Introduction to Architecture

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Administrivia

HW2 second deadline moved from Tuesday, September 28, 23:59 to

Friday, Oct 1, 29:59

You should have issues, they should be assigned similar to HW1. This is an easy way to get points!

Learning Goals

Understand the abstraction level of architectural reasoning

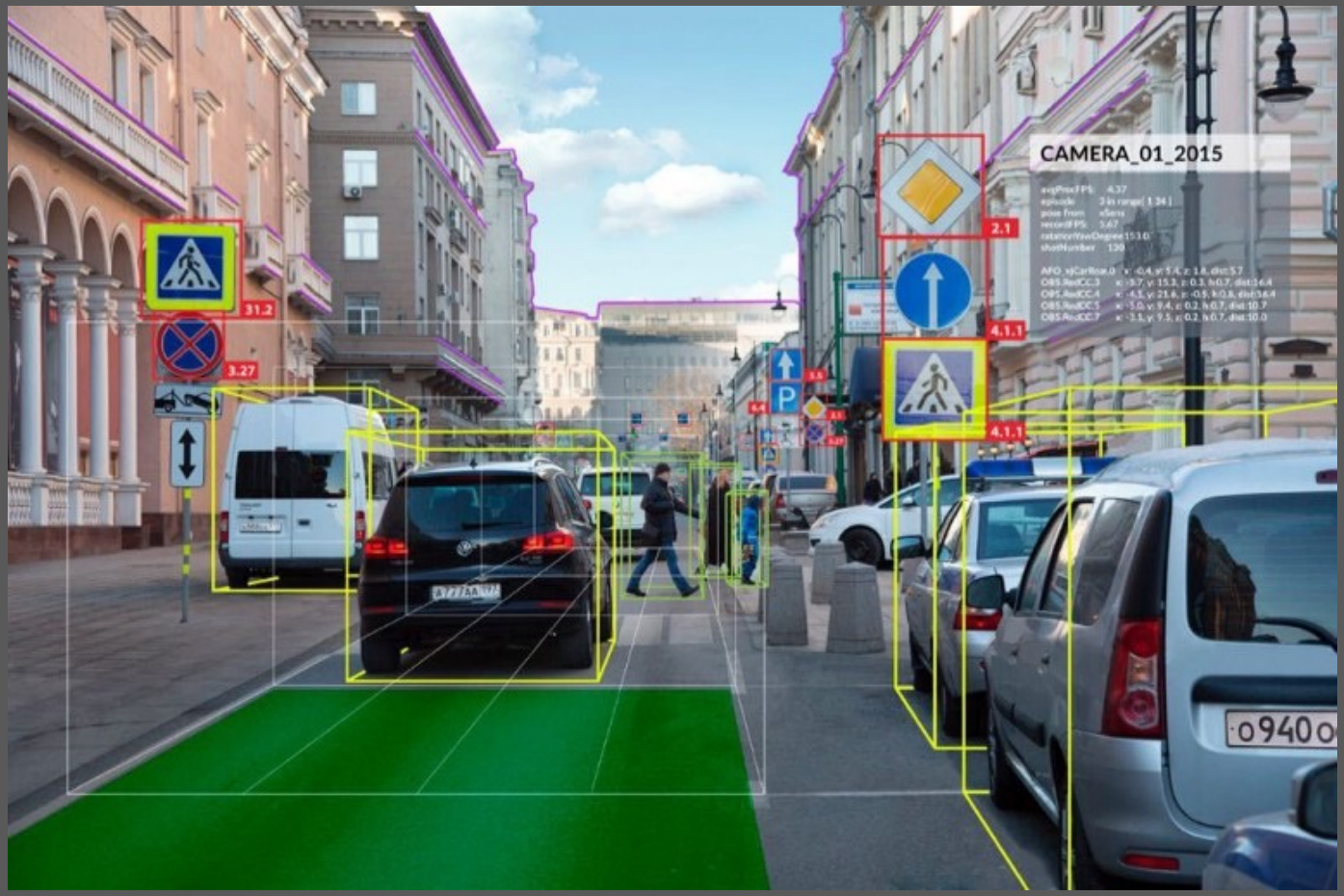
Appreciate how software systems can be viewed at different abstraction levels

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

Autonomous Vehicle Study



Autonomous Vehicle Study

Recall the “bike prediction” and “side pass” features from the videos (https://www.youtube.com/watch?v=XAQeL8eflT0 and https://www.youtube.com/watch?v=BXNDUtNZdM4)

What part of the software is responsible for implementing this feature?

