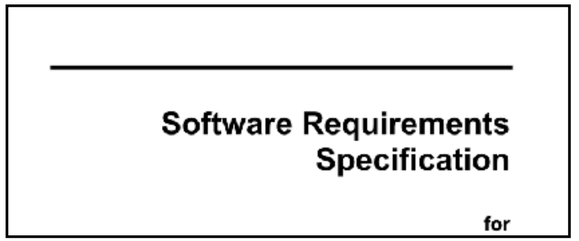


Image Credit: Google Maps

§1. Why software architecture?

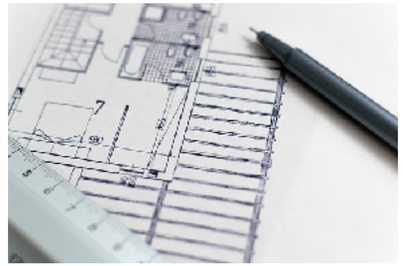
1.1. Partitioning, knowledge, and abstraction





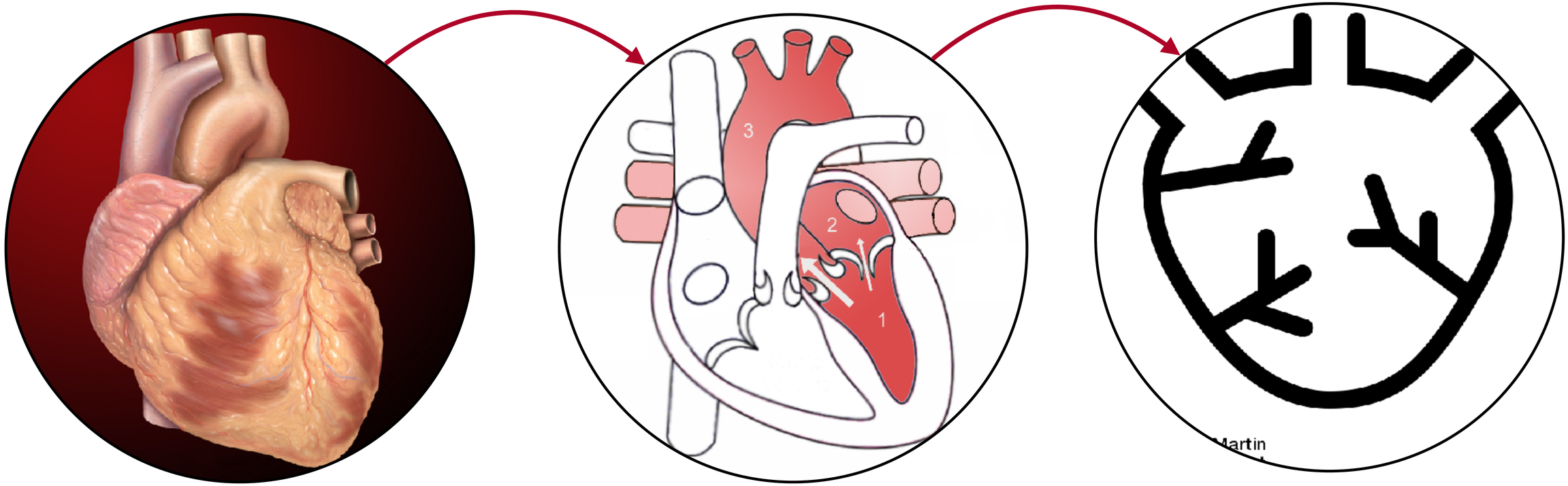
prior problems

current problem



§1. Why software architecture?

1.1. Partitioning, knowledge, and abstraction



complex real problems

less complex model problem

simpler abstract problem

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1.1. Partitioning, knowledge, and abstraction

- Partitioning: divide and conquer
- Knowledge: experience transfer
- Abstractions: shrink problems

Example architectures: Searching for events in log files

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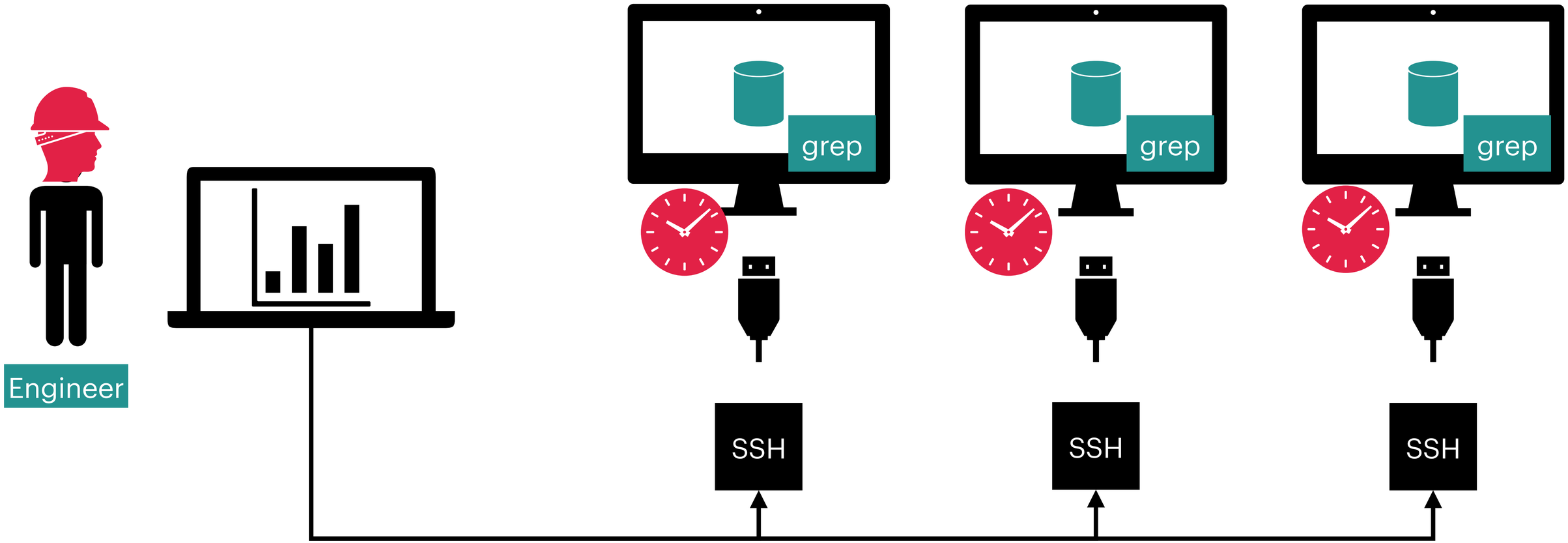
1.2. Example architecture of a logging system

