

Introduction to Software Architecture and Documentation

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Administrivia

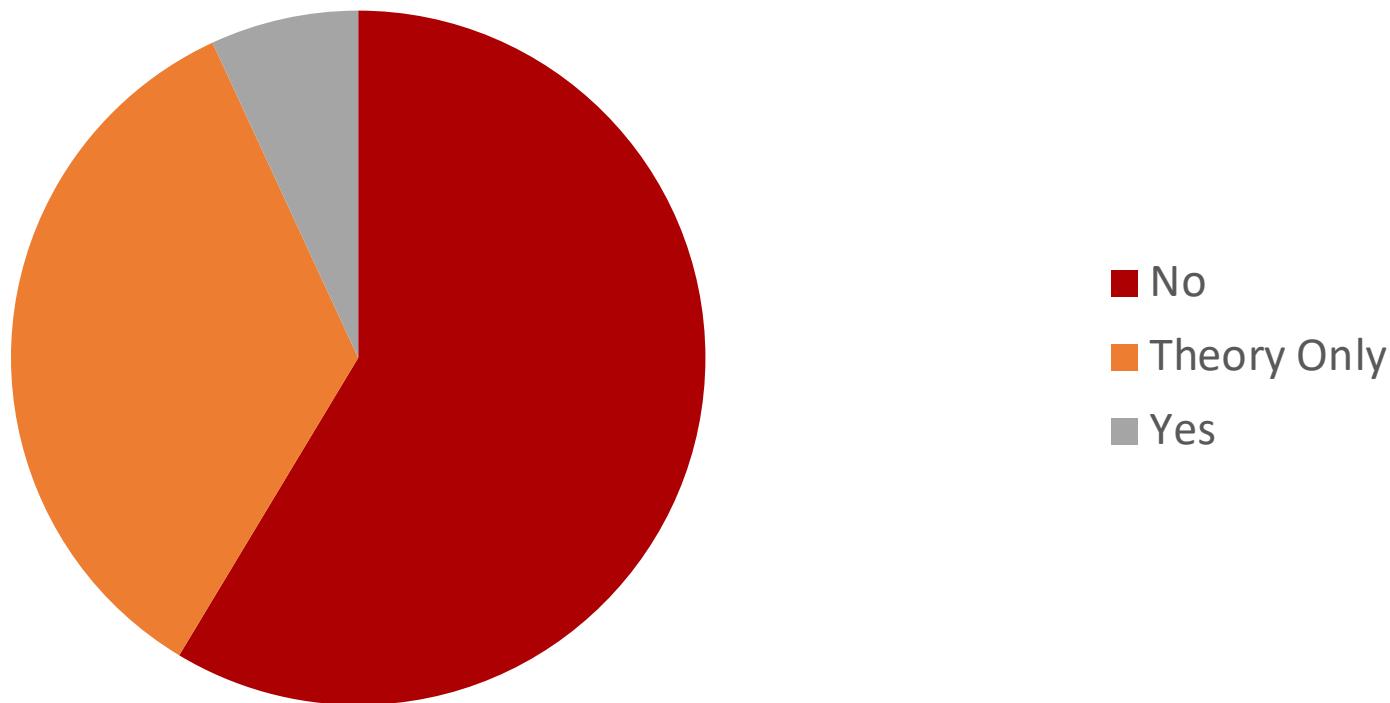
- Recitation instructions posted: do some install ahead of time.
- Schedule your HW3 interviews!

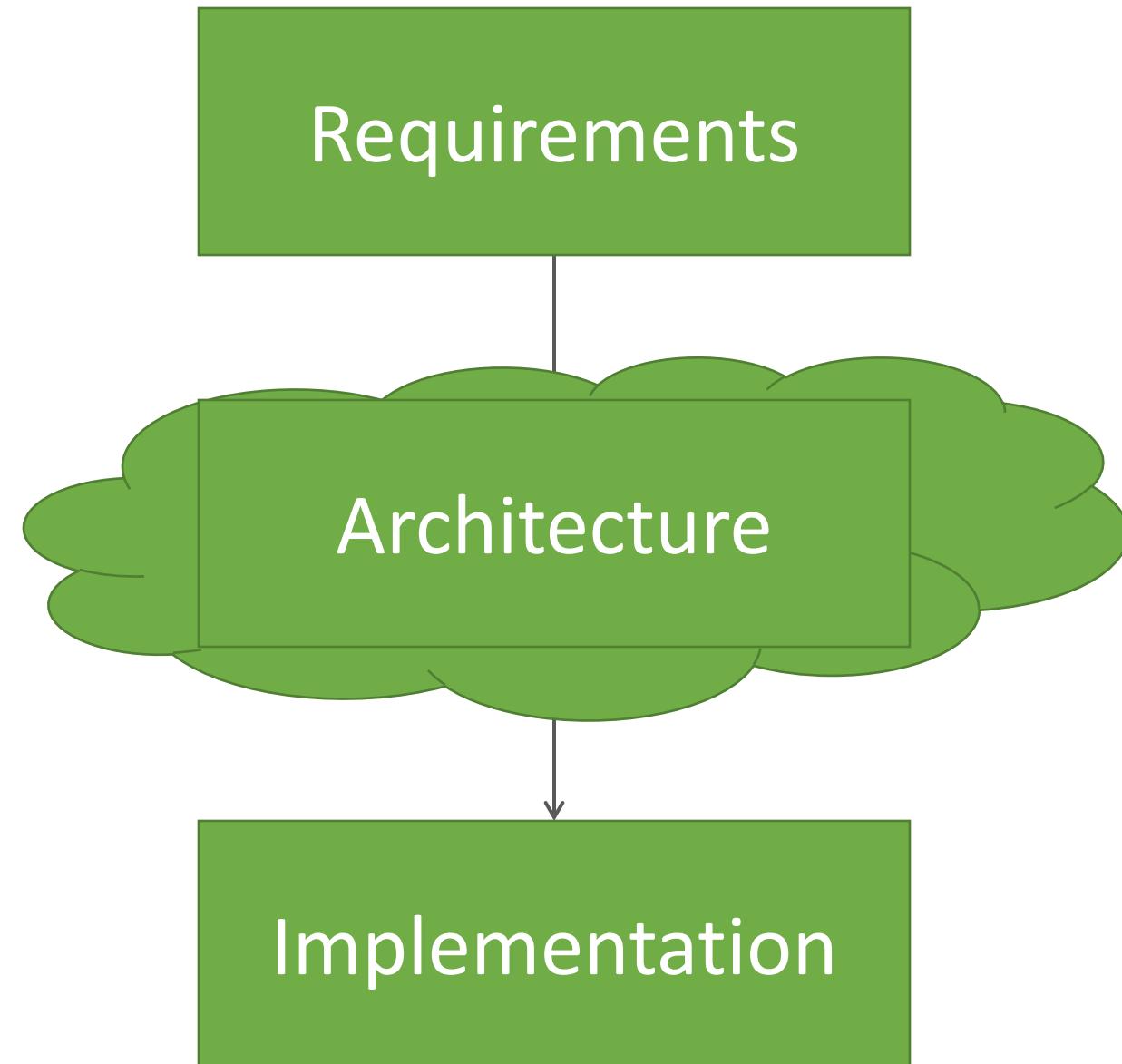
Learning Goals

- Understand the abstraction level of architectural reasoning
- Approach software architecture with quality attributes in mind
- Distinguish software architecture from (object-oriented) software design
- Use notation and views to describe the architecture suitable to the purpose
- Document architectures clearly, without ambiguity

About You

I am familiar with how to design distributed,
high-availability, or high-performance systems





Quality Requirements, now what?

- "should be highly available"
- "should answer quickly, accuracy is less relevant"
- "needs to be extensible"
- "should efficiently use hardware resources"

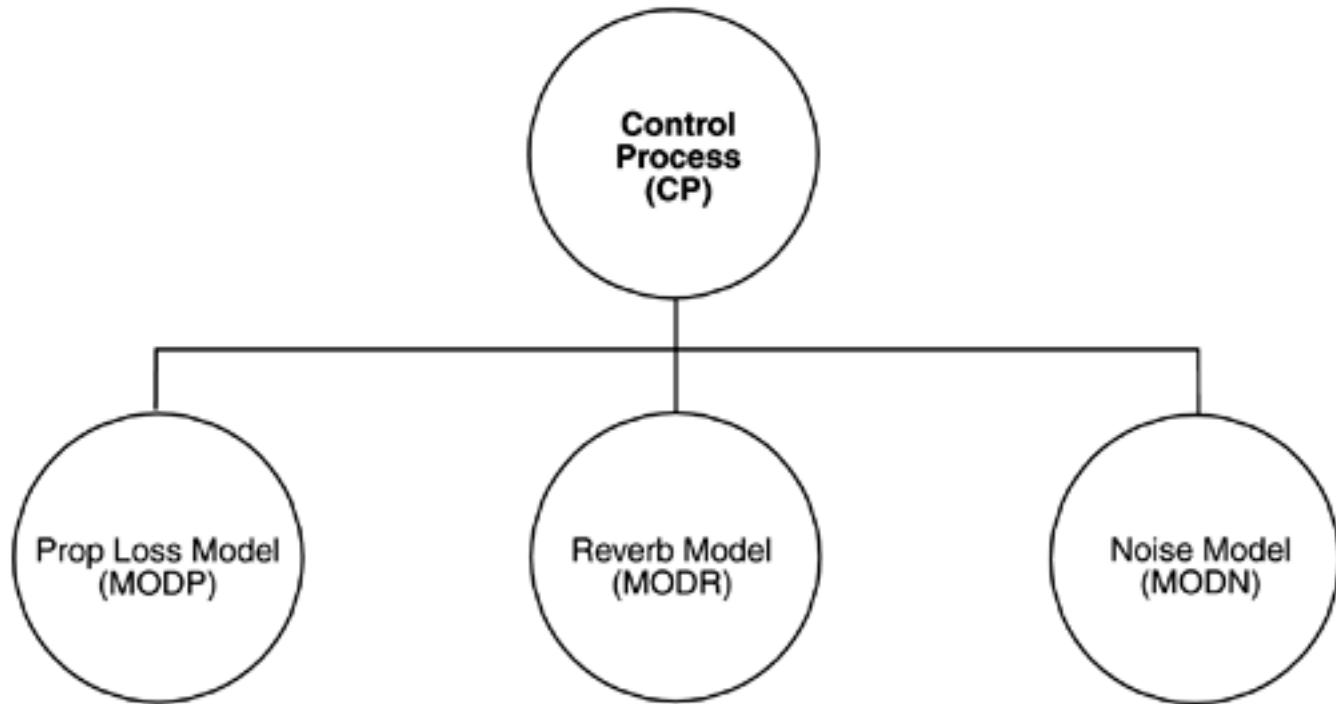
SOFTWARE ARCHITECTURE

Software Architecture

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 among them.

[class et al. 2003]

Note: this definition is ambivalent
to whether the architecture is
known, or whether it's any good!



Why Architecture? [BCK03]

- Represents earliest design decisions.
- Aids in **communication** with stakeholders
 - Shows them “how” at a level they can understand, raising questions about whether it meets their needs
- Defines **constraints** on implementation
 - Design decisions form “load-bearing walls” of application
- Dictates **organizational structure**
 - Teams work on different components
- Inhibits or enables **quality attributes**
 - Similar to design patterns
- Supports **predicting** cost, quality, and schedule
 - Typically by predicting information for each component
- Aids in software **evolution**
 - Reason about cost, design, and effect of changes
- Aids in **prototyping**
 - Can implement architectural skeleton early

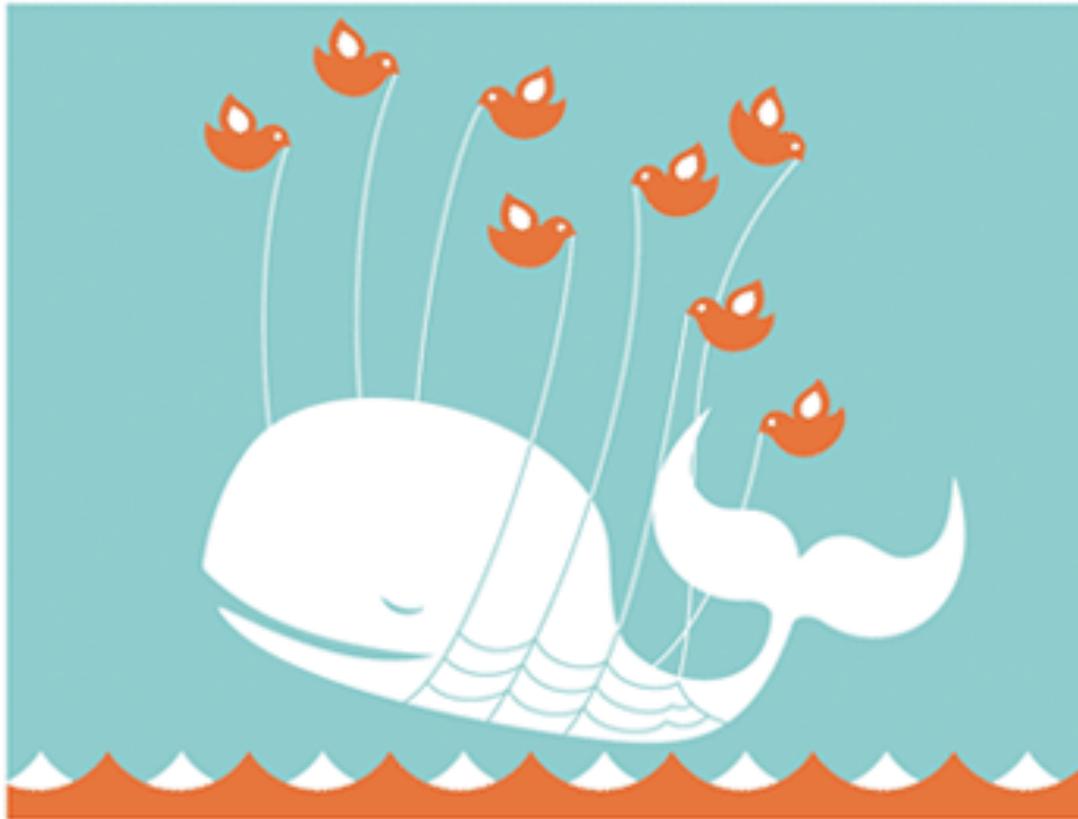
Beyond functional correctness

- Quality matters, eg.,
 - Performance
 - Availability
 - Modifiability, portability
 - Scalability
 - Security
 - Testability
 - Usability
 - Cost to build, cost to operate

CASE STUDY: ARCHITECTURE AND QUALITY AT TWITTER

Twitter is over capacity.

Too many tweets! Please wait a moment and try again.

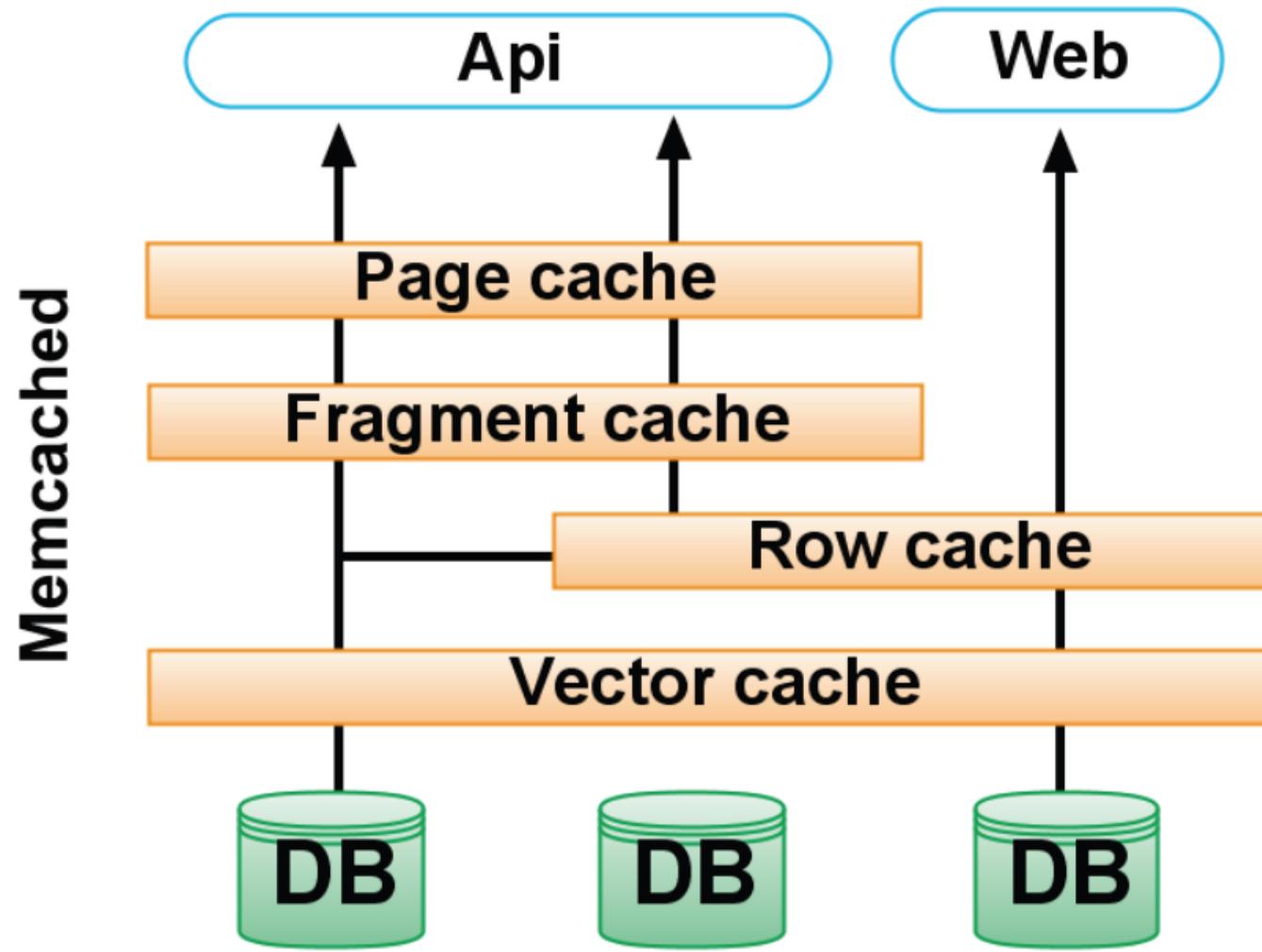




Inspecting the State of Engineering

- Running one of the world's largest Ruby on Rails installations
 - 200 engineers
- Monolithic: managing raw database, memcache, rendering the site, and presenting the public APIs in one codebase
- Increasingly difficult to understand system; organizationally challenging to manage and parallelize engineering teams
- Reached the limit of throughput on our storage systems (MySQL); read and write hot spots throughout our databases
- Throwing machines at the problem; low throughput per machine (CPU + RAM limit, network not saturated)
- Optimization corner: trading off code readability vs performance

Caching



Twitter's Quality Requirements/Redesign goals??