Source: https://github.com/ApolloAuto/apollo

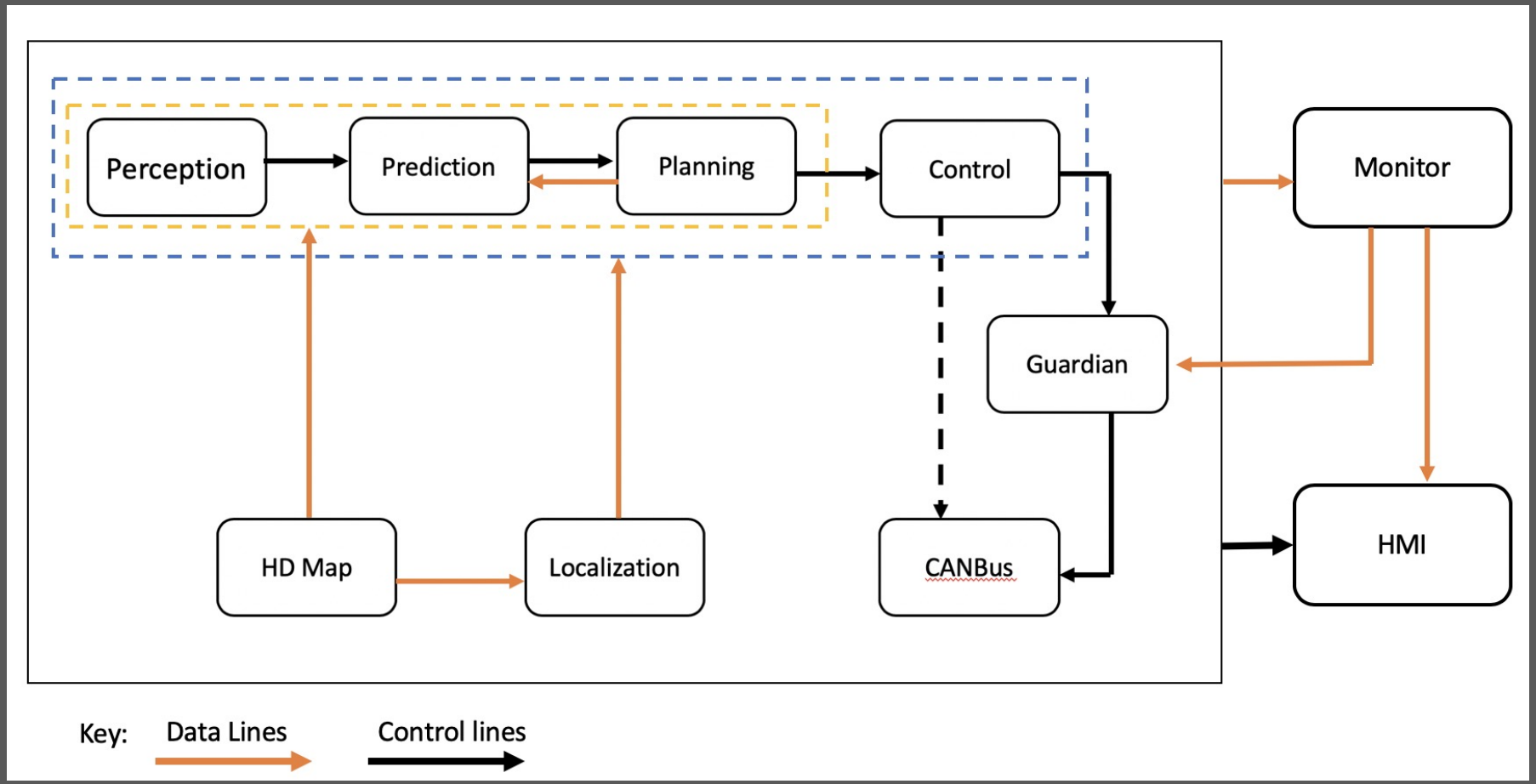
Doxygen: : https://hidetoshi-furukawa.github.io/apollo-doxygen/index.html

Apollo Software Stack

<table>
<tr><td>Cloud Service Platform</td><td>HD Map</td><td>Simulation</td><td>Data Platform</td><td>Security</td><td>OTA</td><td>DuerOS</td><td>Volume Production Service Components</td><td>V2X Roadside Service</td></tr>
<tr><td rowspan="3">Open Software Platform</td><td>Map Engine</td><td>Localization</td><td>Perception</td><td>Planning</td><td>Control</td><td>End-to-End</td><td colspan="2">HMI</td><td rowspan="3">V2X Adapter</td></tr>
<tr><td colspan="8">Apollo Cyber RT Framework</td></tr>
<tr><td colspan="8">RTOS</td></tr>
<tr><td>Hardware Development Platform</td><td>Computing Unit</td><td>GPS/IMU</td><td>Camera</td><td>LiDAR</td><td>Radar</td><td>Ultrasonic Sensor</td><td>HMI Device</td><td>Black Box</td><td>Apollo Sensor Unit</td><td>Apollo Extension Unit</td><td>V2X OBU</td></tr>
<tr><td>Open Vehicle Certificate Platform</td><td colspan="7">Certified Apollo Compatible Drive-by-wire Vehicle</td><td colspan="3">Open Vehicle Interface Standard</td></tr>
</table>