- **Version 1: local log files**



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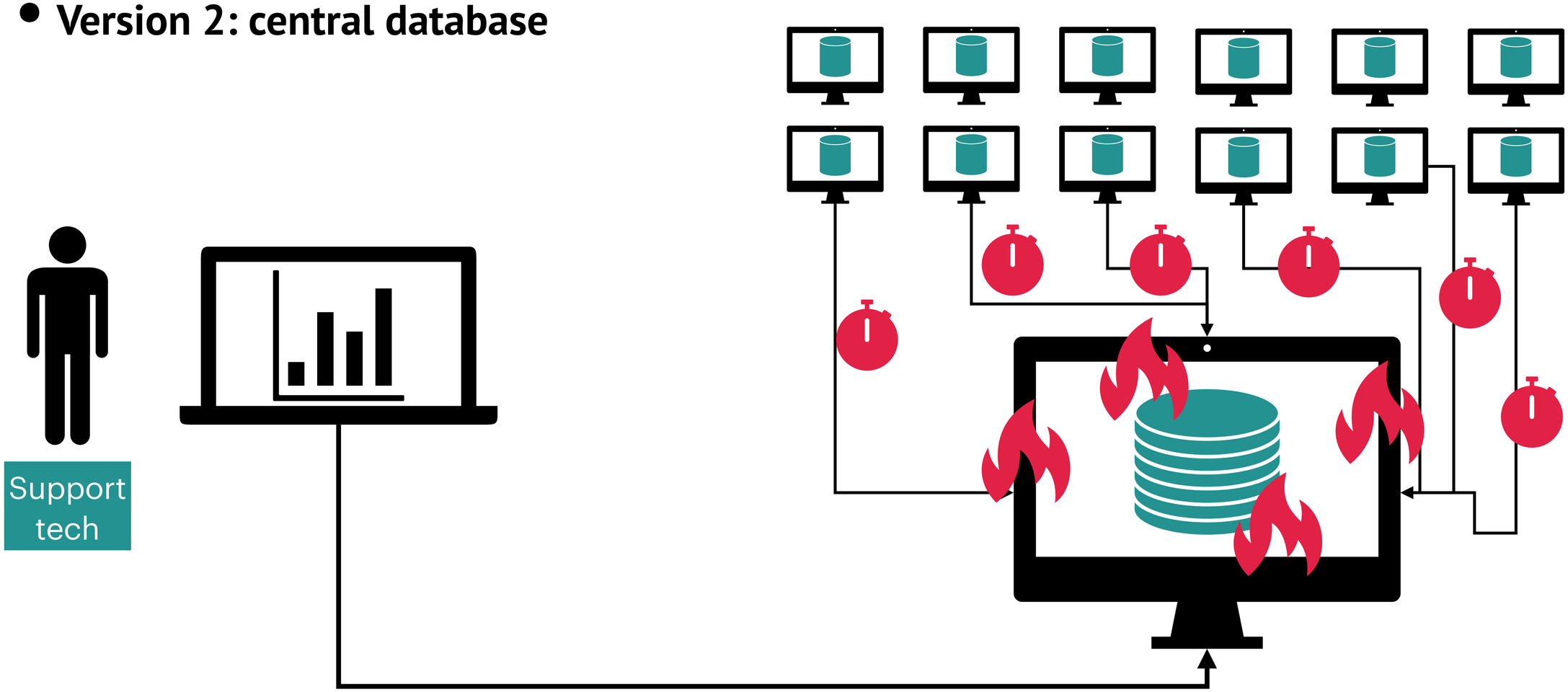
1.2. Example architecture of a logging system

- **Version 2: central database**



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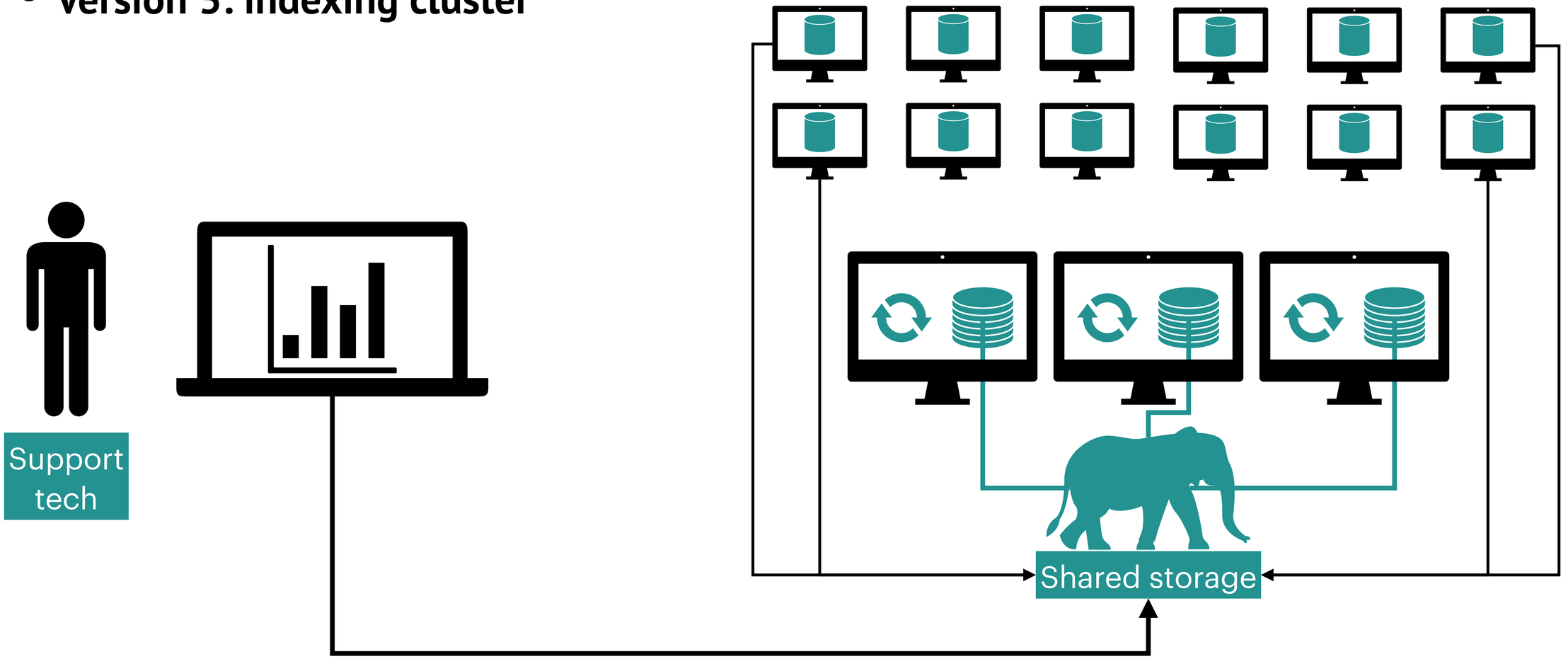
1.2. Example architecture of a logging system

- **Version 3: indexing cluster**



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1.2. Example architecture of a logging system

Version 1: local log files

Version 2: central DB

Version 3: indexing cluster

Same functionality

Different architecture

Different quality attributes

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1.2. Example architecture of a logging system

Same functionality	Different architecture	Different quality attributes		
	Ad hoc queries?	modifiability	scalability	latency
Version 1: local log files		seconds	not so scalable	online
Version 2: central DB		seconds	not so scalable	near online
Version 3: indexing cluster		schedule &run	very scalable	a bit stale

What is software architecture?

§1. Why software architecture?

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1.3. What is software architecture?

- "Software architecture level of design is… organization of a system as a composition of components; global control structures; the protocols for communication, synchronization, and data access; the assignment of functionality to design elements; the composition of design elements; physical distribution; scaling and performance; dimensions of evolution; and selection among design alternatives" —Shaw & Garlan, 1996
- "The software architecture of a computing system is the set of structures needed to reason about the system, which comprise software elements, relations among them, and properties of both" — Clemens, 2010.
- "The fundamental organization of a system embodied in its components, their relationships to each other and to the environment, and the principles guiding its design and evolution" — IEEE 1471

components relations properties

Why and *When* is architecture important?

§1. Why software architecture?

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1.4. Why and When is architecture important?