- Improve median latency; lower outliers *performance*
- Reduce number of machines 10x
- Isolate failures *reliability*
- "We wanted cleaner boundaries with "related" logic being in one place"
 - encapsulation and modularity at the systems level (rather than at the class, module, or package level) *maintainability*
- Quicker release of new features
 - "run small and empowered engineering teams that could make local decisions and ship user-facing changes, independent of other teams" *modifiability*

JVM vs Ruby VM

- Rails servers capable of 200-300 requests / sec / host
- Experience with Scala on the JVM; level of trust
- Rewrite for JVM allowed 10-20k requests / sec / host

Programming Model

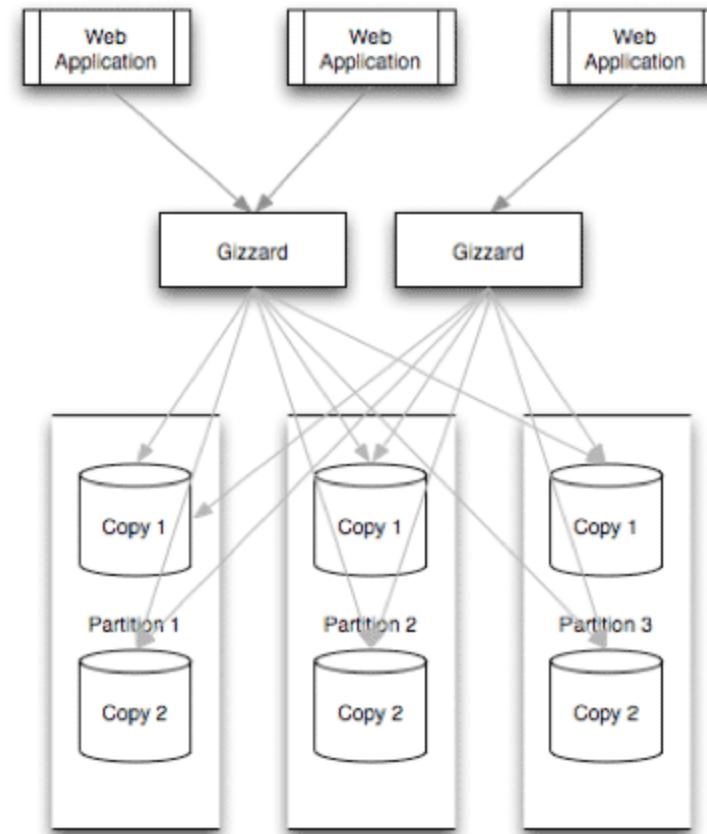
- Ruby model: Concurrency at process level; request queued to be handled by one process
- Twitter response aggregated from several services – additive response times
- *"As we started to decompose the system into services, each team took slightly different approaches. For example, the failure semantics from clients to services didn't interact well: we had no consistent back-pressure mechanism for servers to signal back to clients and we experienced "thundering herds" from clients aggressively retrying latent services."*
- Goal: Single and uniform way of thinking about concurrency
 - Implemented in a library for RPC (Finagle), connection pooling, failover strategies and load balancing

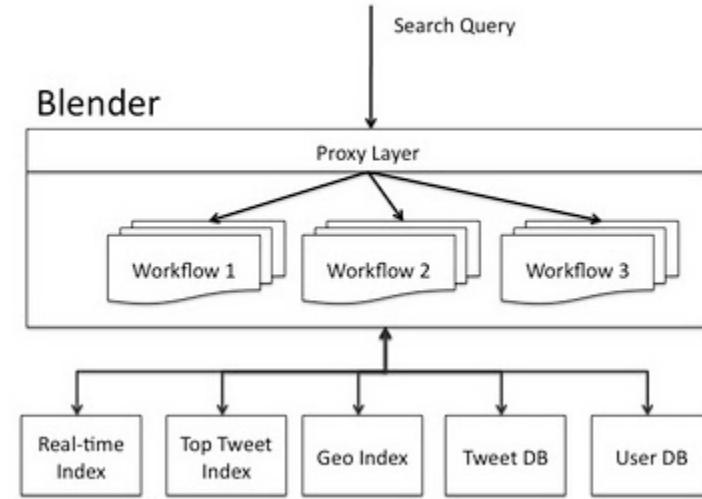
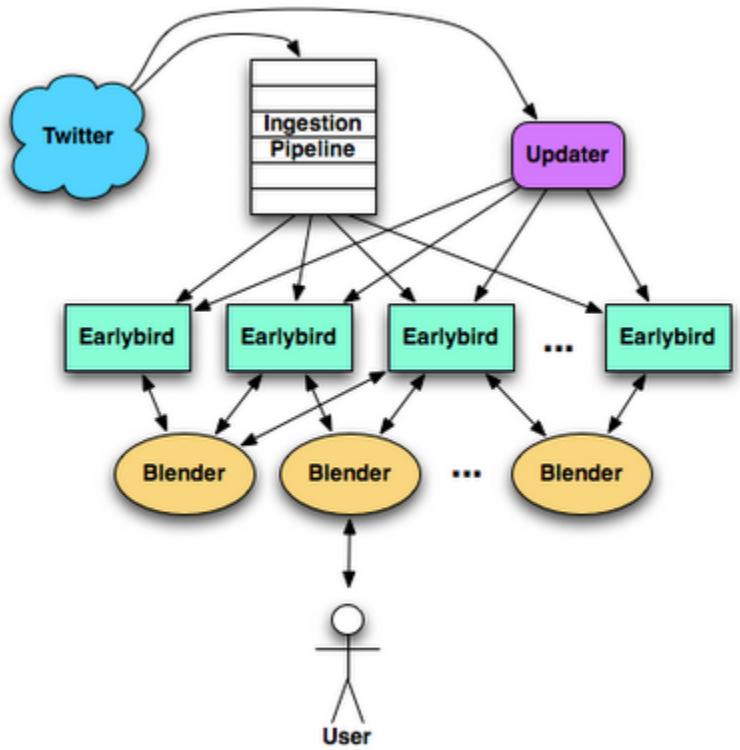
Independent Systems

- "In our monolithic world, we either needed experts who understood the entire codebase or clear owners at the module or class level. Sadly, the codebase was getting too large to have global experts and, in practice, having clear owners at the module or class level wasn't working. Our codebase was becoming harder to maintain, and teams constantly spent time going on "archeology digs" to understand certain functionality. Or we'd organize "whale hunting expeditions" to try to understand large scale failures that occurred."
- From monolithic system to multiple services
 - Agree on RPC interfaces, develop system internals independently
 - Self-contained teams

Storage

- Single-master MySQL database bottleneck despite more modular code
- Temporal clustering
 - Short-term solution
 - Skewed load balance
 - One machine + replications every 3 weeks
- Move to distributed database (Glizzard on MySQL) with "roughly sortable" ids
- Stability over features – using older MySQL version

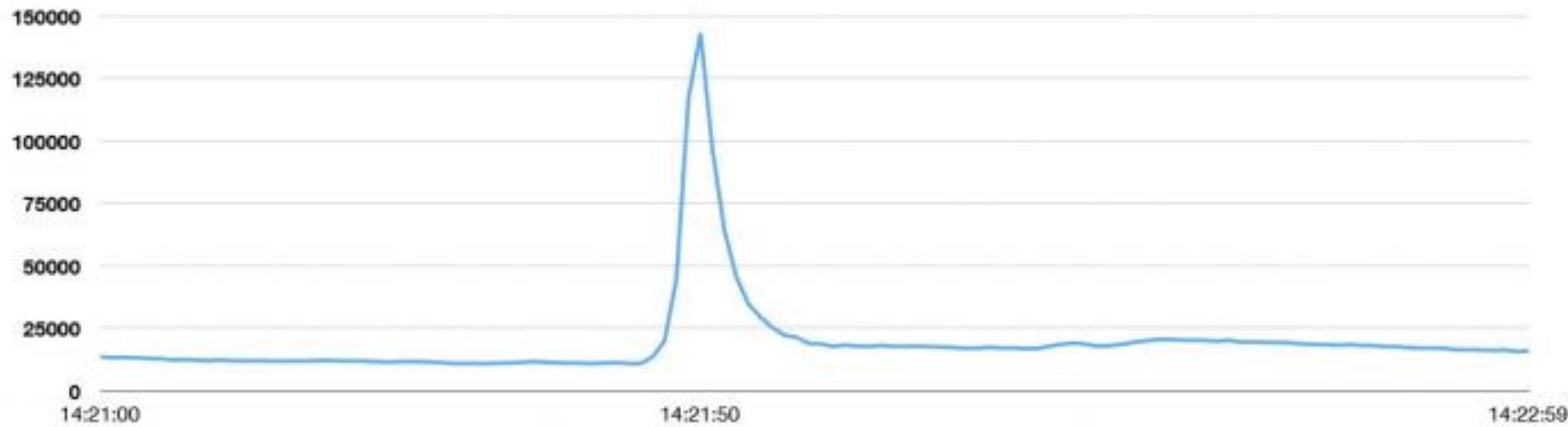




Data-Driven Decisions

- Many small independent services, number growing
- Own dynamic analysis tool on top of RPC framework
- Framework to configure large numbers of machines
 - Including facility to expose feature to parts of users only





On Saturday, August 3 in Japan, people watched an airing of [Castle in the Sky](#), and at one moment they took to Twitter so much that we hit a one-second peak of 143,199 Tweets per second.

Key Insights: Twitter Case Study

- Architectural decisions affect entire systems, not only individual modules
- Abstract, different abstractions for different scenarios
- Reason about quality attributes early
- Make architectural decisions explicit
- Question: *Did the original architect make poor decisions?*

ARCHITECTURE VS OBJECT-LEVEL DESIGN

Levels of Abstraction

- Requirements
 - high-level “what” needs to be done

→ Architecture (High-level design)

- high-level “how”, mid-level “what”

→ OO-Design (Low-level design, e.g. design patterns)

- mid-level “how”, low-level “what”

→ Code

- low-level “how”

Design vs. Architecture

Design Questions

- How do I add a menu item in Eclipse?
- How can I make it easy to add menu items in Eclipse?
- What lock protects this data?
- How does Google rank pages?
- What encoder should I use for secure communication?
- What is the interface between objects?

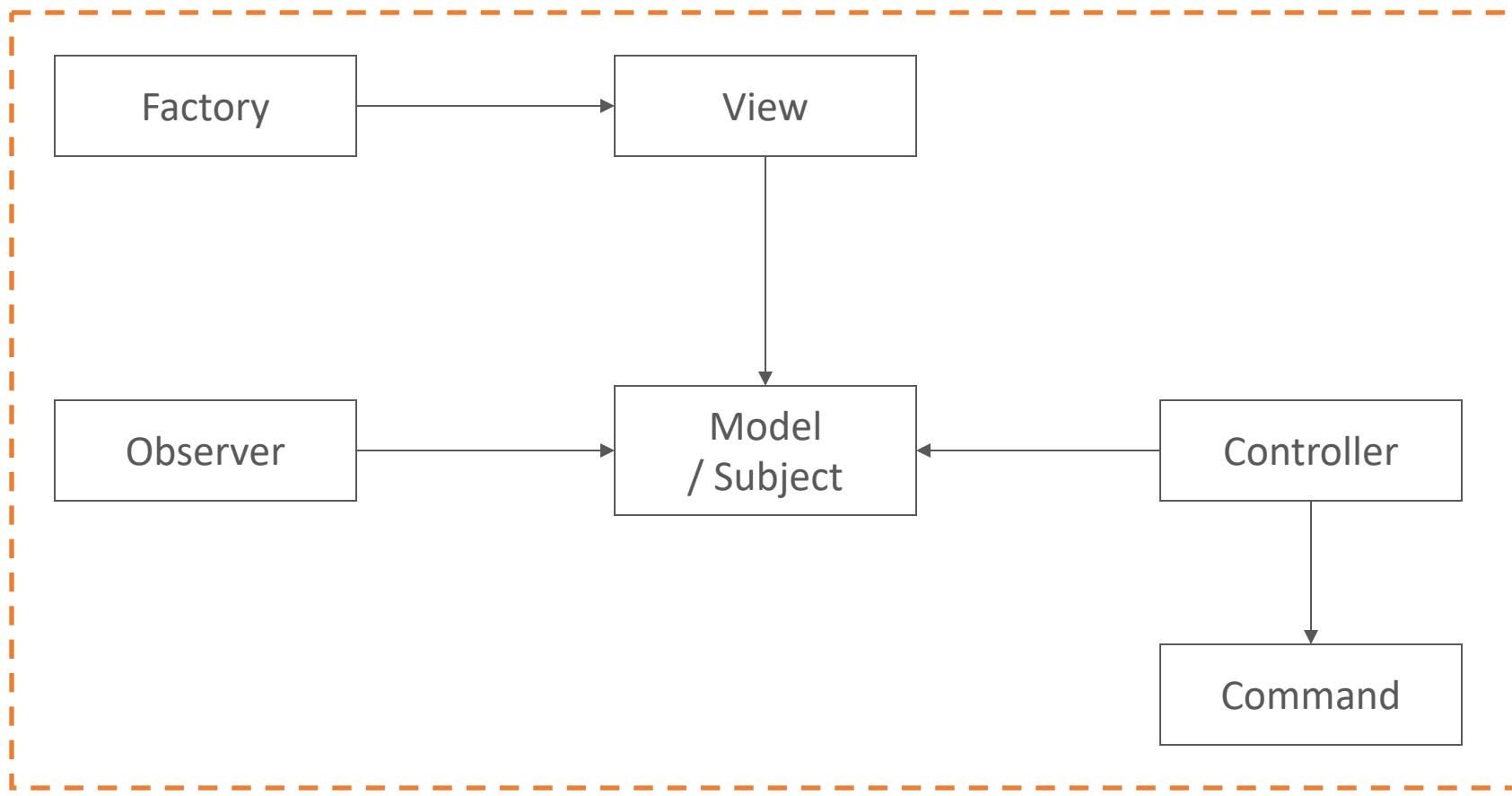
Architectural Questions

- How do I extend Eclipse with a plugin?
- What threads exist and how do they coordinate?
- How does Google scale to billions of hits per day?
- Where should I put my firewalls?
- What is the interface between subsystems?