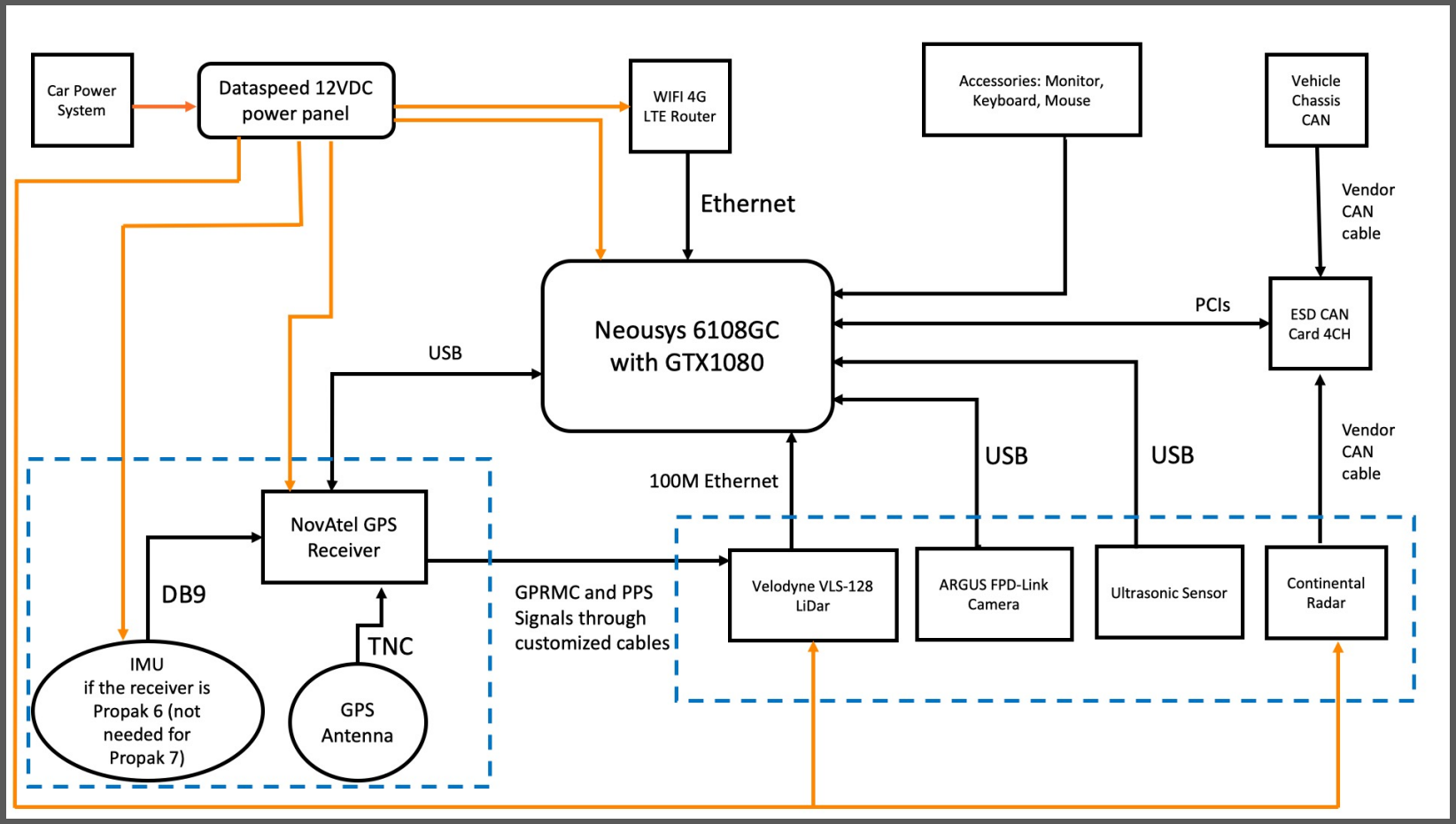
Major Updates in Apollo 3.5

Apollo Software Architecture



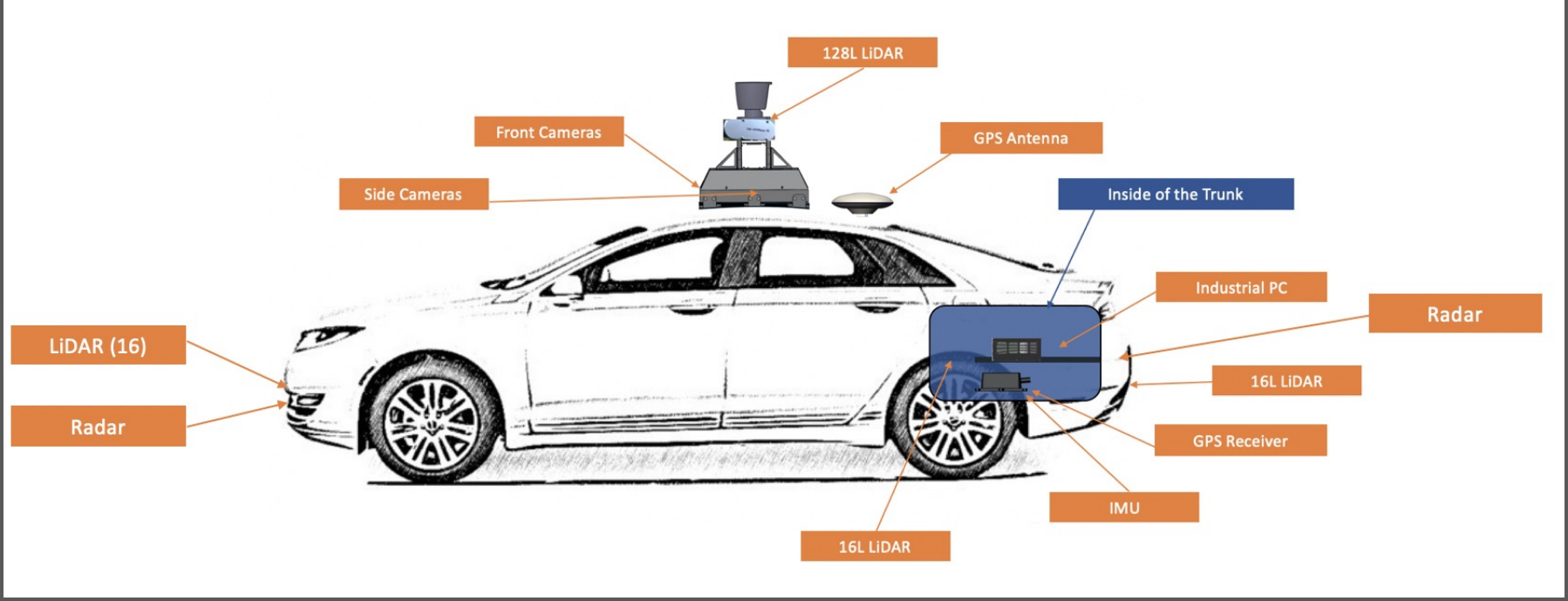
Source: https://github.com/ApolloAuto/apollo/blob/v6.0.0/docs/specs/Apollo_5.5_Software_Architecture.md