Architecture as a skeleton

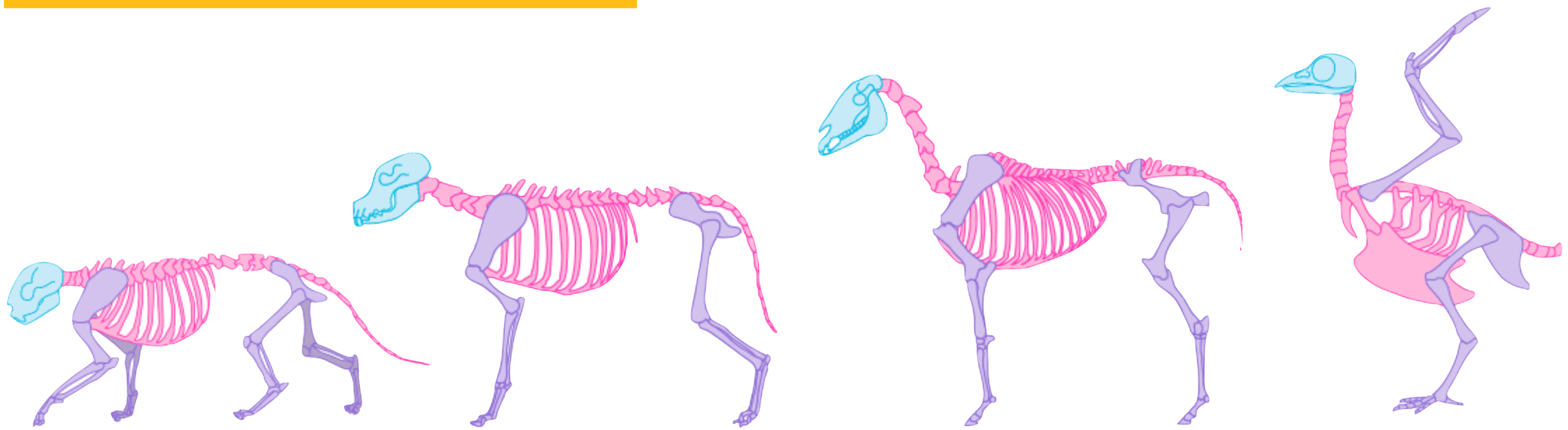

Image Credit: Monika Zagrobelna tutsplus.com

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1.4. Why and When is architecture important?

Architecture influences quality

Image Credit: TechPrevue

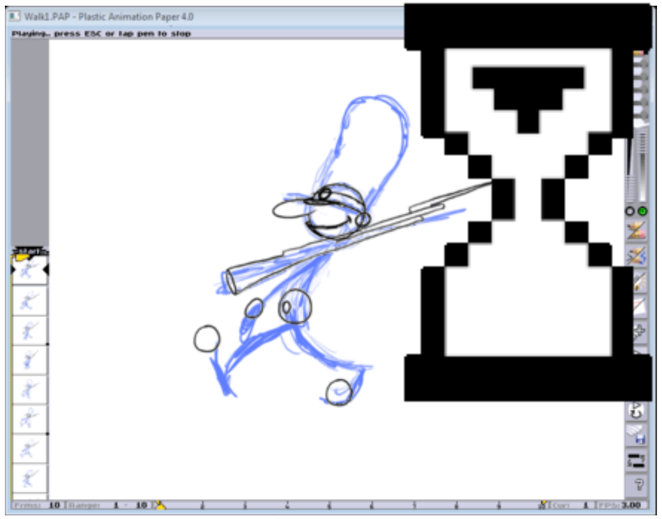

Image Credit: listoffreeware.com

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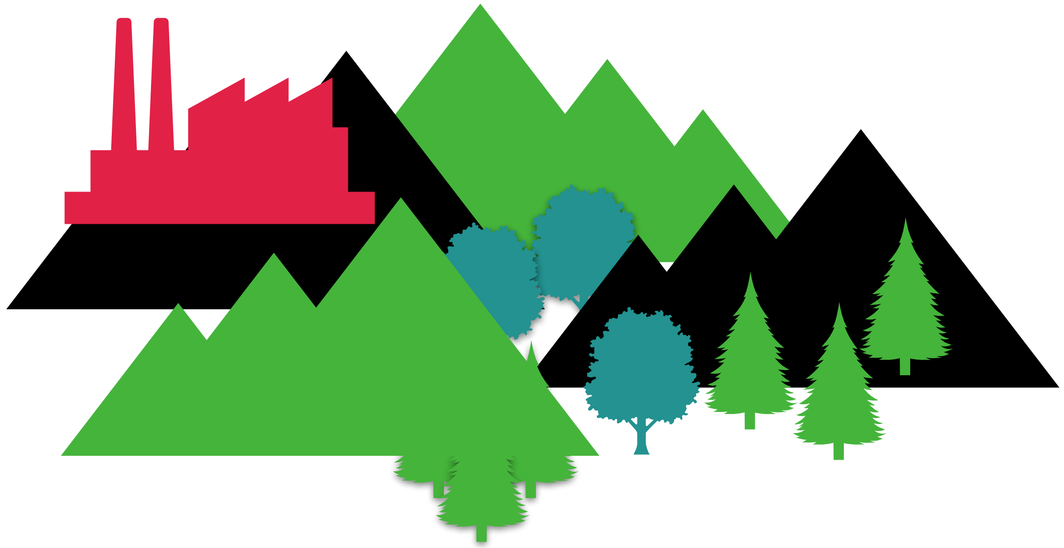
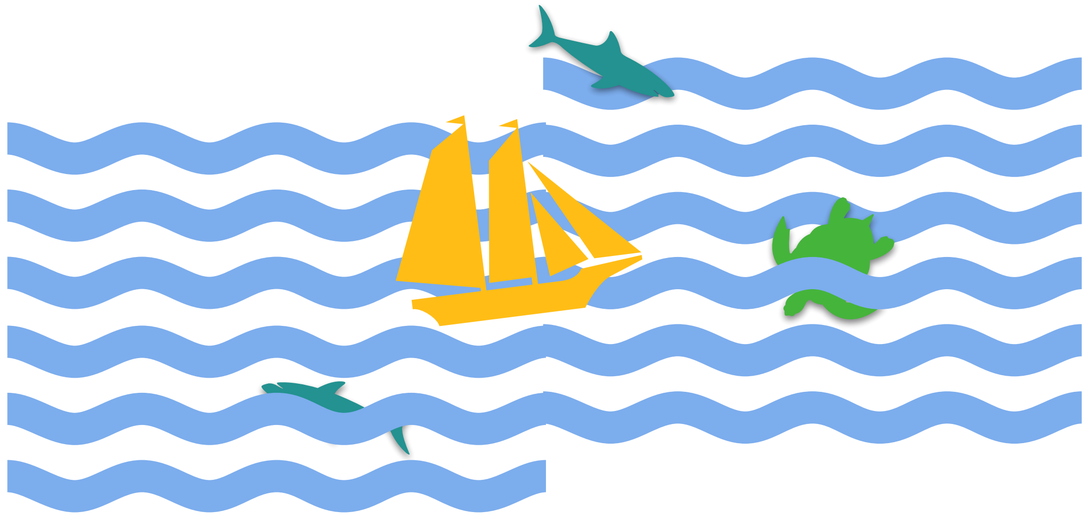
1.4. Why and When is architecture important?

Architecture ⊥ functionality





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1.4. Why and When is architecture important?