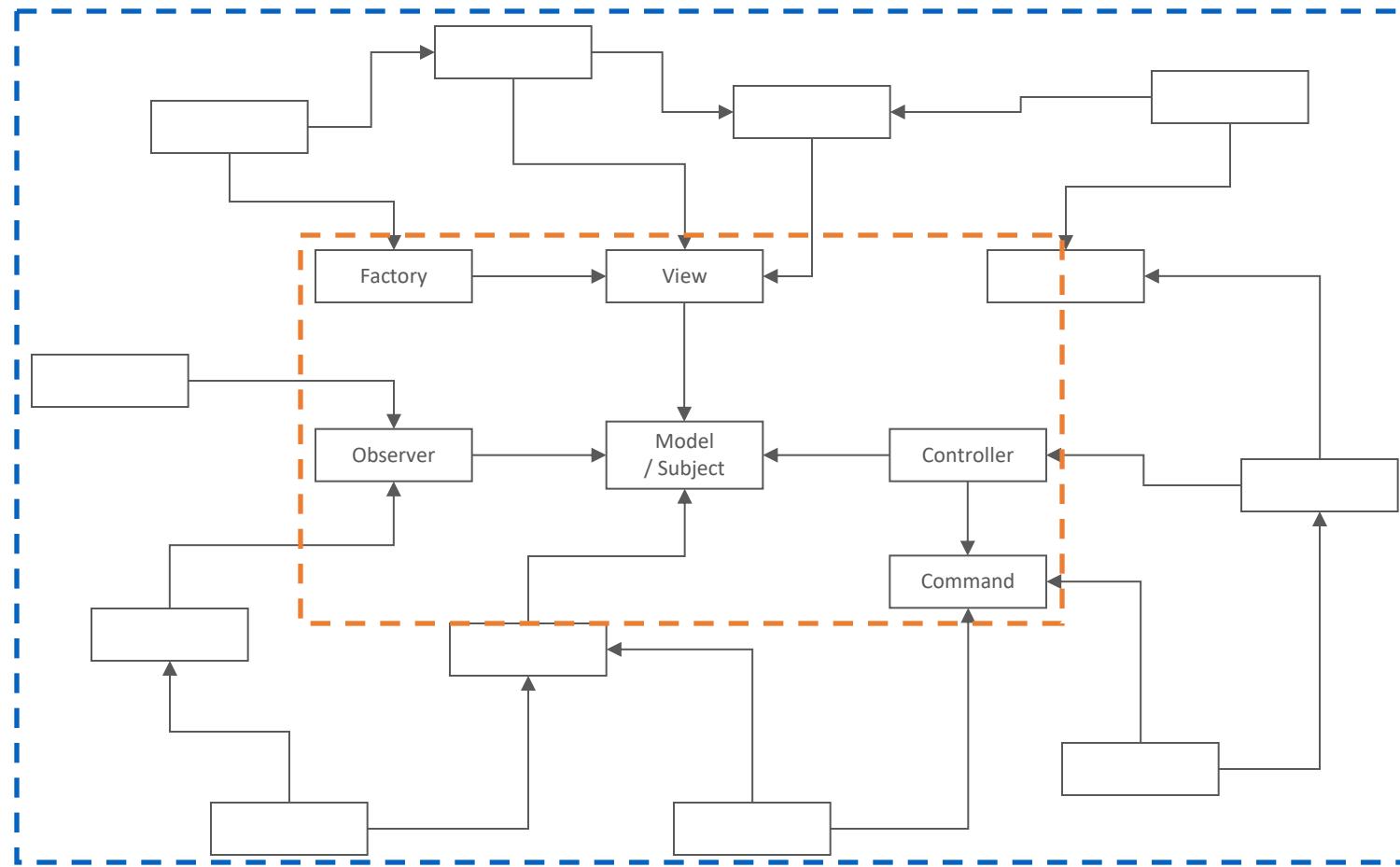
Objects

Model

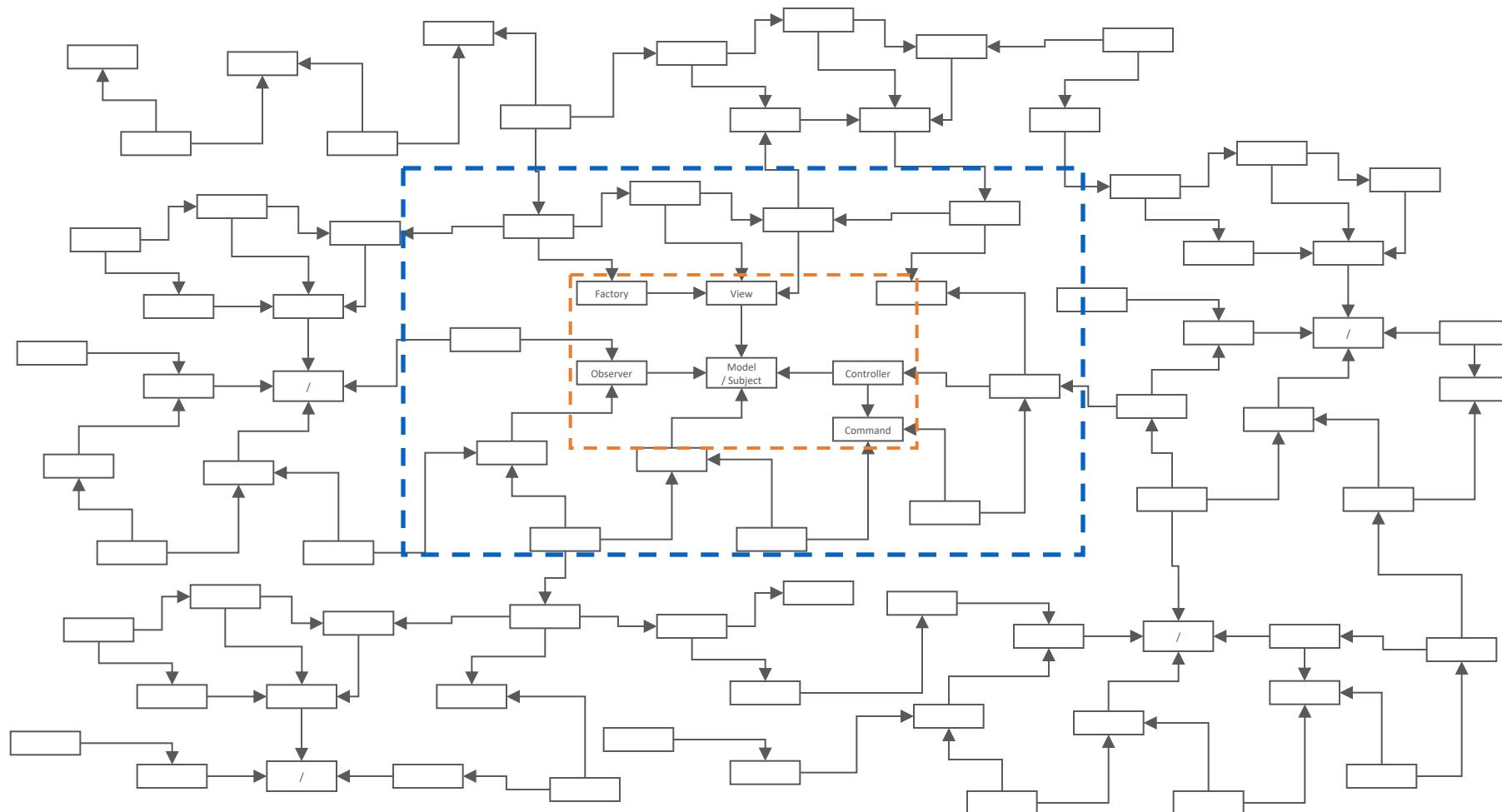
Design Patterns



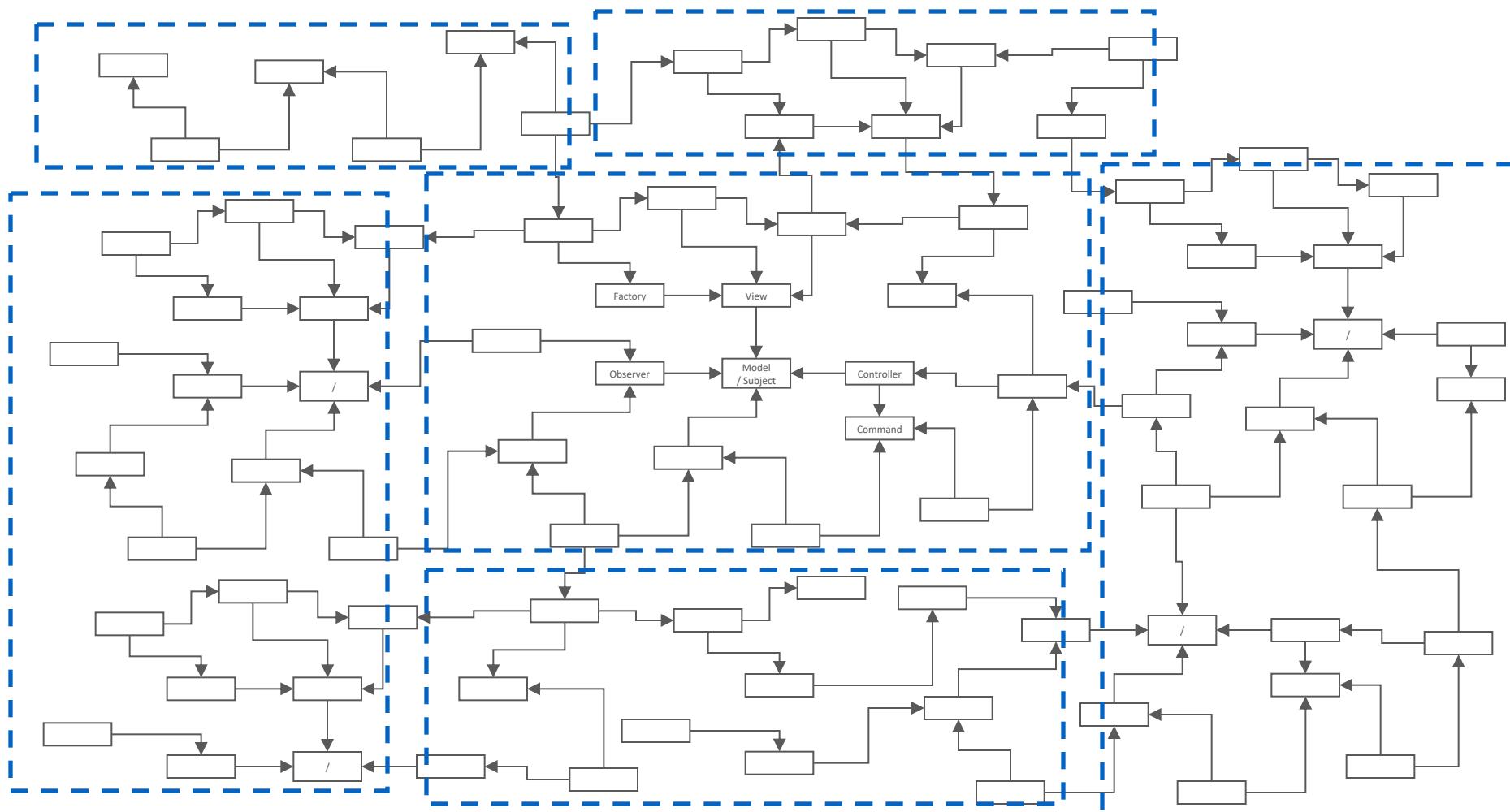
Design Patterns



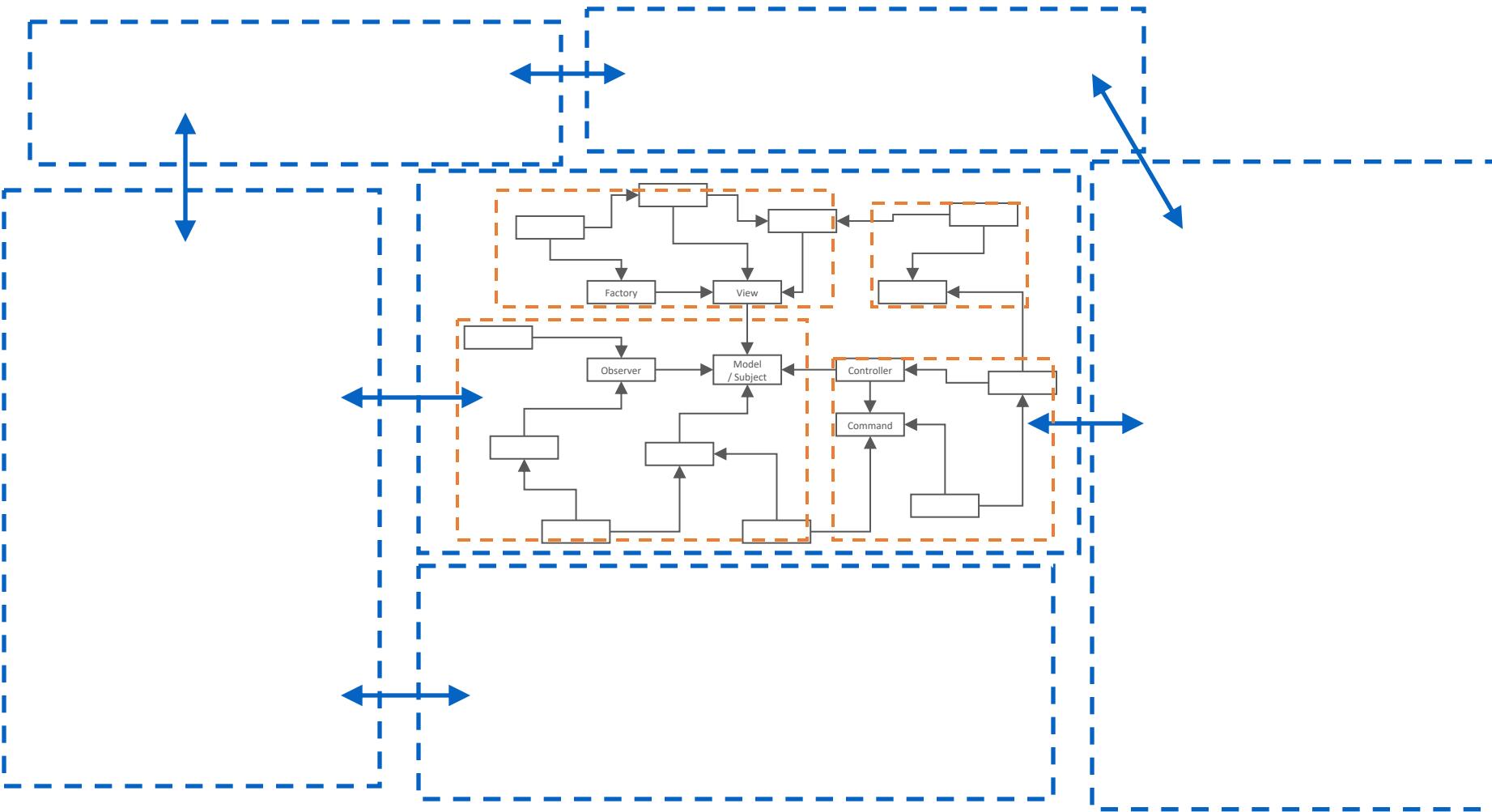
Design Patterns



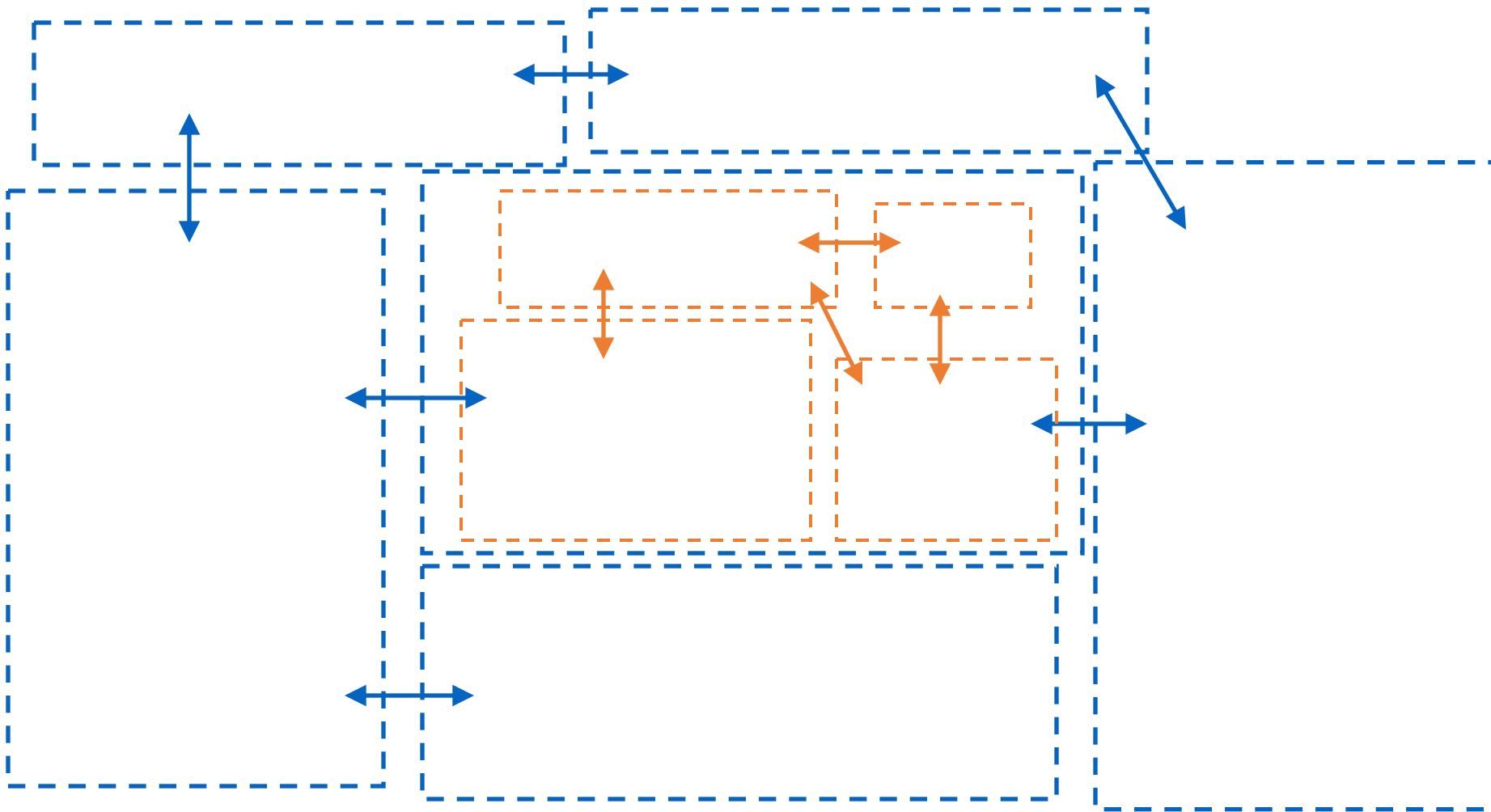
Architecture



Architecture



Architecture



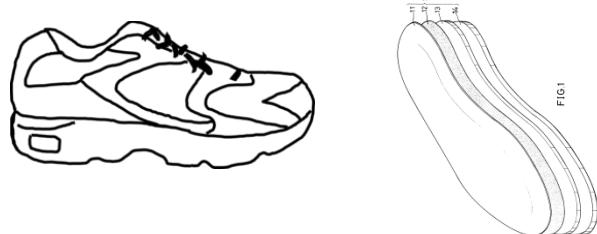
ARCHITECTURE DOCUMENTATION & VIEWS

Architecture Disentangled

Architecture as
structures and relations
(the actual system)