Apollo Hardware Architecture



Source: https://github.com/ApolloAuto/apollo/blob/v6.0.0/README.md

Apollo Hardware/Vehicle Overview



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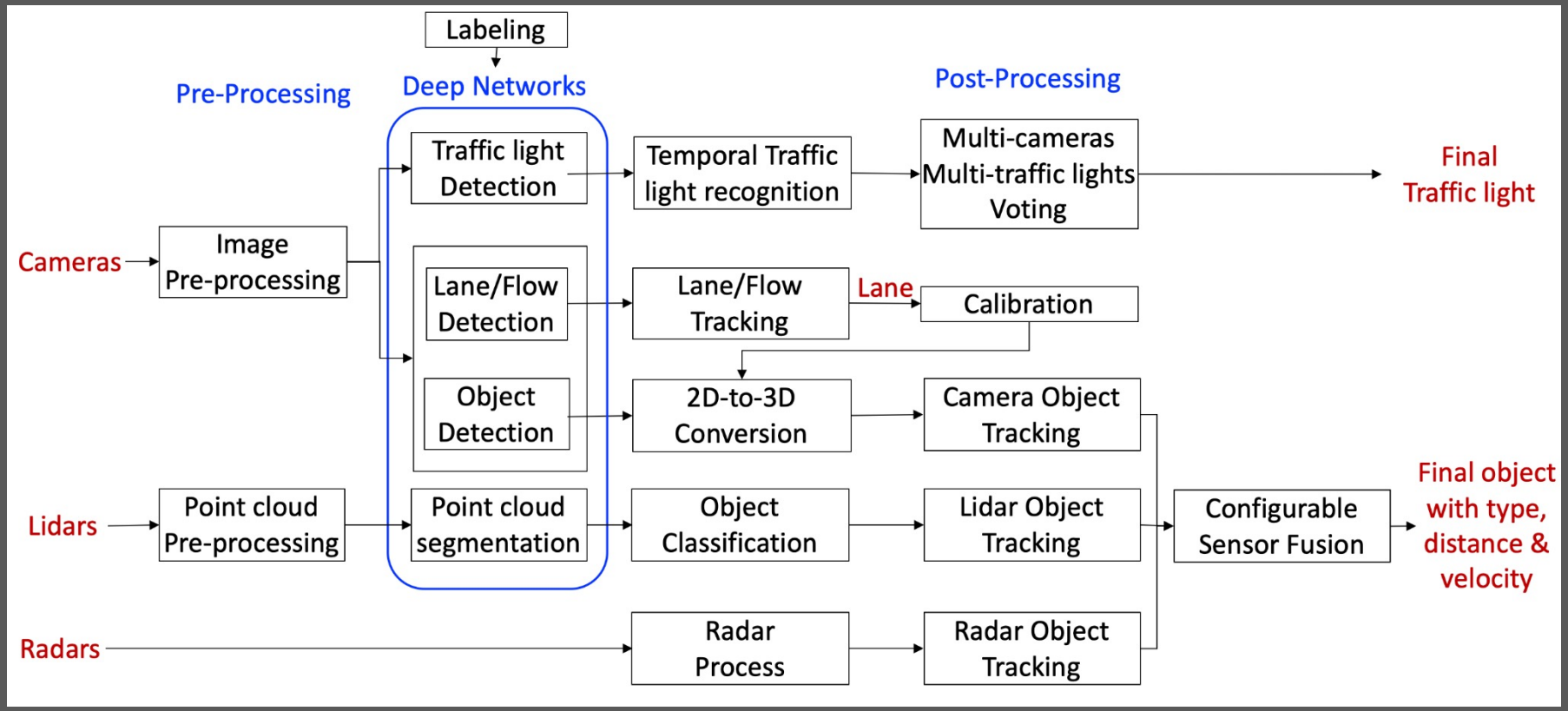
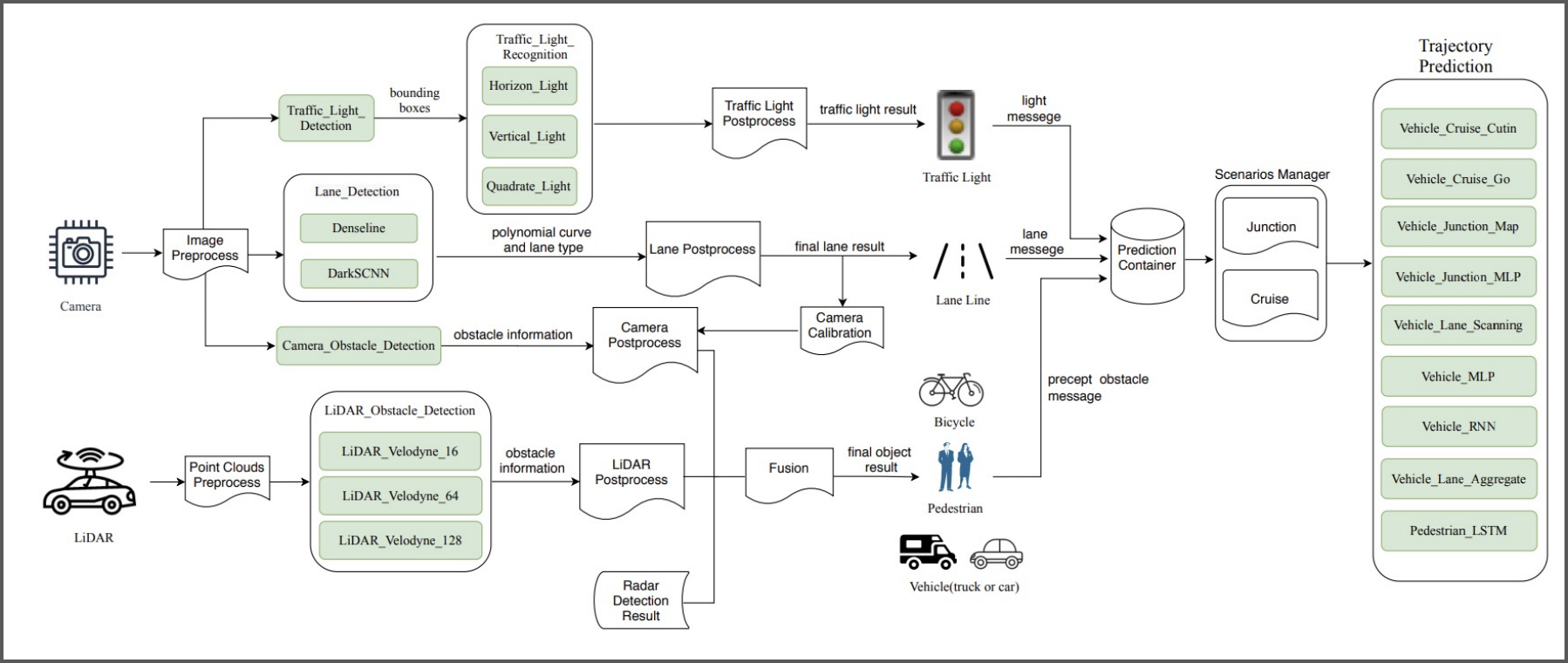
Apollo Perception Module