Architecture constrains systems

legacy

vendors

resources

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Summary

- Components and their separation
- Partitioning to create sub-systems to be created separately
- Buy vs. build decisions
- Mistakes are hard to recover from
- Team organization

§2. Some principles of software architecture

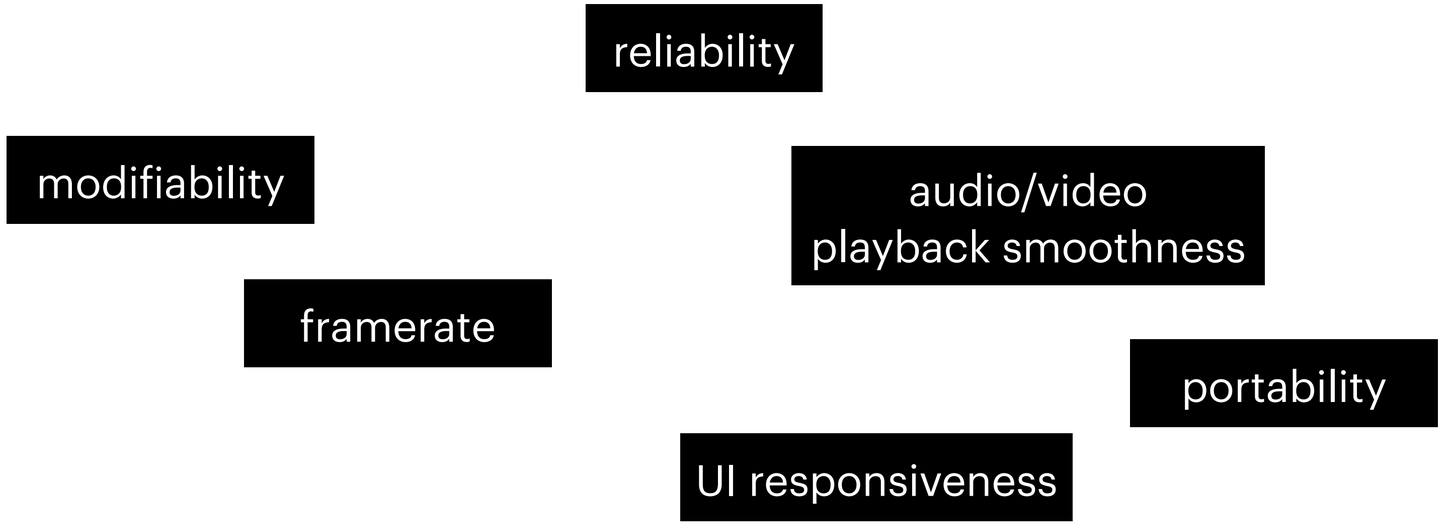
Image Credit: pxhere.com

Prioritizing quality attributes

§2. Some principles of software architecture

2.1. Prioritizing quality attributes

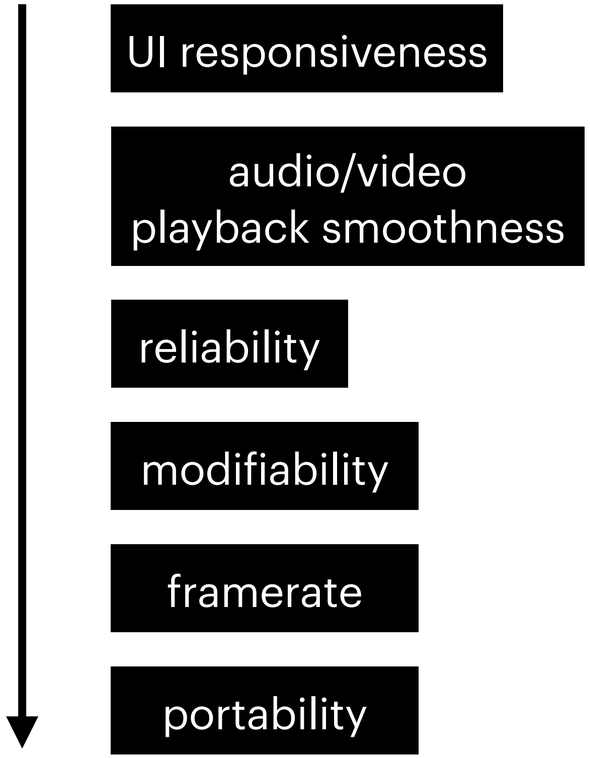
- **Identify** quality attributes
  - Customer survey
  - Requirements engineering
- **Prioritize** quality attributes



§2. Some principles of software architecture

2.1. Prioritizing quality attributes

- **Identify** quality attributes
  - Customer survey
  - Requirements engineering
- **Prioritize** quality attributes



§2. Some principles of software architecture

2.1. Prioritizing quality attributes

- Quality attribute scenarios
  - Source
  - Stimulus
  - Environment
  - Artifact
  - Response
  - Response measure

Source	Yinzer Member
Stimulus	Request web page from Yinzer server
Environment	Normal operations
Artifact	Entire system
Response	Server replies with web page
Response Measure	Web page sent out by Yinzer system within 1 second
Full QA scenario	A Yinzer Member clicks on a link in his Web Browser; it sends a request to the Yinzer system, which sends out a web page as a reply within 1 second

Figure 9.7: An example of a full quality attribute scenario for the Yinzer System. You may omit some sections, but you should strive to write falsifiable scenarios.

Credit: George Fairbanks, *Just Enough Software Architecture*

Tradeoffs, design decisions, and architecture drivers

§2. Some principles of software architecture

2.2. Tradeoffs, design decisions, and architecture drivers

portability means adding...

extra compatibility layers that hurt...

latency

audio fidelity

audio/video playback smoothness

platform-specific API

not really portable

modifiability

add new codecs or video sources

framerate

codec-dependent tweaks to improve

§2. Some principles of software architecture

2.2. Tradeoffs, design decisions, and architecture drivers

- Prioritization of quality attribute scenarios
  - Stakeholders: what is **important**
  - Developers: how **difficult to achieve**

- Some priorities are pretty clear (easy / deferrable)

- **Architecture drivers:** important and hard to achieve

§2. Some principles of software architecture

2.2. Tradeoffs, design decisions, and architecture drivers

- Architecture driver #1:
  - “When a user gives a command, such as pressing pause on the remote control, the system should comply with the command within 50ms.”

- Architecture driver #2:
  - “The reference H.264/MPEG-4 AVC video from local disk should play smoothly on the reference hardware.”

§2. Some principles of software architecture

2.2. Tradeoffs, design decisions, and architecture drivers

- Design decision:
  - “To promote reliability, each top-level component will run in its own process to isolate faults, like services in an operating system.”

- Design decision:
  - “The Media Rendering/Playback component communicates using shared memory with the Media Buffer component to minimize latency, considering the high rate of data movement.”

§2. Some principles of software architecture

Summary

- Quality attributes (QAs): describe observable properties of a system.
- Quality attribute scenarios: describing QA requirements
- Architecture drivers: QA scenarios that need increased attention during design
- Tradeoffs: balancing quality attributes to achieve a desired result

§3. Software architecture notation

§3. Software architecture notation

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3.1. Canonical model of software design

- **Domain model:**
  - enduring truth about the domain
  - something “just true”
  - “billing cycles are 30 days”
- **Design model:**
  - the system to be built
  - partial set of design commitments
  - “deallocate resources explicitly”
- **Code model**
  - full set of design commitments
  - “the customer address is stored in a varchar(80) field”