Architecture as
documentation
(representations of the system)

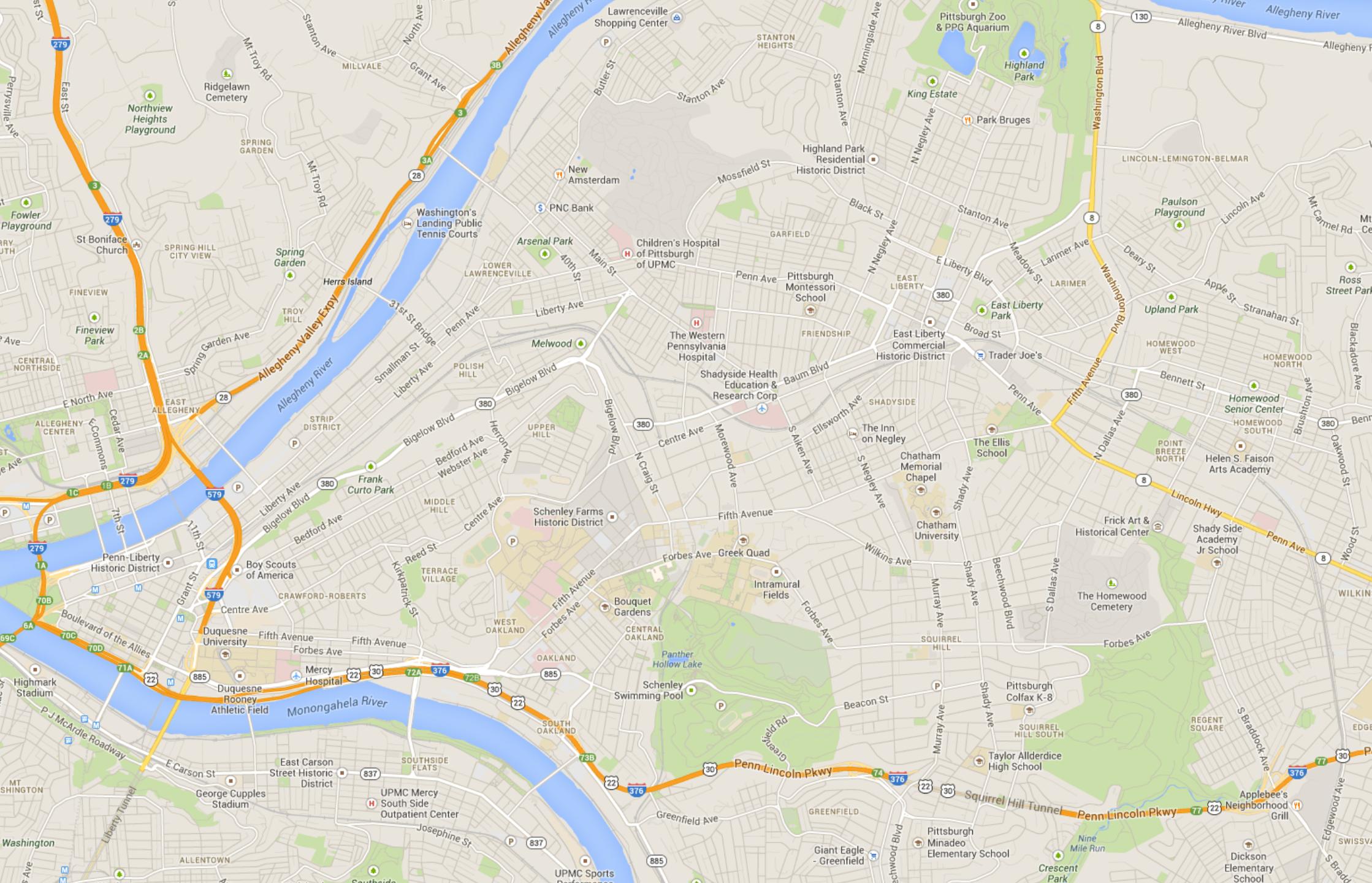


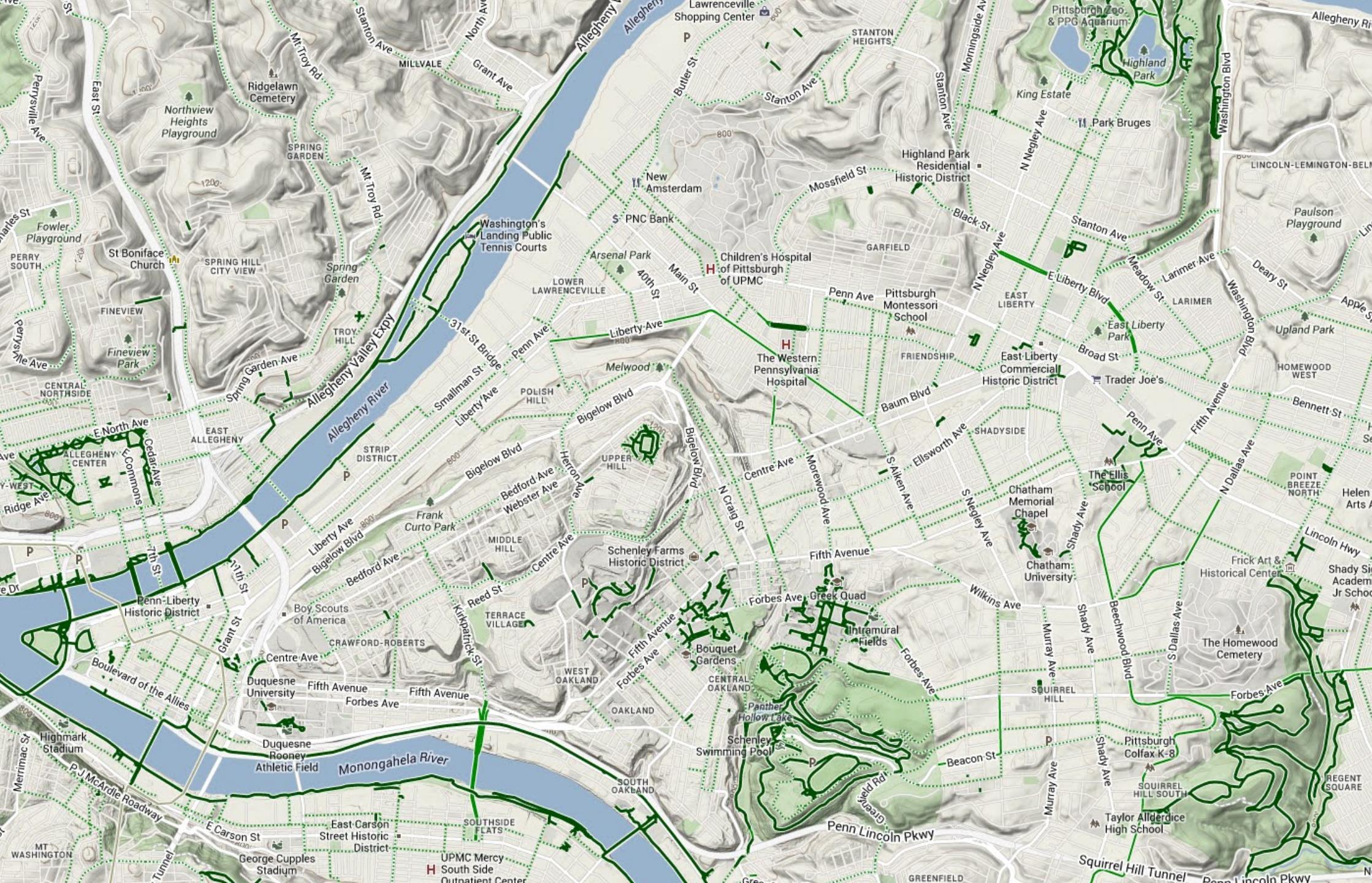
Architecture as (design) process
(activities around the other two)

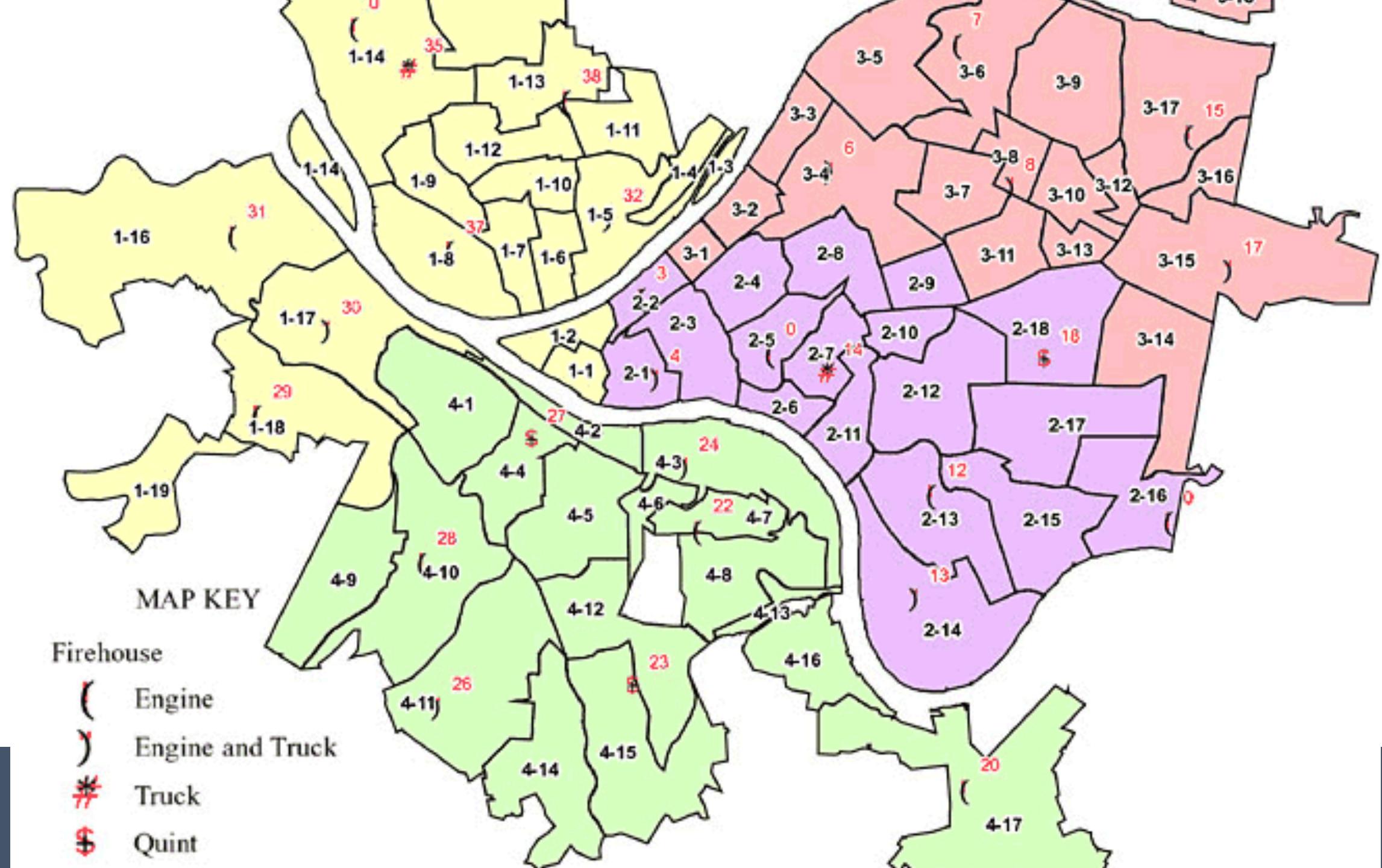


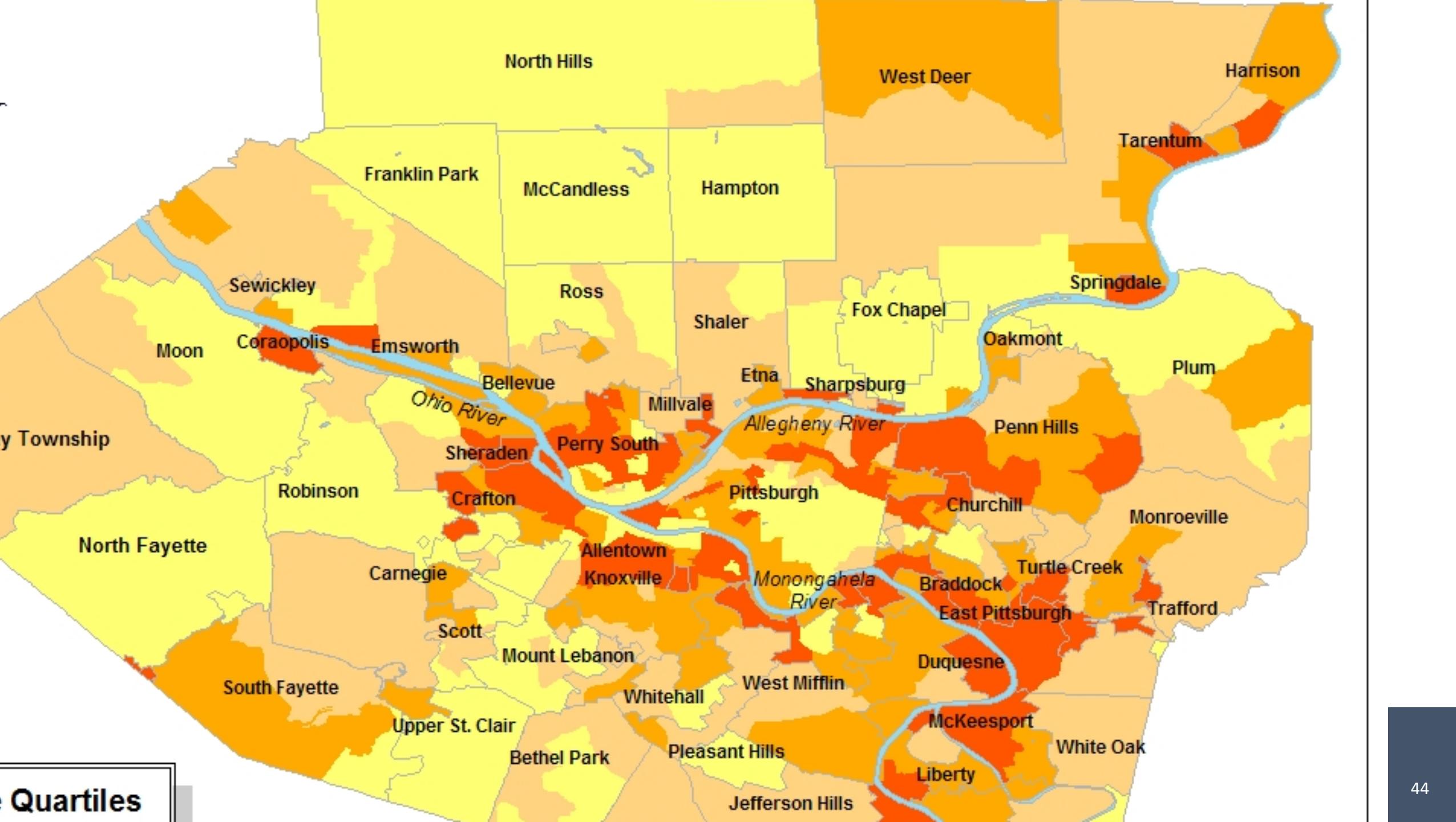
Why Document Architecture?