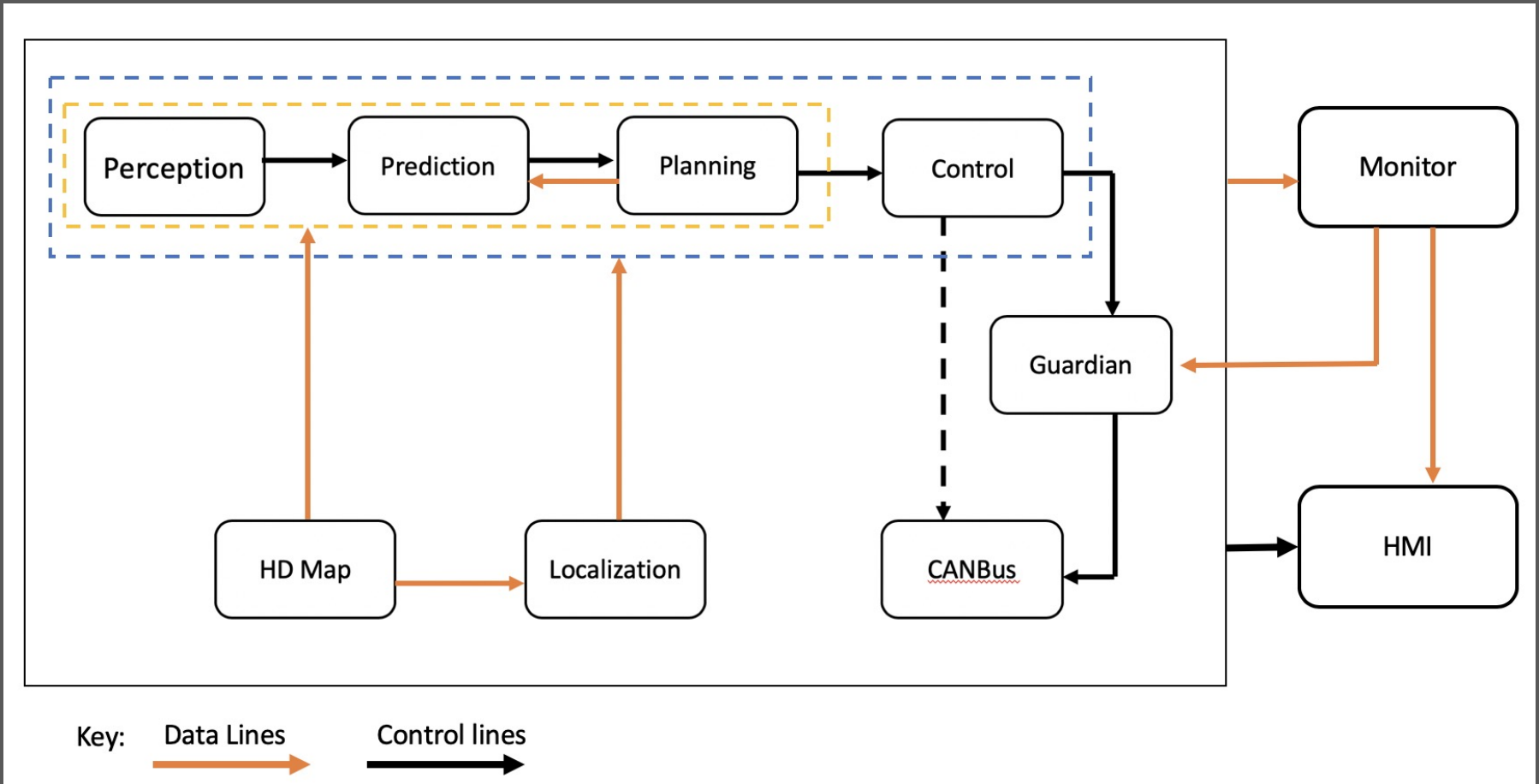


Apollo ML Models



Source: Zi Peng, Jinqiu Yang, Tse-Hsun (Peter) Chen, and Lei Ma. 2020. A First Look at the Integration of Machine Learning Models in Complex Autonomous Driving Systems: A Case Study on Apollo. In Proceedings of the 28th ACM Joint European Software Engineering Conference and Symposium on the Foundations of Software Engineering (ESEC/FSE '20), https://doi.org/10.1145/ 3368089.3417063