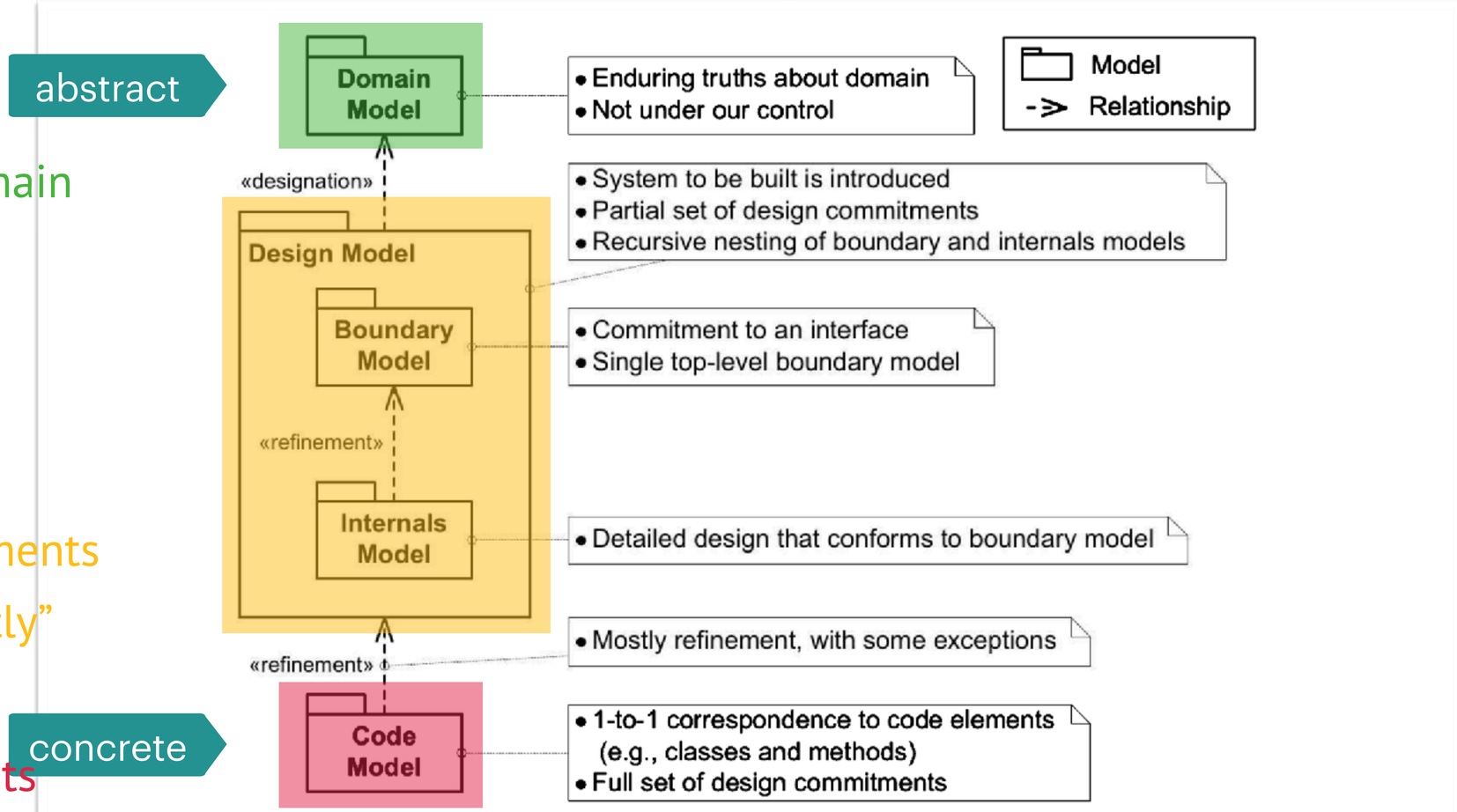

Figure 7.1: The canonical model structure that organizes the domain, design, and code models. The design model contains a top-level boundary model and recursively nested internals models.

Credit: George Fairbanks, *Just Enough Software Architecture*

§3. Software architecture notation

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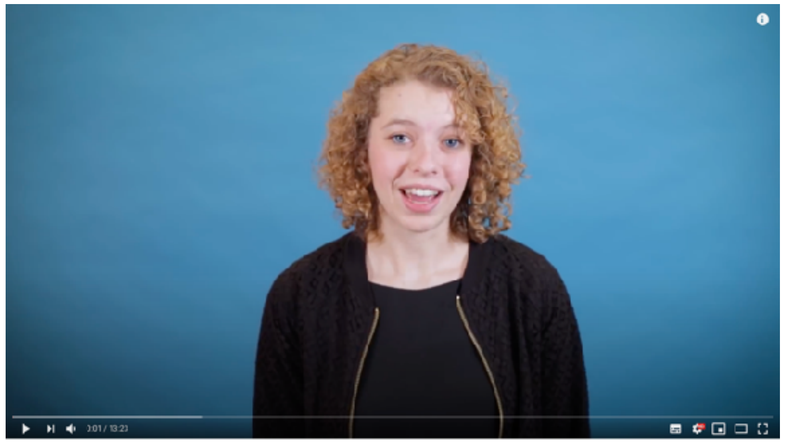
3.1. Canonical model of software design



UML Use Case

UML Class

UML Sequence

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3.1. Canonical model of software design: Domain model

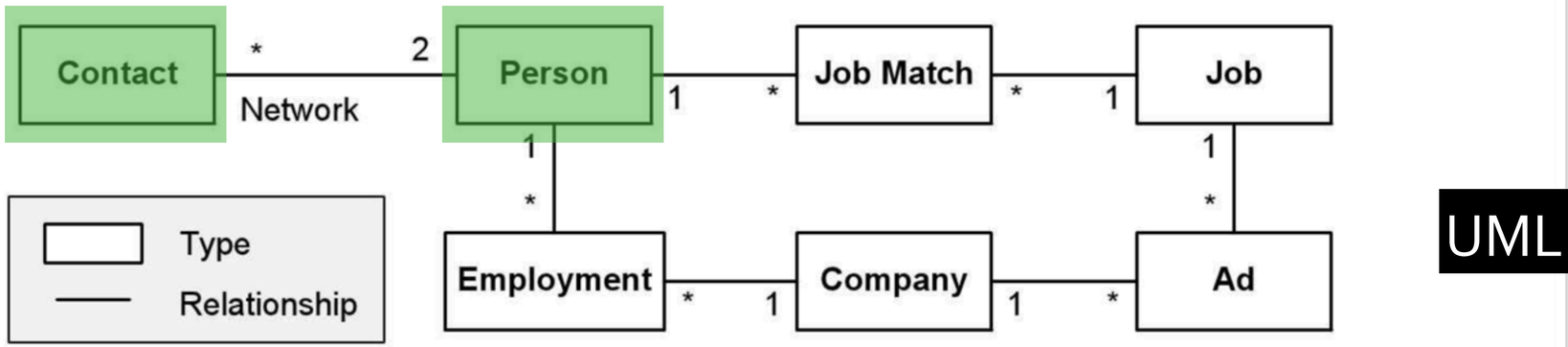

Figure 8.2: An information model for the job advertisement and business networking domain, shown graphically using a UML class diagram.