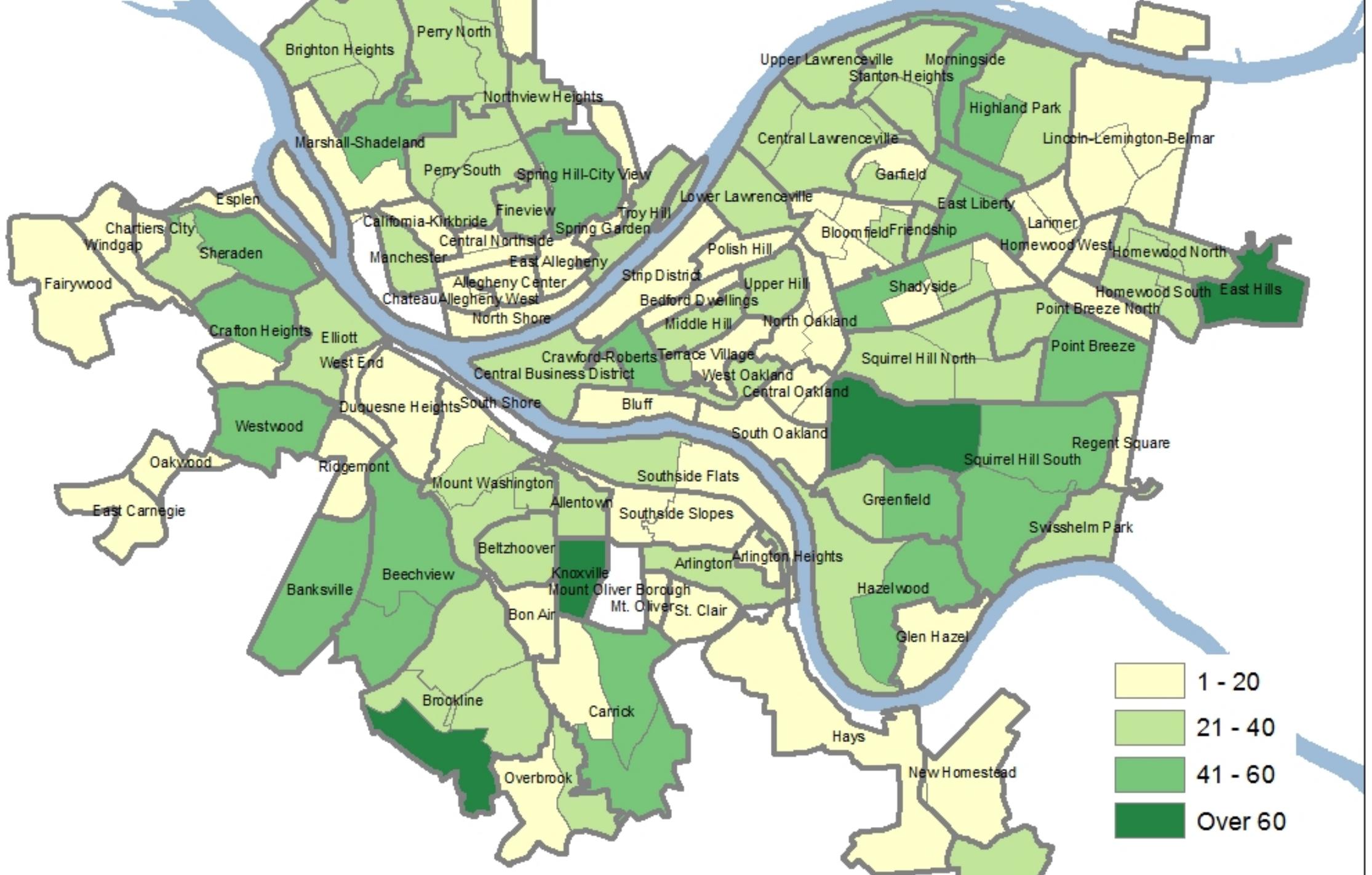
- Blueprint for the system
 - Artifact for early analysis
 - Primary carrier of quality attributes
 - Key to post-deployment maintenance and enhancement
- Documentation speaks for the architect, today and 20 years from today
 - As long as the system is built, maintained, and evolved according to its documented architecture
- Support traceability.











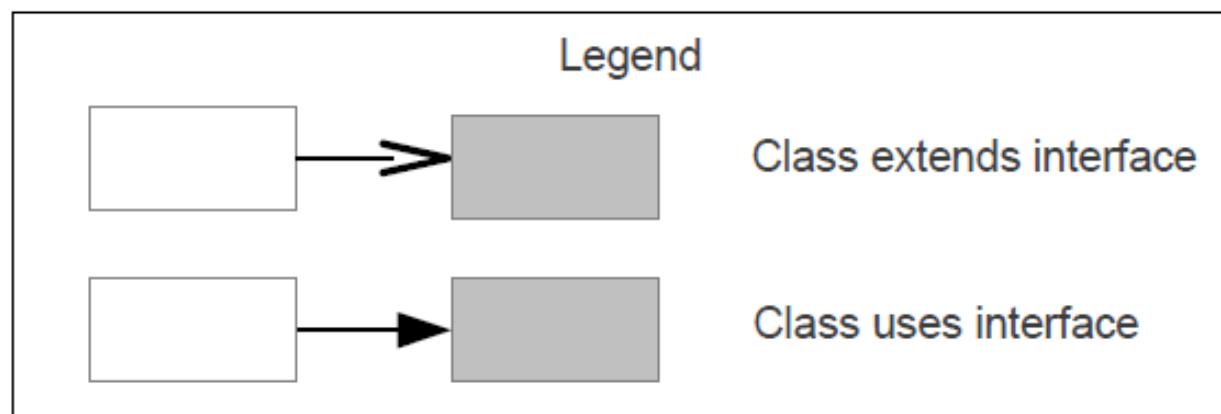
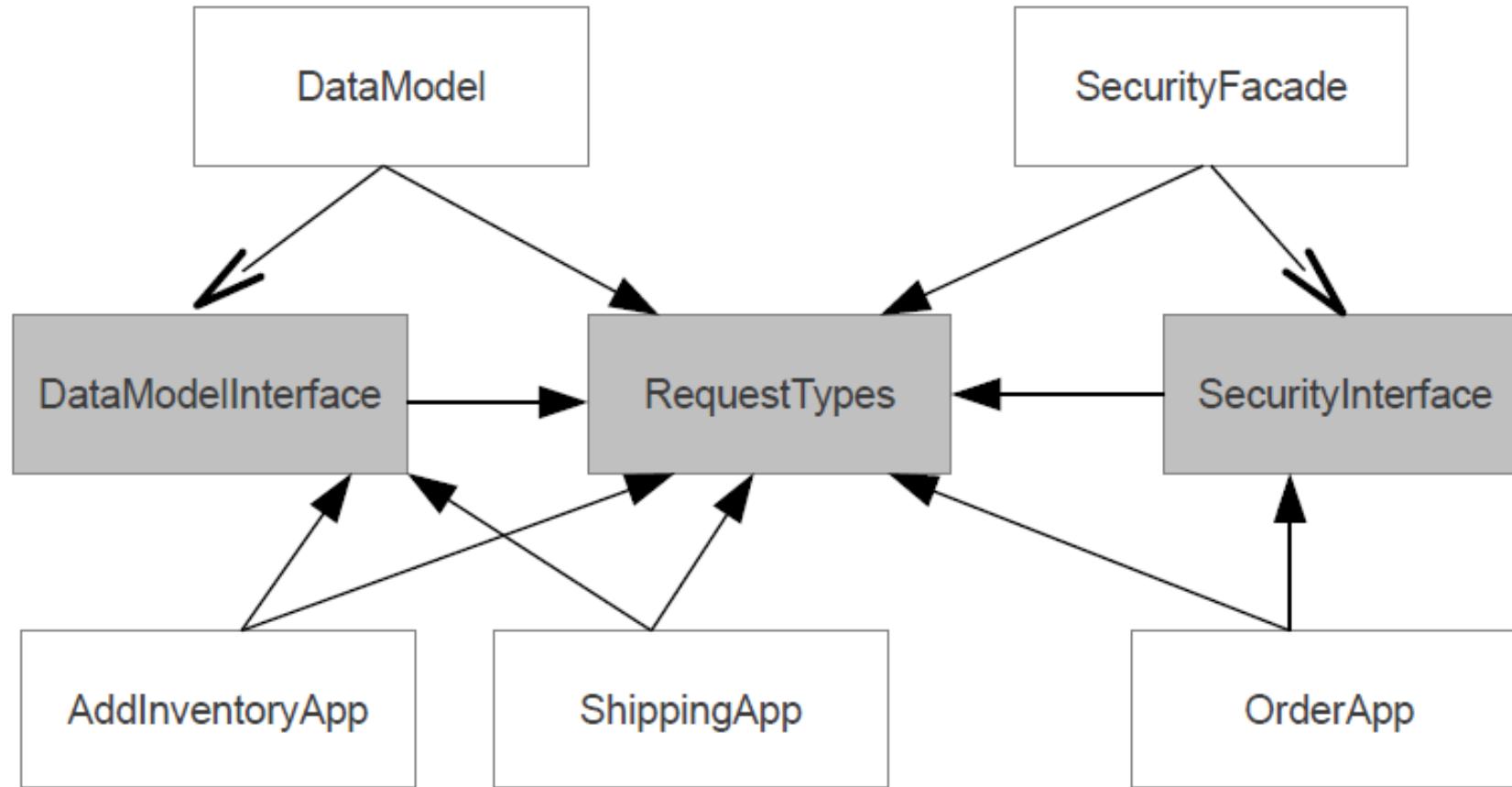


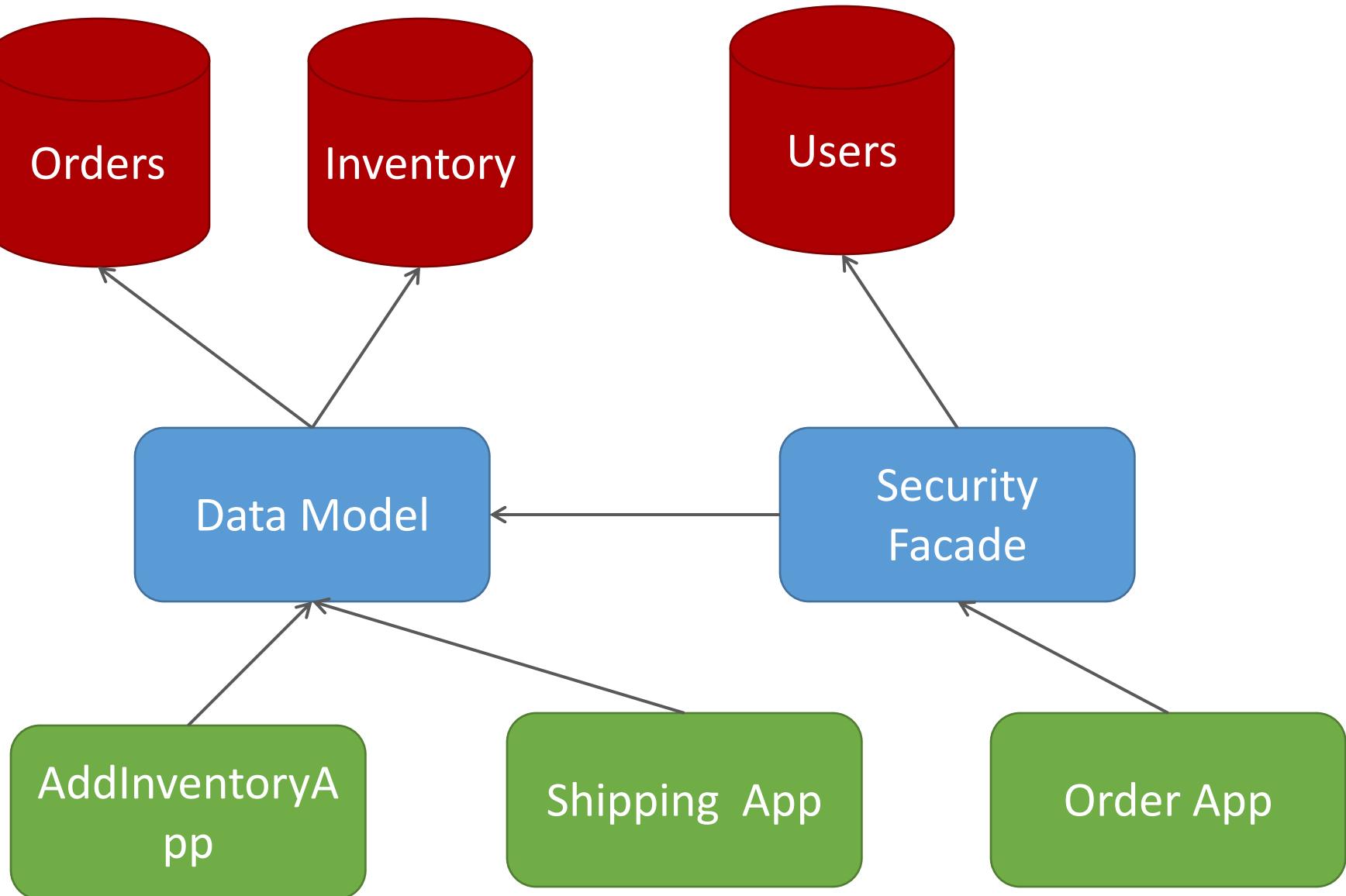
Common Views in Documenting Software Architecture

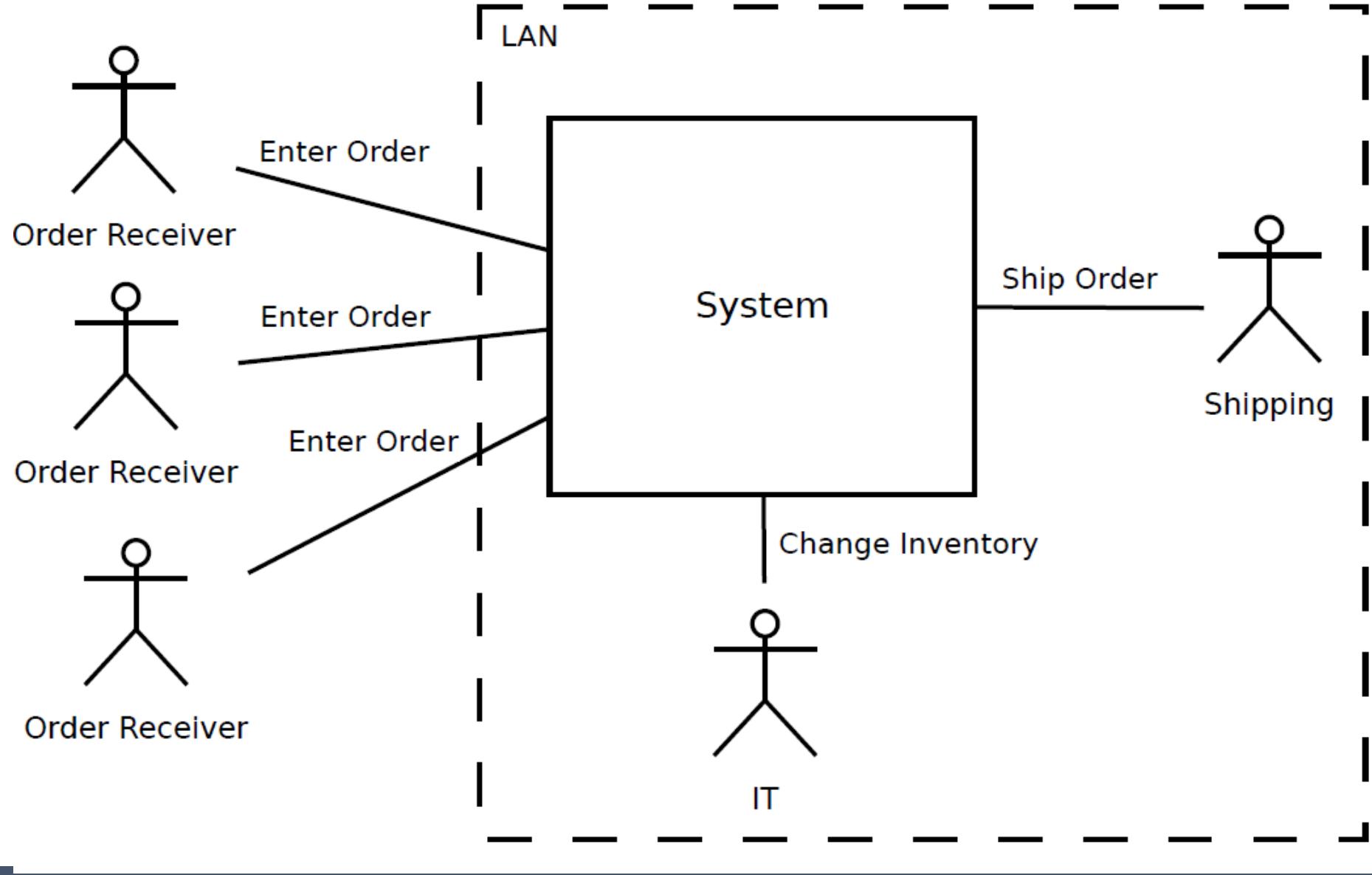
- Static View
 - Modules (subsystems, structures) and their relations (dependencies, ...)
- Dynamic View
 - Components (processes, runnable entities) and connectors (messages, data flow, ...)
- Physical View (Deployment)
 - Hardware structures and their connections