Apollo Software Architecture



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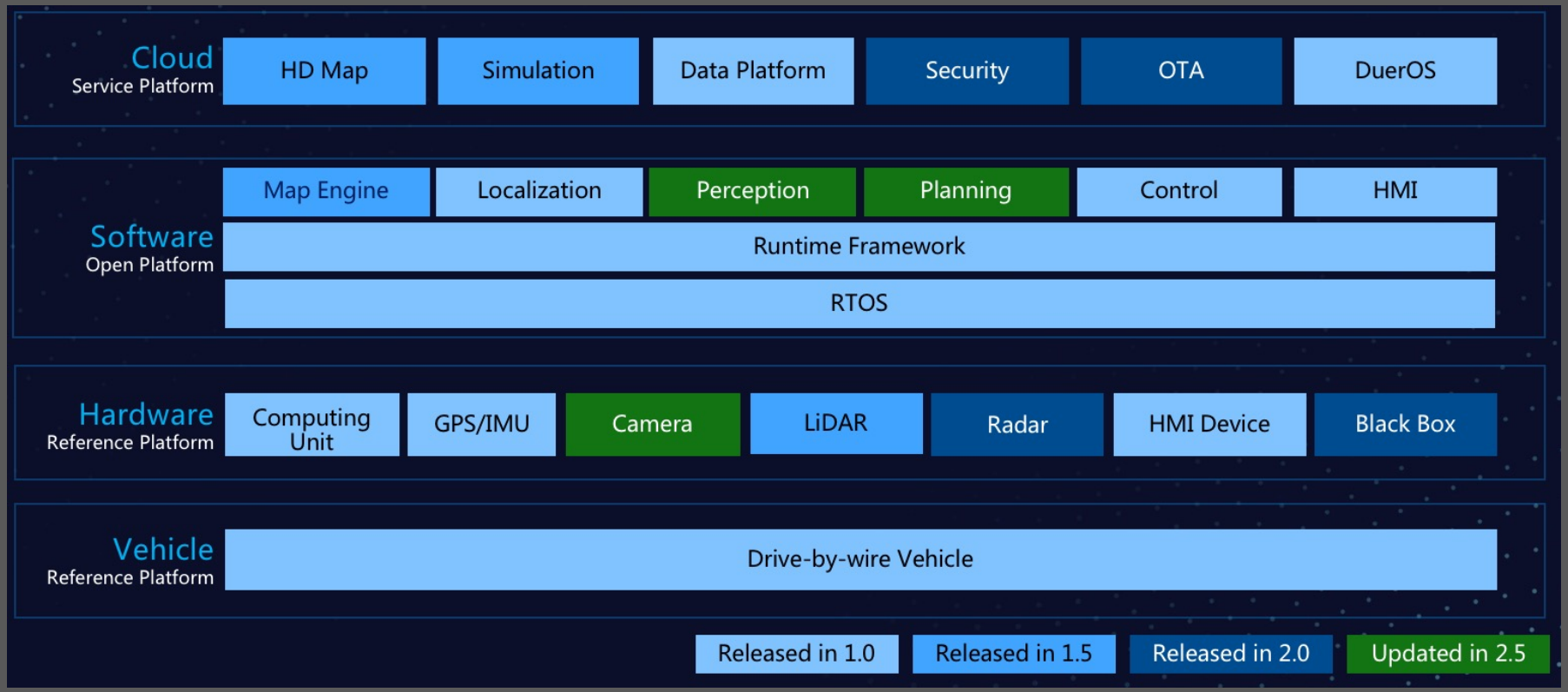
Feature Evolution (Software Stack View)



Source: https://github.com/ApolloAuto/apollo

CONSIDER: UPDATE TO LIDAR MODULE

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.

[Bass et al. 2003]

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

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

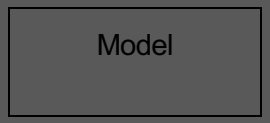
low-level “how”