Credit: George Fairbanks, *Just Enough Software Architecture*

- *Company*: an employer that offers *Jobs* to *People*
- *Employment*: a relationship indicating that the *Person* is or was employed at a *Job* at the *Company*

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3.1. Canonical model of software design: Design model

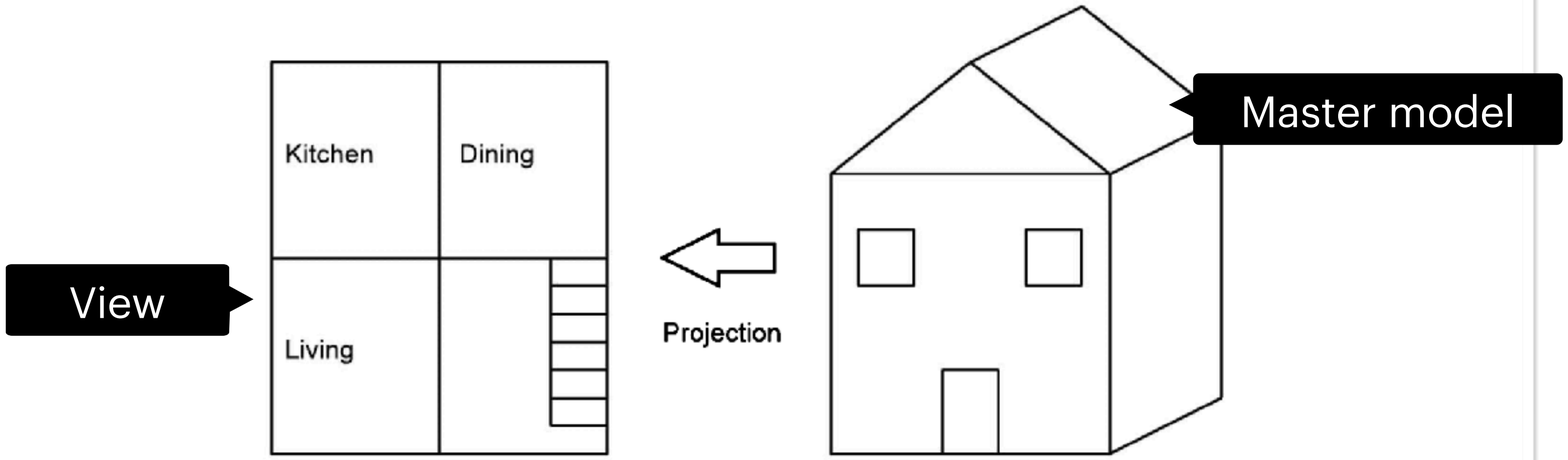

Figure 13.2: A two dimensional (2-D) floorplan view (i.e., a projection) of a three dimensional (3-D) house model.

Credit: George Fairbanks, *Just Enough Software Architecture*

- **View:** a projection of the model that reveals important detail
- Examine a variety of views on the job advertisement "Yinzer system":
  - Use case, system context, components, ports/connectors, modules, component assembly, deployment

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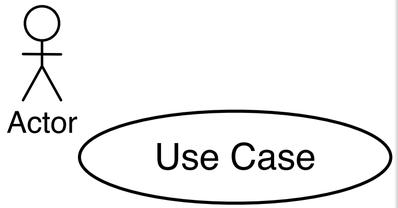
3.1. Design model: Use case

- **Use case:**
  - Compact view of functionality
  - Actors
  - Use-cases



- **Functionality scenario:**
  - X invites a contact Y / System sends Y email
  - Y clicks a link in the email and accepts invitation to be a contact
- Make some commitments, but keep other design options open

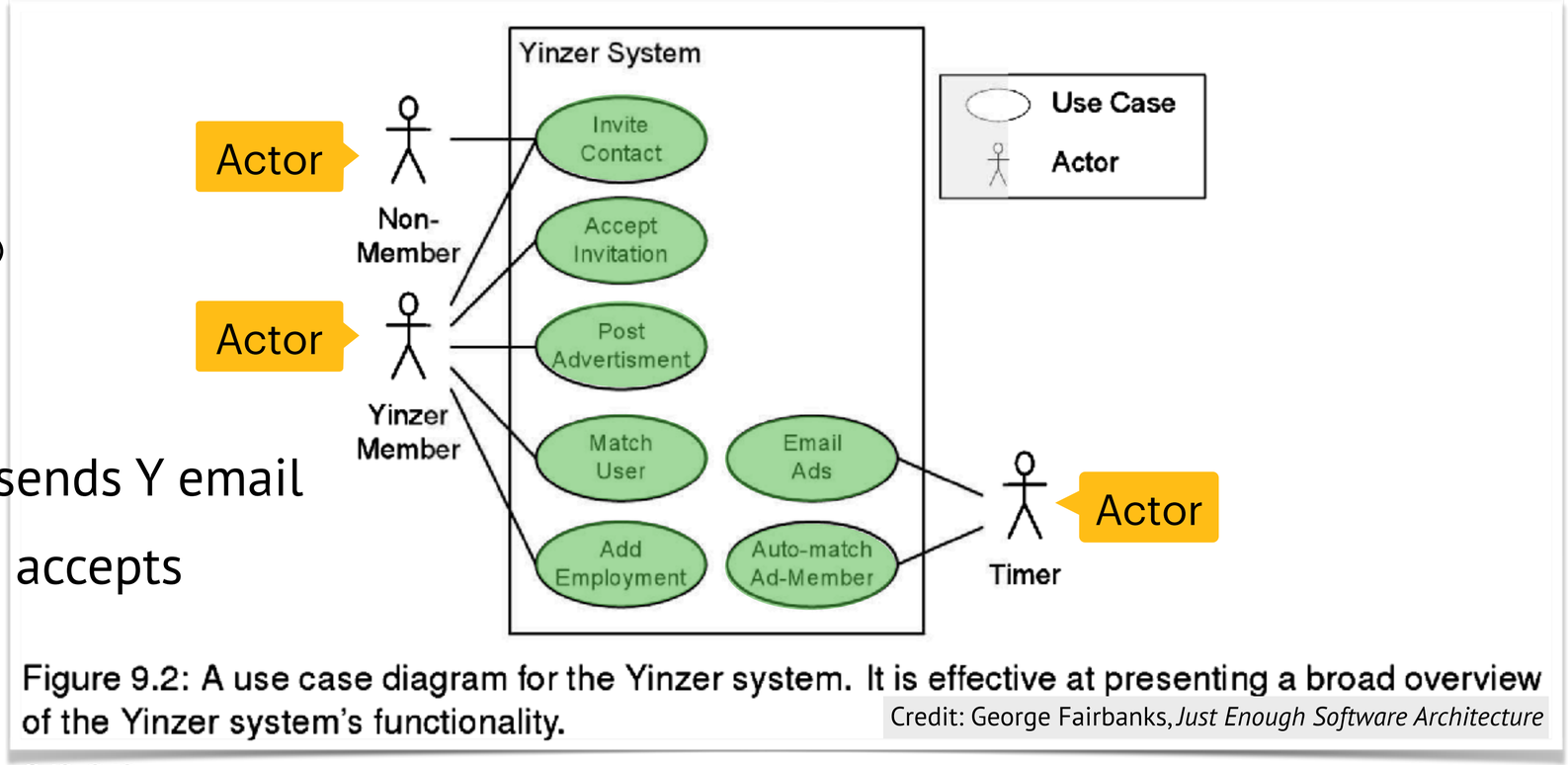


Figure 9.2: A use case diagram for the Yinzer system. It is effective at presenting a broad overview of the Yinzer system's functionality.