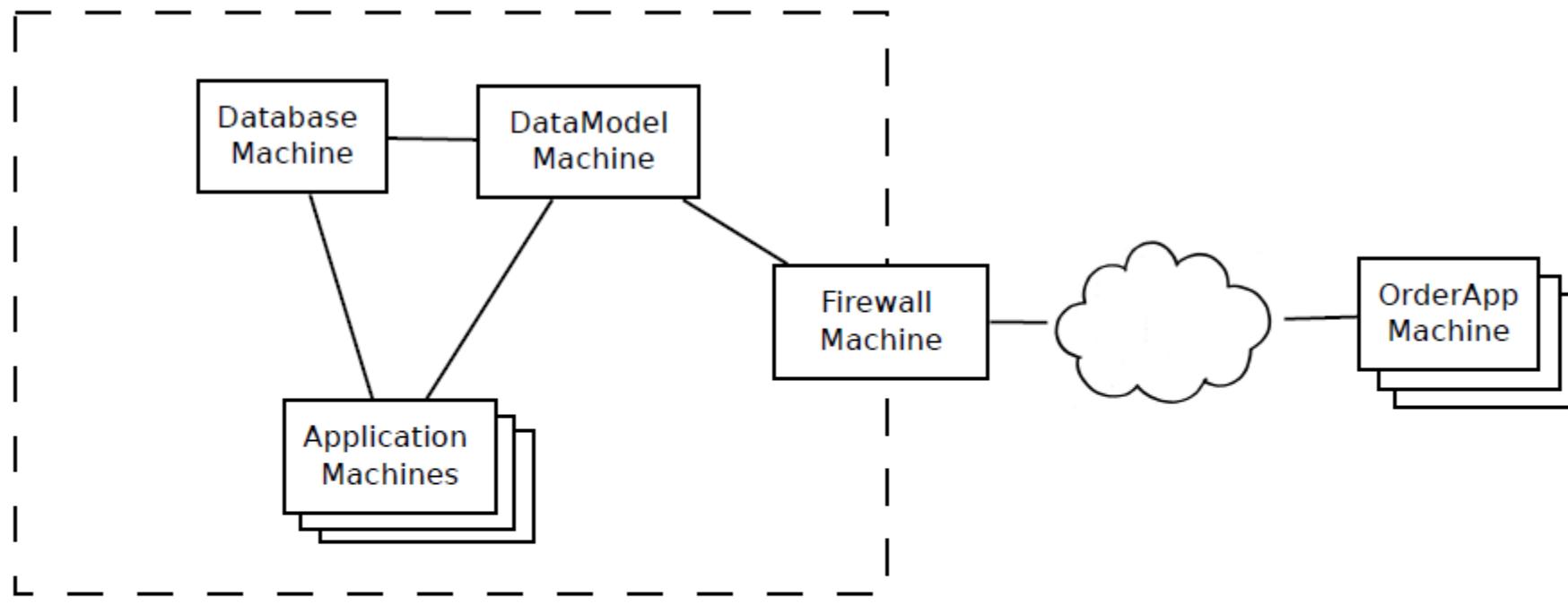
Views and Purposes

- Every view should align with a purpose
- Different views are suitable for different reasoning aspects (different quality goals), e.g.,
 - Performance
 - Extensibility
 - Security
 - Scalability
 - ...

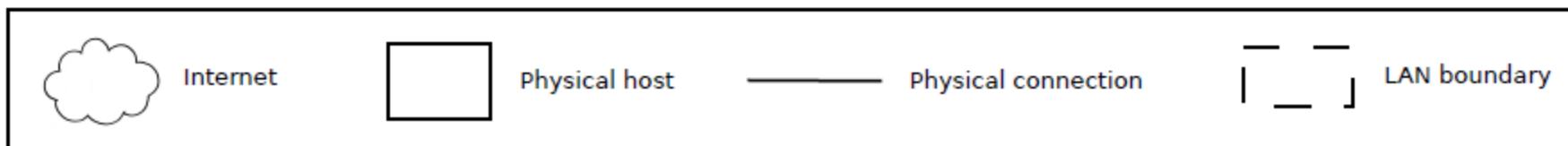








Legend



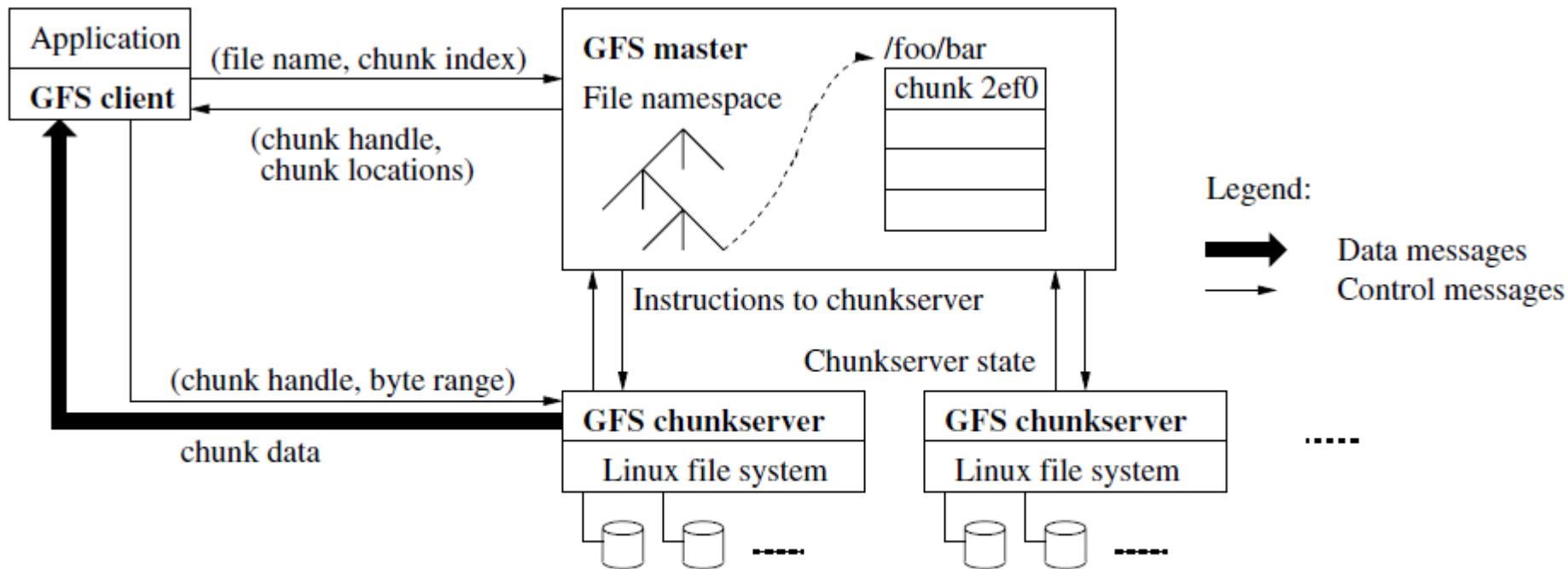


Figure 1: GFS Architecture

Ghemawat, Sanjay, Howard Gobioff, and Shun-Tak Leung. "The Google file system." *ACM SIGOPS operating systems review*. Vol. 37. No. 5. ACM, 2003.

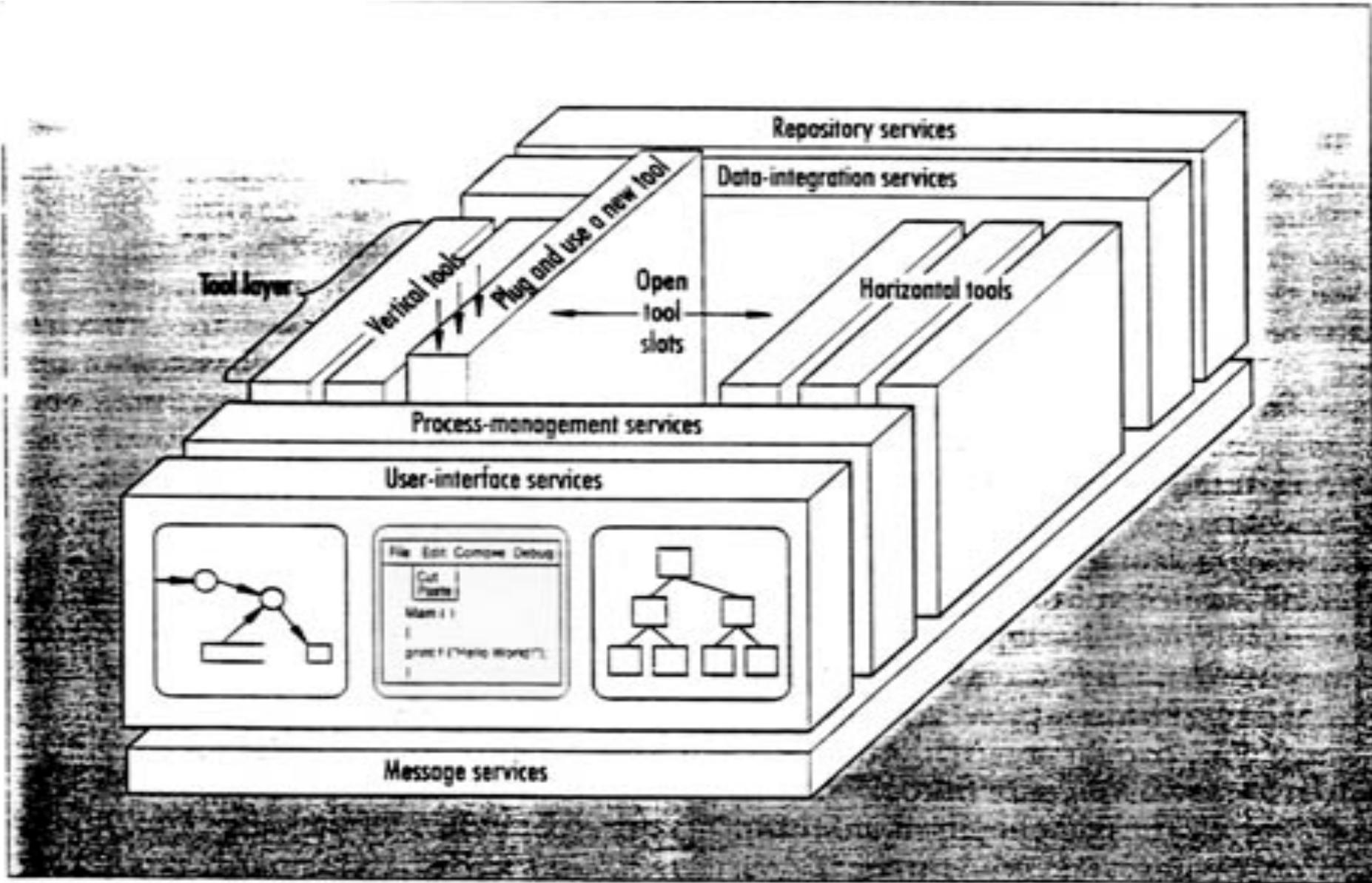


Figure 1. The NIST/ECMA reference model.

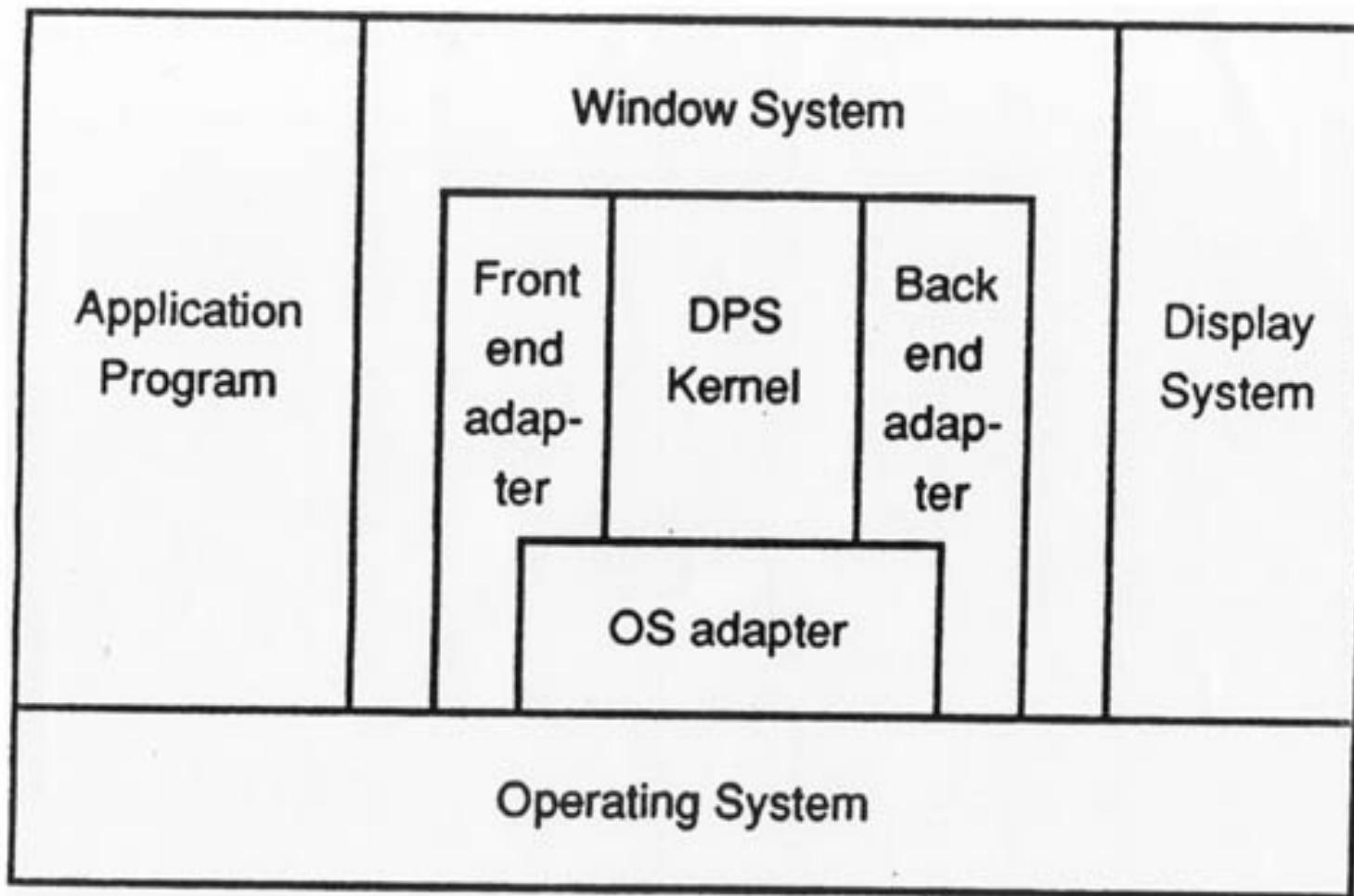
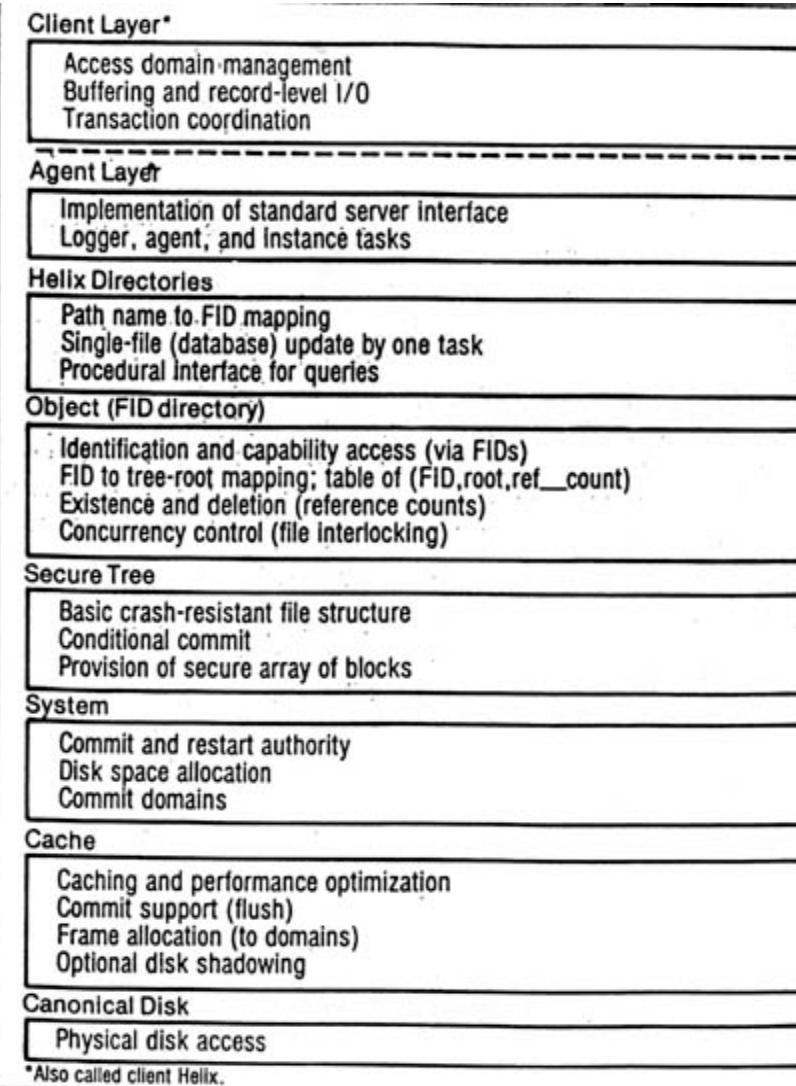


Figure 2. Display PostScript interpreter components.