Credit: George Fairbanks, *Just Enough Software Architecture*

§3. Software architecture notation

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3.1. Design model: System context

- **System context:**
  - Model channels of communication with external systems
  - Connectors/ports
  - Components

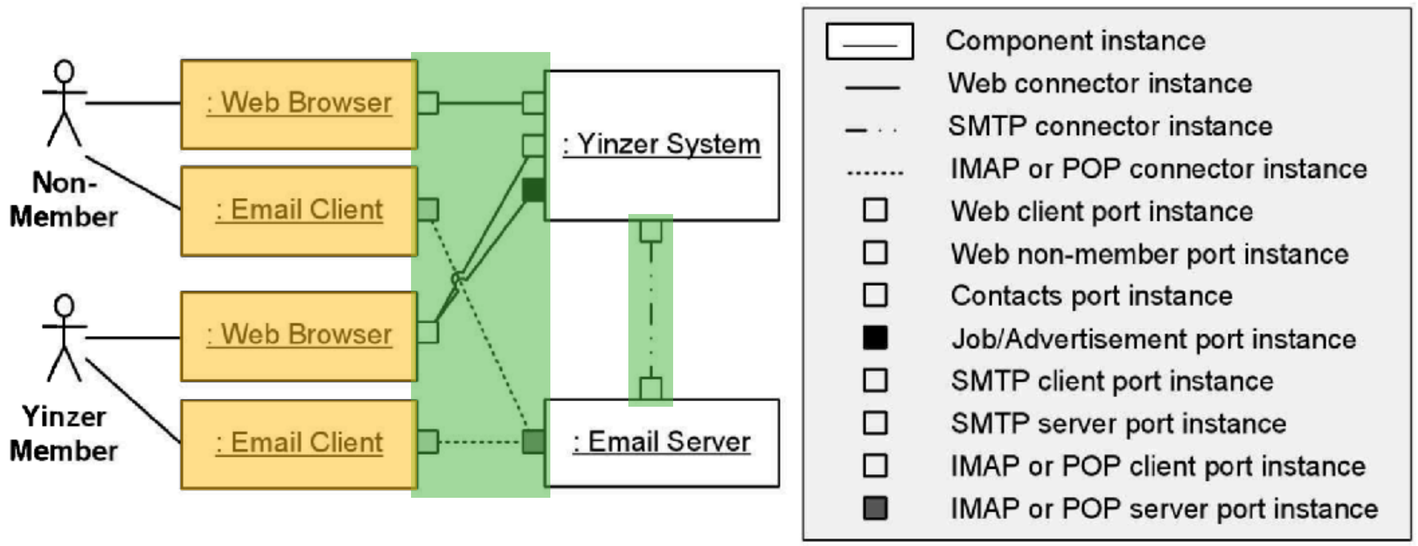

Figure 9.4: A system context diagram for the Yinzer system that shows the Yinzer System component instance and all the external systems it connects to.

Credit: George Fairbanks, *Just Enough Software Architecture*

§3. Software architecture notation

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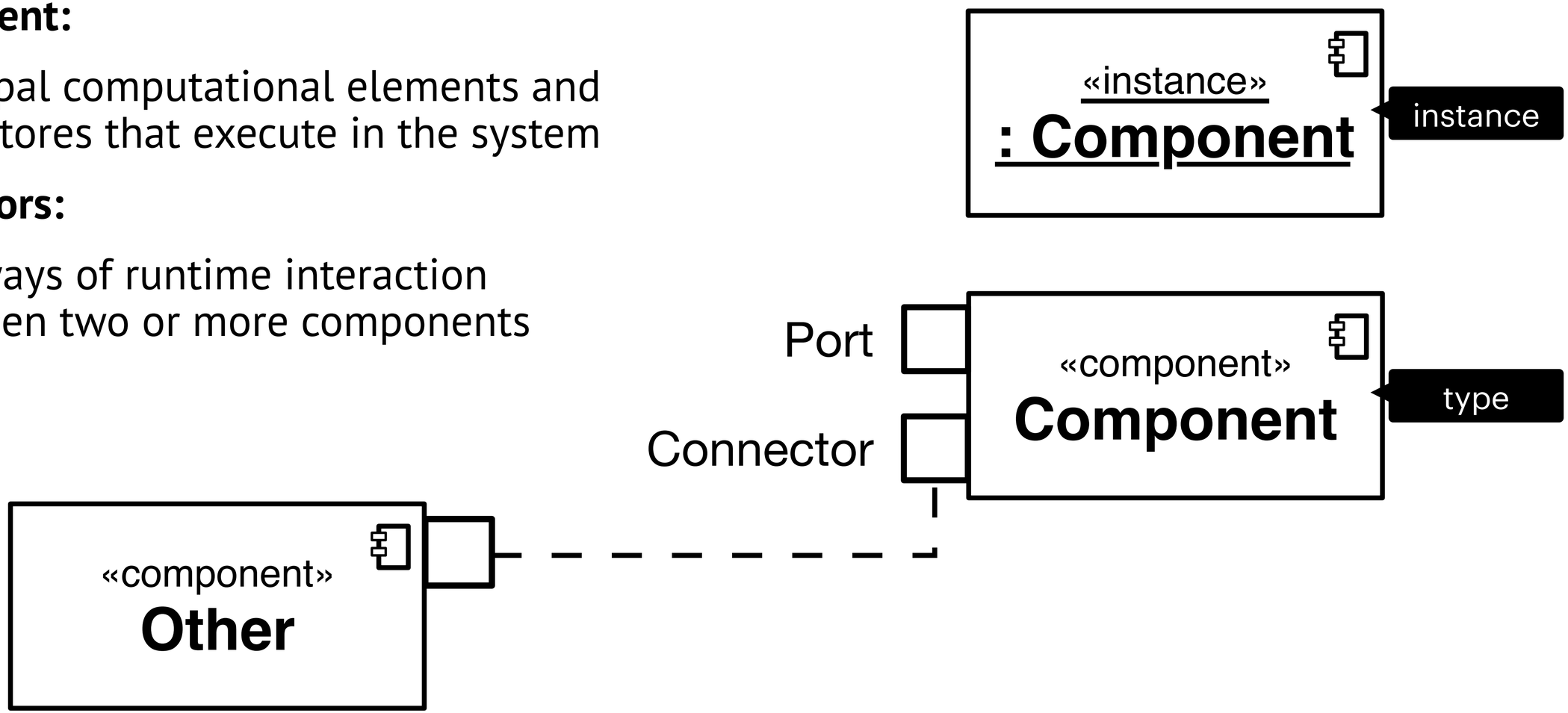
3.2. Components and connectors

- **Component:**
  - Principal computational elements and data stores that execute in the system
- **Connectors:**
  - Pathways of runtime interaction between two or more components



§3. Software architecture notation

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3.2. Components and connectors

On importance of connectors

convert, transform, translate datatypes

adapt protocols

broadcast, clean, prioritize events

encrypt, compress, synchronize

local/remote procedure calls

pipes, batch transfer

interrupts, shared memory

RPC, ESB

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3.1. Design model: Component assembly

- **Component assembly:**
  - Configuration of component instances in a system
  - External ports bound to internal ports