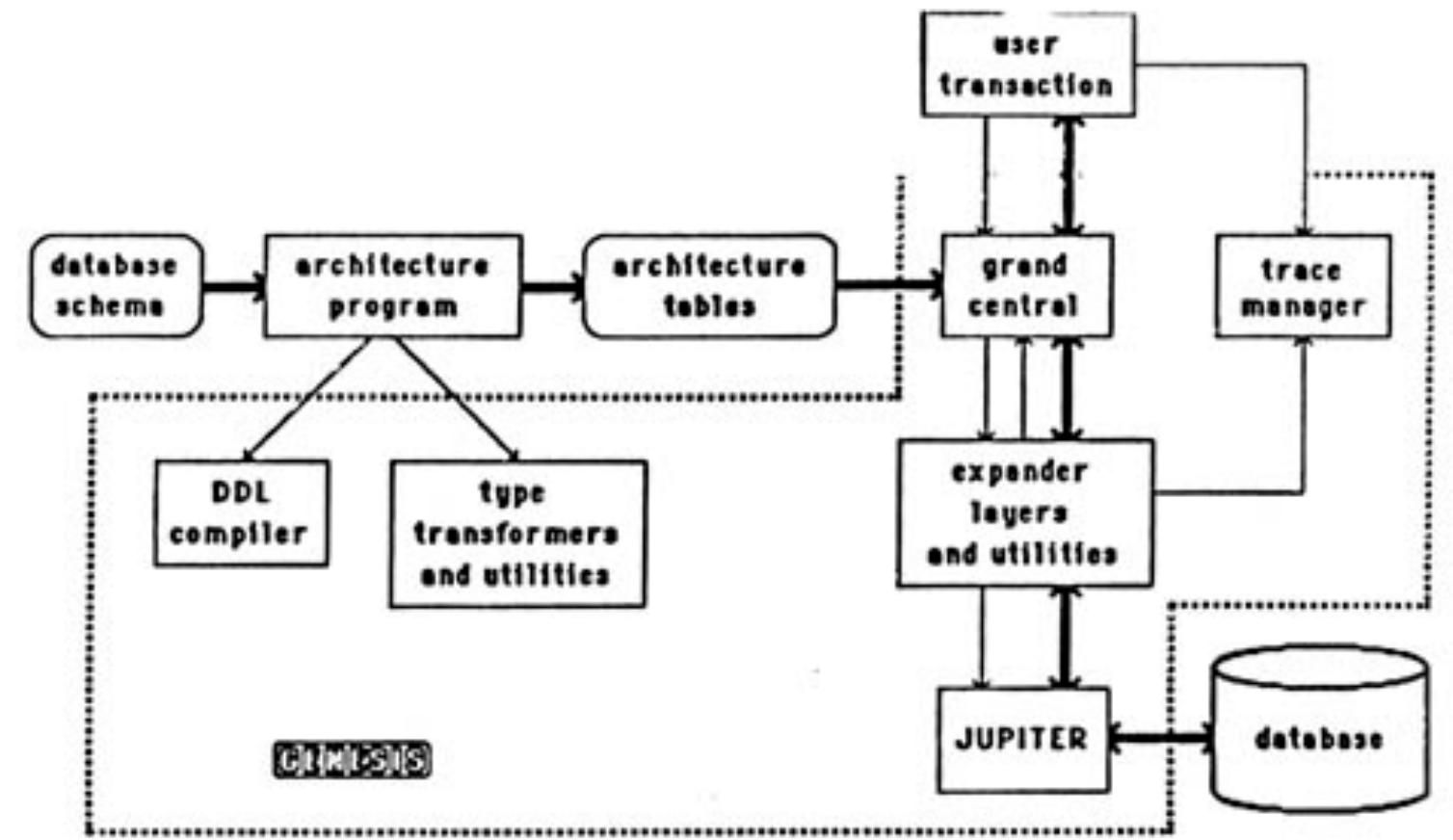
An Overview of the DISPLAY POSTSCRIPT™ System, Adobe Systems Incorporated, March 16, 1988, P. 10



*Also called client Helix.

Figure 2. Abstraction layering.

IEEE Software, "Helix: The architecture of the XMS Distributed File System,
Marek Fridrich and William Older, May 1985, Vol. 2, No. 3, P. 23

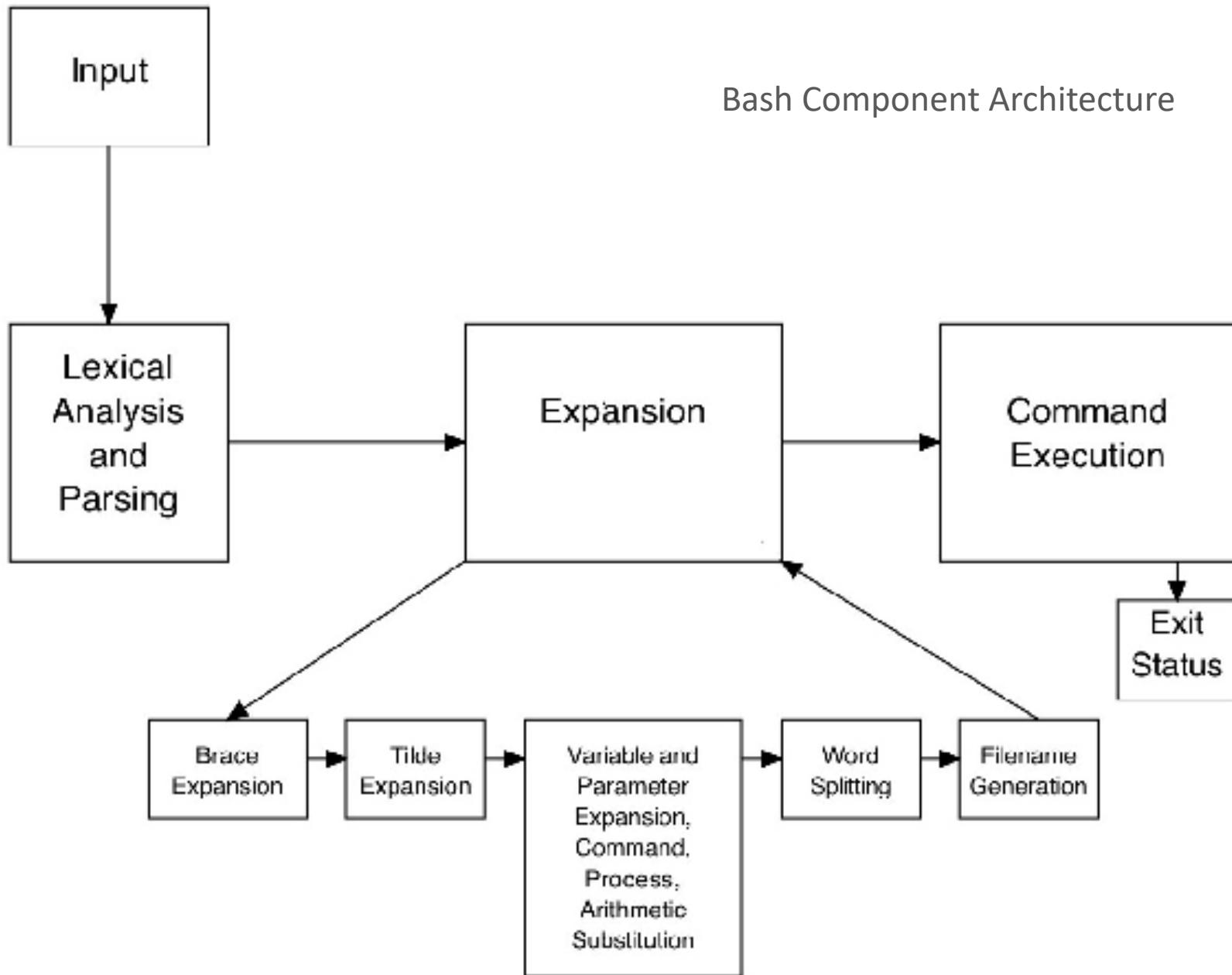


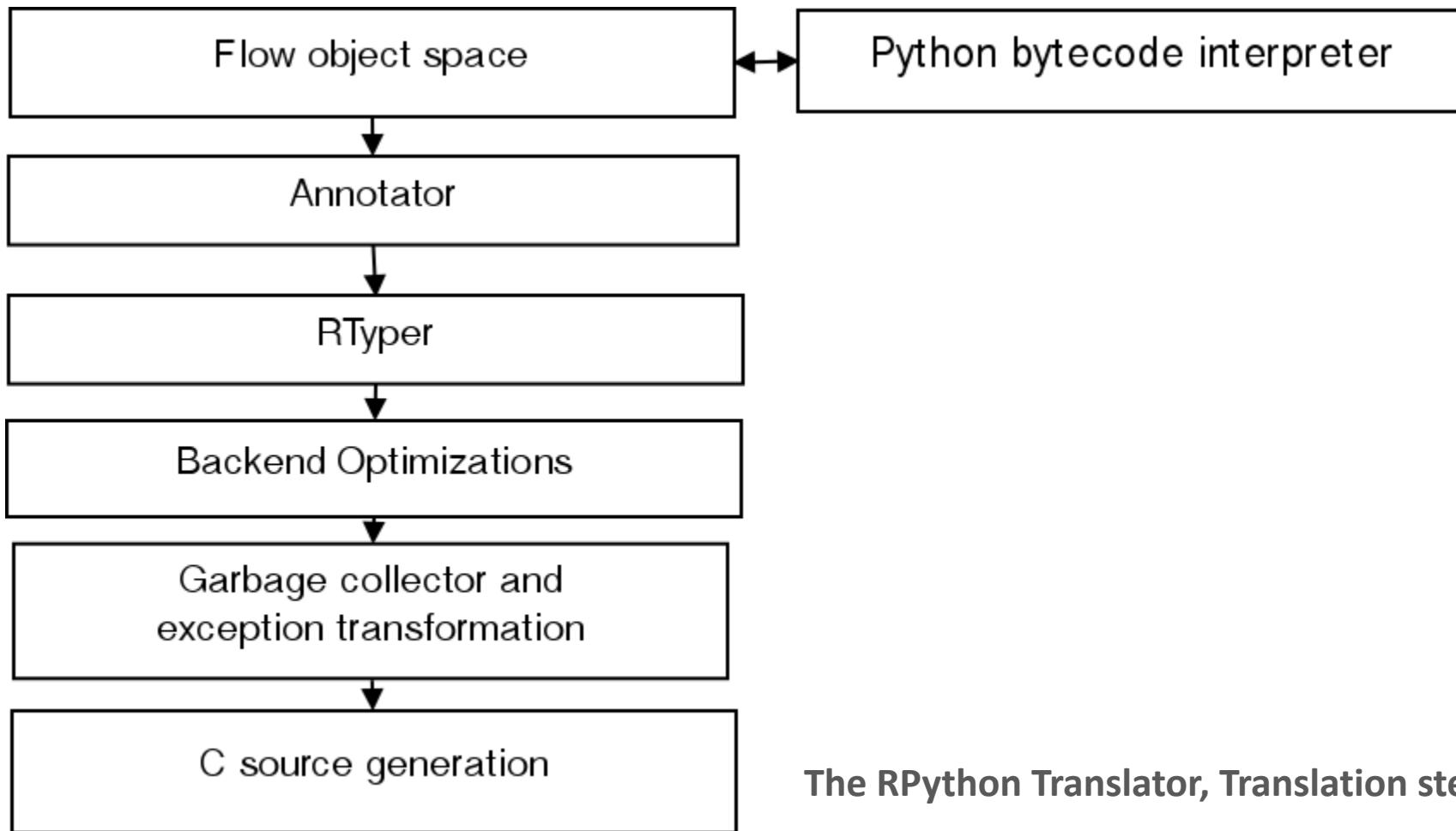
Legend

- | | | | |
|--|-------------------|--------------------------|-------------|
| | module or program | $A \rightarrow B$ | A calls B |
| | schema or tables | $A \xrightarrow{data} B$ | A data path |

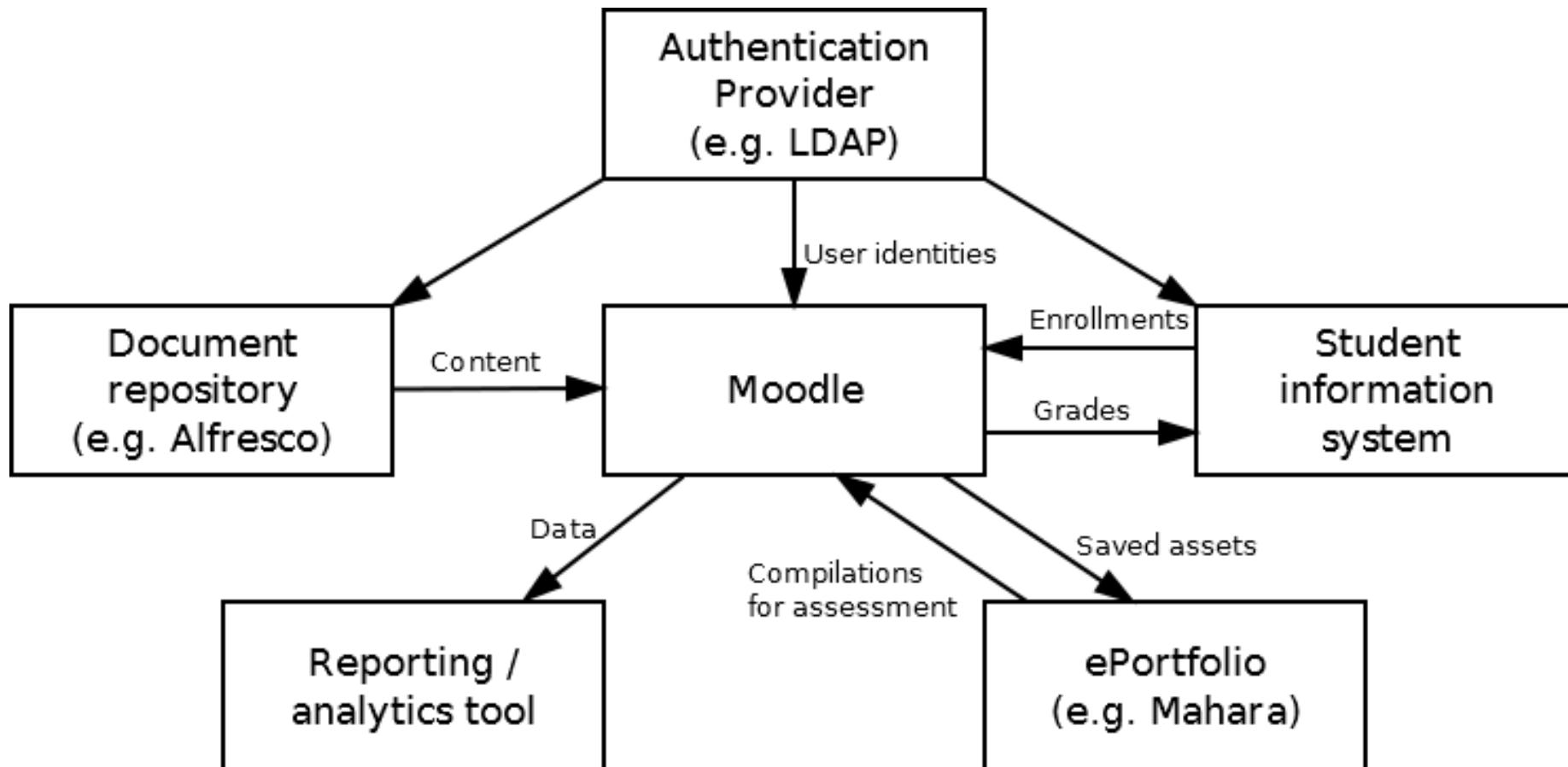
Figure 3.1 The Configuration of the GENESIS Prototype

Genesis: A Reconfiguration Database Management System, D. S. Batory, J.R. Barnett, J.F. Garza, K.P. Smith, K. Tsukuda, B.C. Twichell, T.E. Wise, Department of Computer Sciences, University of Texas at Austin,





The RPython Translator, Translation steps



Moodle: Typical university systems architecture – Key subsystems

Selecting a Notation

- Suitable for purpose
- Often visual for compact representation
- Usually boxes and arrows
- UML possible (semi-formal), but possibly constraining
 - Note the different abstraction level – Subsystems or processes, not classes or objects
- Formal notations available
- Decompose diagrams hierarchically and in views

What is Wrong Today?

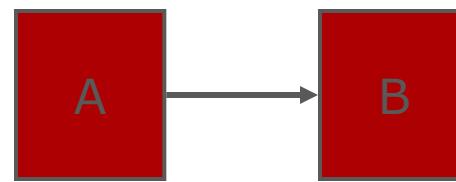
- In practice today's documentation consists of
 - Ambiguous box-and-line diagrams
 - Inconsistent use of notations
 - Confusing combinations of viewtypes
- Many things are left unspecified:
 - What kind of elements?
 - What kind of relations?
 - What do the boxes and arrows mean?
 - What is the significance of the layout?

Guidelines: Avoiding Ambiguity

- Always include a legend
- Define precisely what the boxes mean
- Define precisely what the lines mean
- Don't mix viewtypes unintentionally
 - Recall: Module (classes), C&C (components)
- Supplement graphics with explanation
 - Very important: rationale (architectural intent)
- Do not try to do too much in one diagram
 - Each view of architecture should fit on a page
 - Use hierarchy

What could the arrow mean?

- Many possibilities
 - A passes control to B
 - A passes data to B
 - A gets a value from B
 - A streams data to B
 - A sends a message to B
 - A creates B
 - A occurs before B
 - B gets its electricity from A
 - ...



Recommendations for Recitation and Homework

- Use UML or UML-like notations:
 - Class diagrams for static and physical views
 - Communication diagrams for dynamic view
 - Use correct abstraction level (usually not classes/objects)
- Extend notation as needed
 - Provide a legend explaining the extensions or deviations from standard UML notation

CASE STUDY: THE GOOGLE FILE SYSTEM

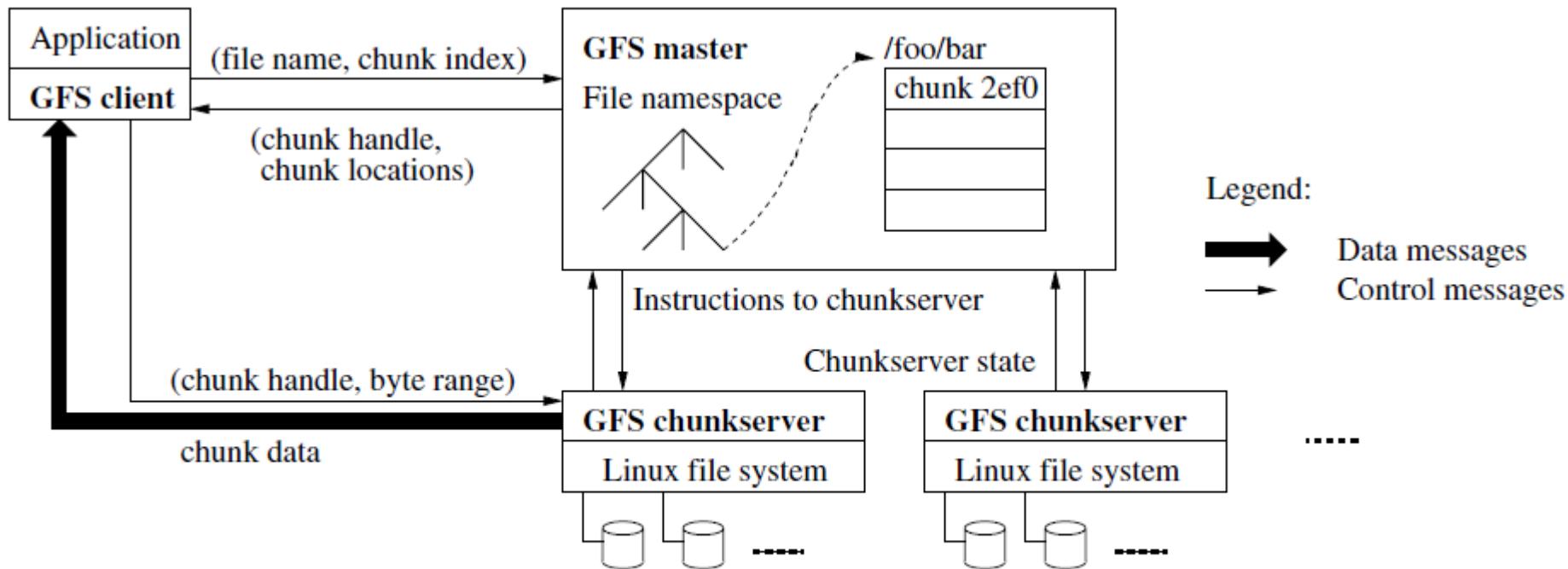


Figure 1: GFS Architecture

Assumptions

Ghemawat, Sanjay, Howard Gobioff, and Shun-Tak Leung. "The Google file system." *ACM SIGOPS operating systems review*. Vol. 37. No. 5. ACM, 2003.

- The system is built from many inexpensive commodity components that often fail.
- The system stores a modest number of large files.
- The workloads primarily consist of two kinds of reads: large streaming reads and small random reads.
- The workloads also have many large, sequential writes that append data to files.
- The system must efficiently implement well-defined semantics for multiple clients that concurrently append to the same file.
- High sustained bandwidth is more important than low latency.

Qualities:
Scalability
Reliability
Performance
Cost

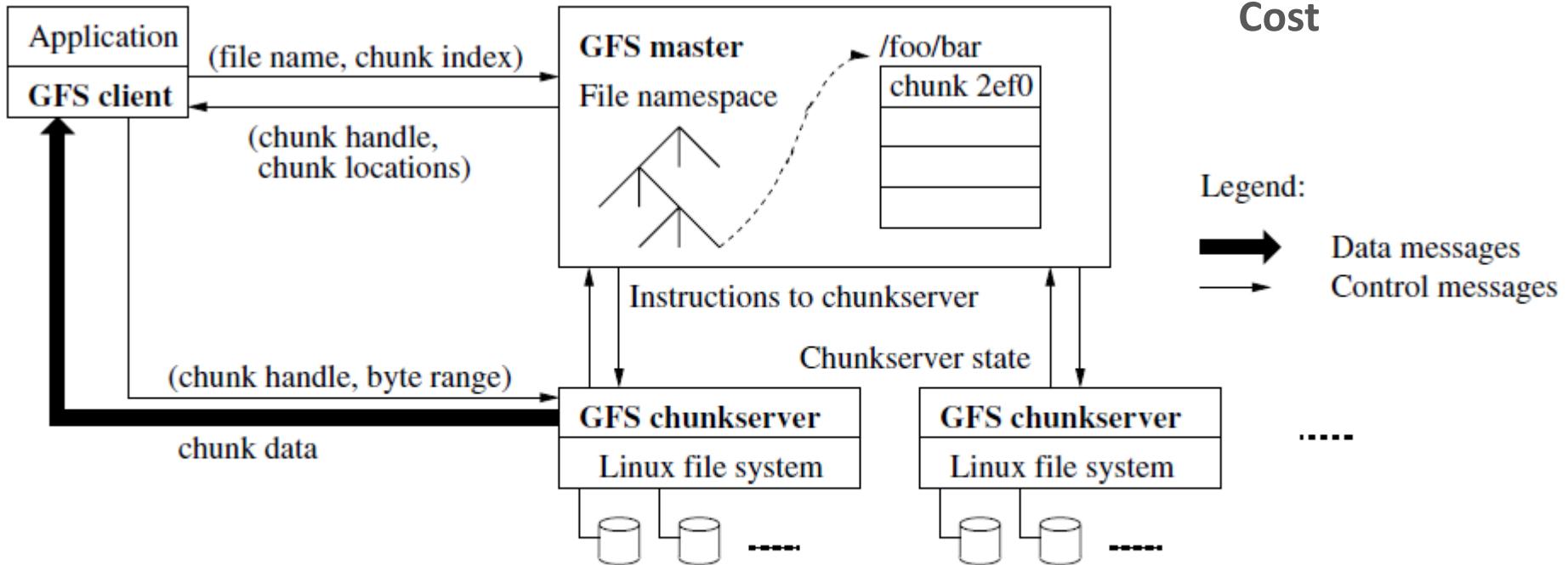


Figure 1: GFS Architecture

Questions

1. What are the most important quality attributes in the design?
2. How are those quality attributes realized in the design?

Qualities:
Scalability
Reliability
Performance
Cost

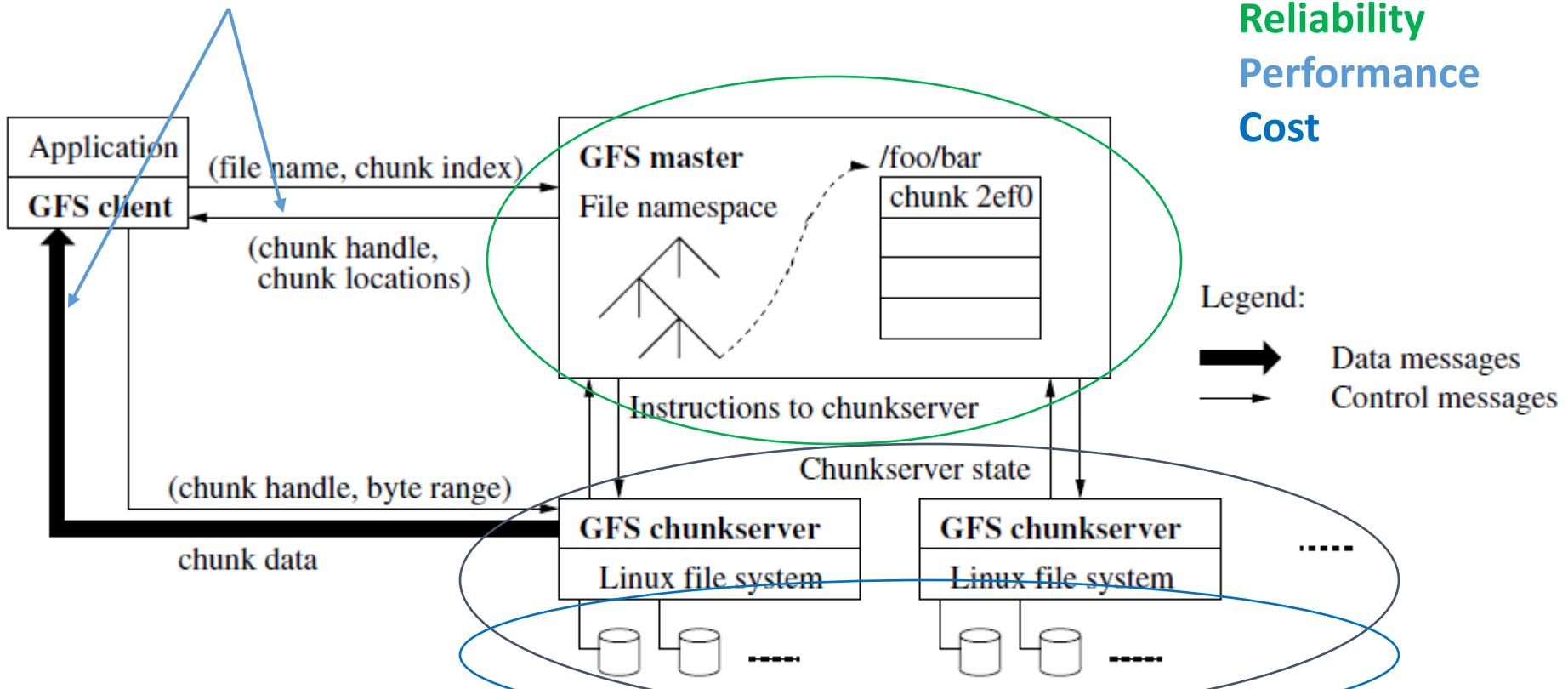


Figure 1: GFS Architecture

Exercise

For the Google File System, create a physical architecture view that addresses a relevant quality attribute

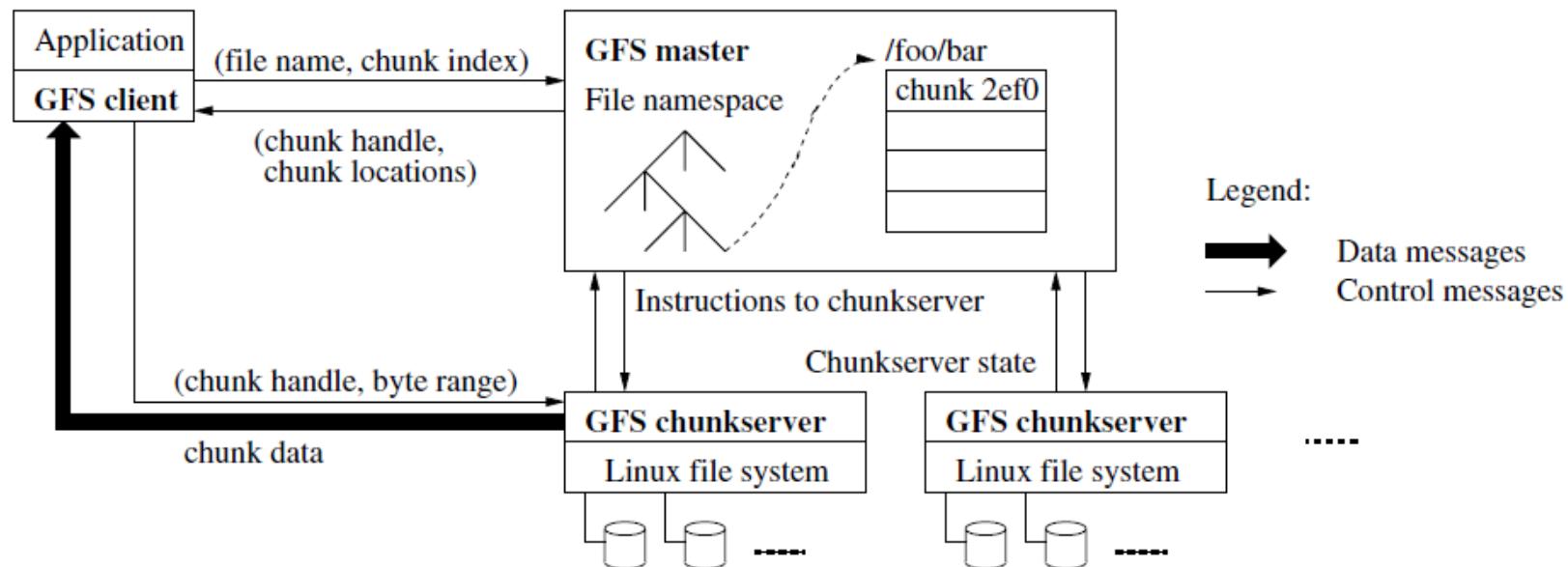


Figure 1: GFS Architecture

Further Readings

- Bass, Clements, and Kazman. Software Architecture in Practice. Addison-Wesley, 2003.
- Boehm and Turner. Balancing Agility and Discipline: A Guide for the Perplexed, 2003.
- Clements, Bachmann, Bass, Garlan, Ivers, Little, Merson, Nord, Stafford. Documenting Software Architectures: Views and Beyond, 2010.
- Fairbanks. Just Enough Software Architecture. Marshall & Brainerd, 2010.
- Jansen and Bosch. Software Architecture as a Set of Architectural Design Decisions, WICSA 2005.
- Lattanze. Architecting Software Intensive Systems: a Practitioner's Guide, 2009.
- Sommerville. Software Engineering. Edition 7/8, Chapters 11-13
- Taylor, Medvidovic, and Dashofy. Software Architecture: Foundations, Theory, and Practice. Wiley, 2009.

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