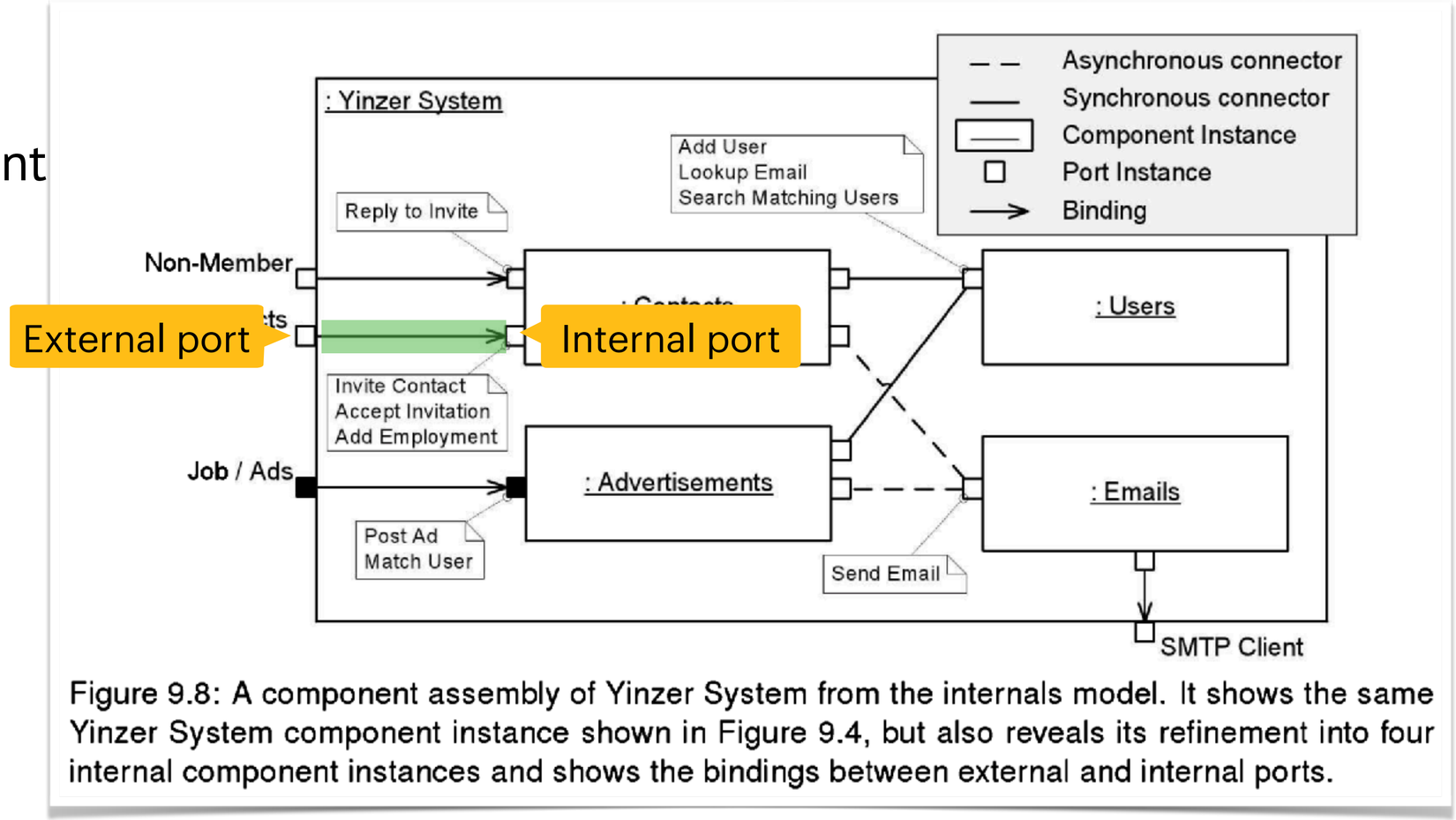

Figure 9.8: A component assembly of Yinzer System from the internals model. It shows the same Yinzer System component instance shown in Figure 9.4, but also reveals its refinement into four internal component instances and shows the bindings between external and internal ports.

Credit: George Fairbanks, *Just Enough Software Architecture*

§3. Software architecture notation

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3.1. Design model: Depoyment

- **Deployment:**
  - Environmental elements
  - Communication channels
  - Allocation of running component instances to hardware

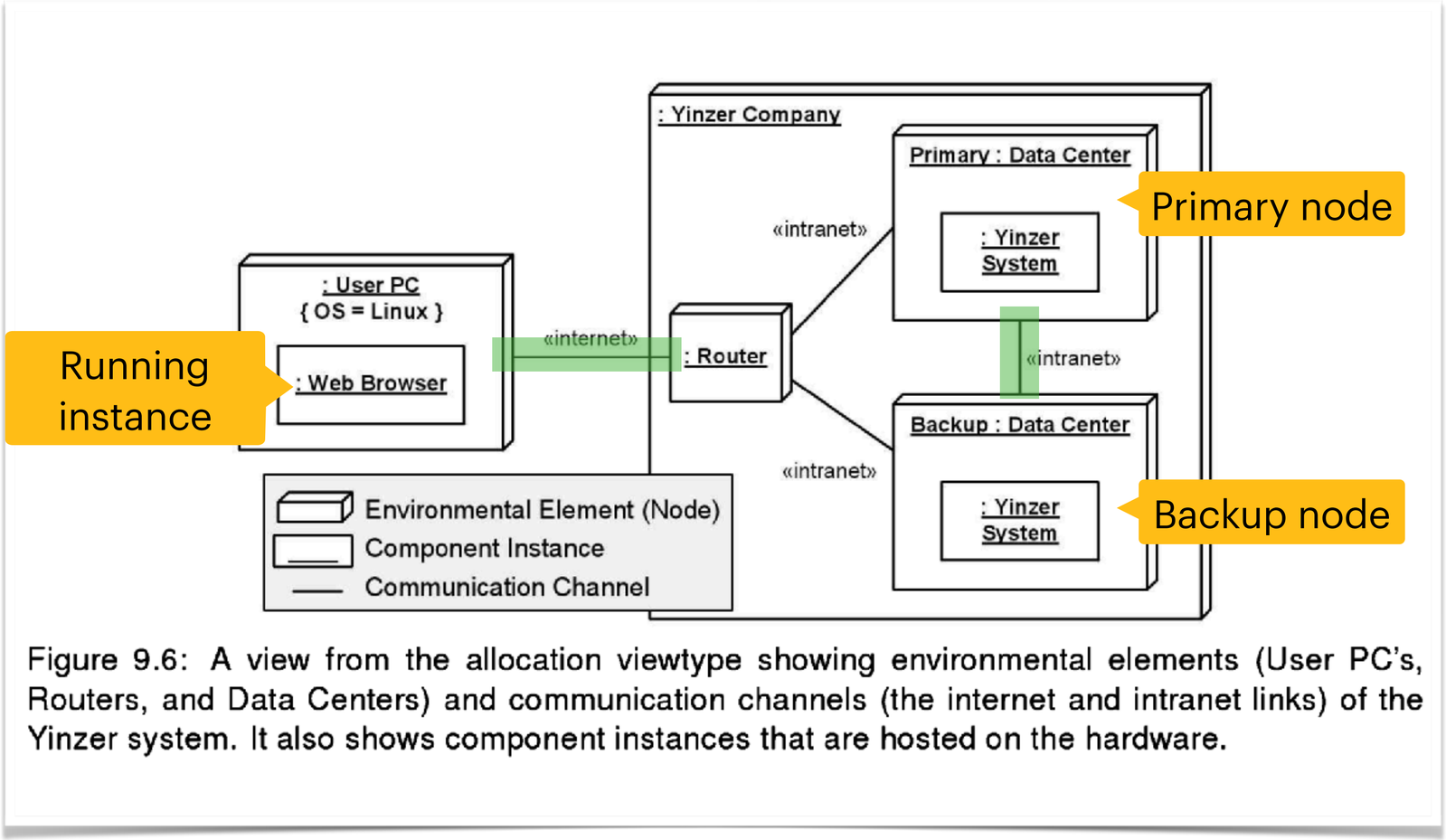

Figure 9.6: A view from the allocation viewtype showing environmental elements (User PC's, Routers, and Data Centers) and communication channels (the internet and intranet links) of the Yinzer system. It also shows component instances that are hosted on the hardware.

Credit: George Fairbanks, *Just Enough Software Architecture*

§3. Software architecture notation

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Summary

- Canonical model: from abstract to concrete
  - Domain model, Design model, Code model
  - UML notation
- Domain models: information models of enduring truths about the domain
- Design model: describe the system to be built
  - Many views (use case, system context, components, ports/connectors, modules, component assembly, deployment)
  - Reasoning with components and connectors

References

1. R. Stephens (2015). Beginning software engineering. John Wiley & Sons.
2. G. Fairbanks (2010). *Just enough software architecture: a risk-driven approach*. Marshall & Brainerd.
3. I. Sommerville (2020) *Software engineering 9th Edition*.