Design vs. Architecture

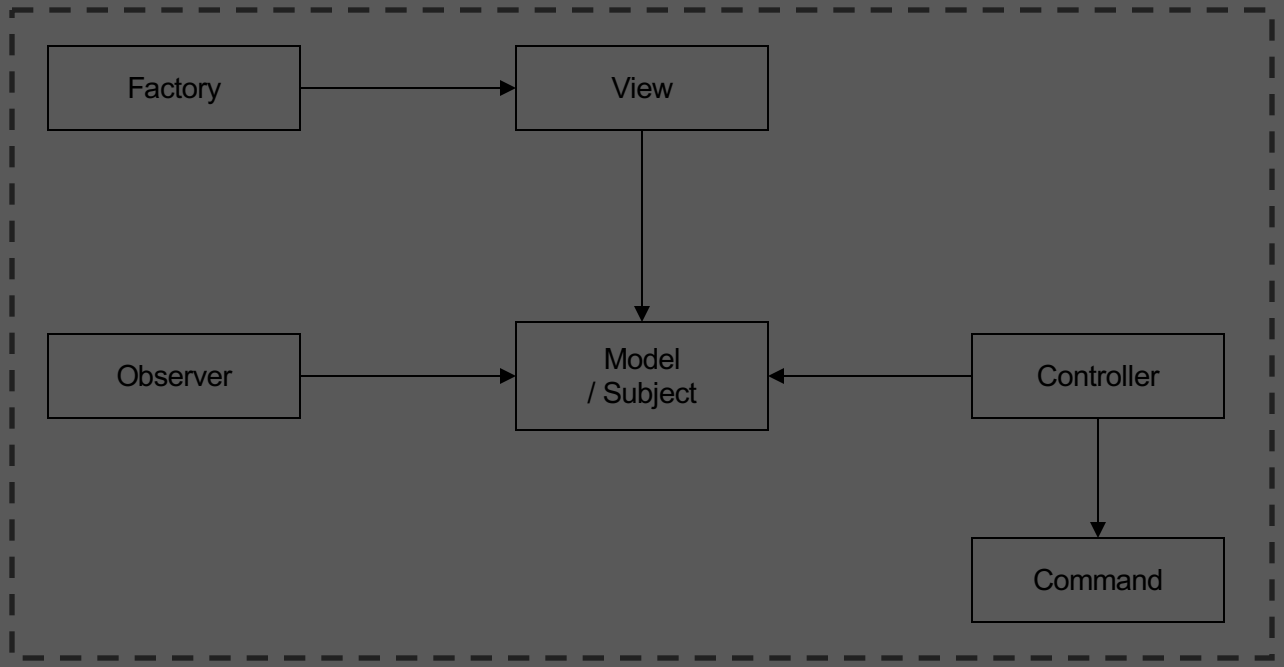
Design Questions

- 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?

Objects



Design Patterns



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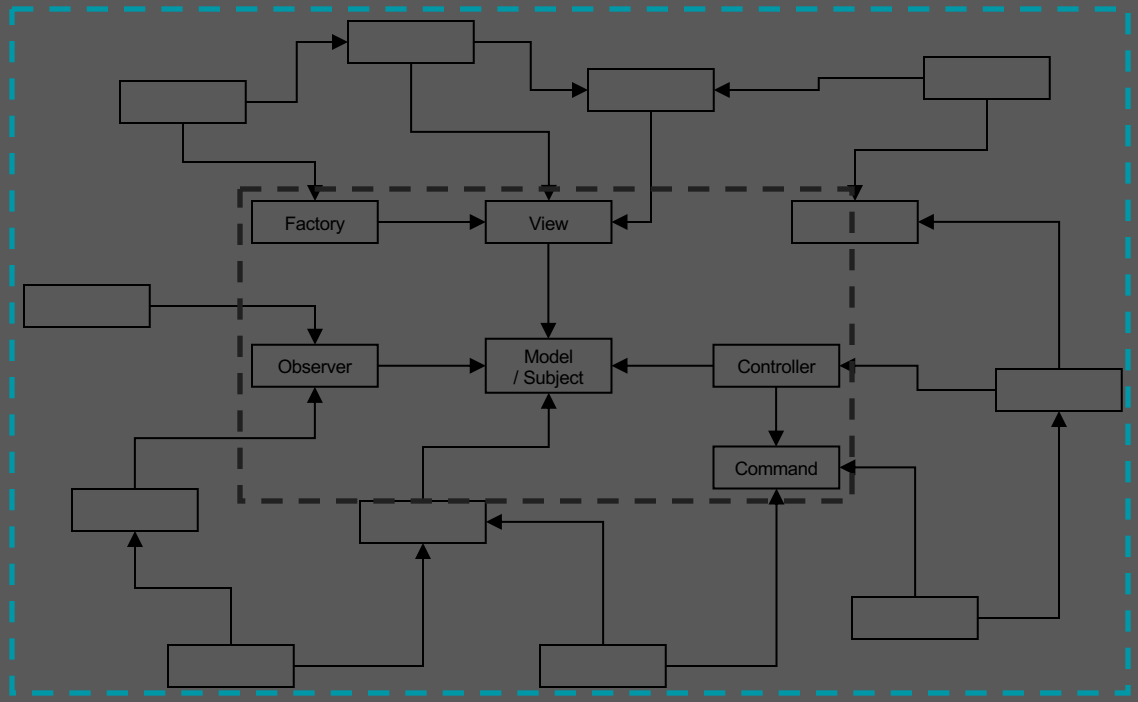
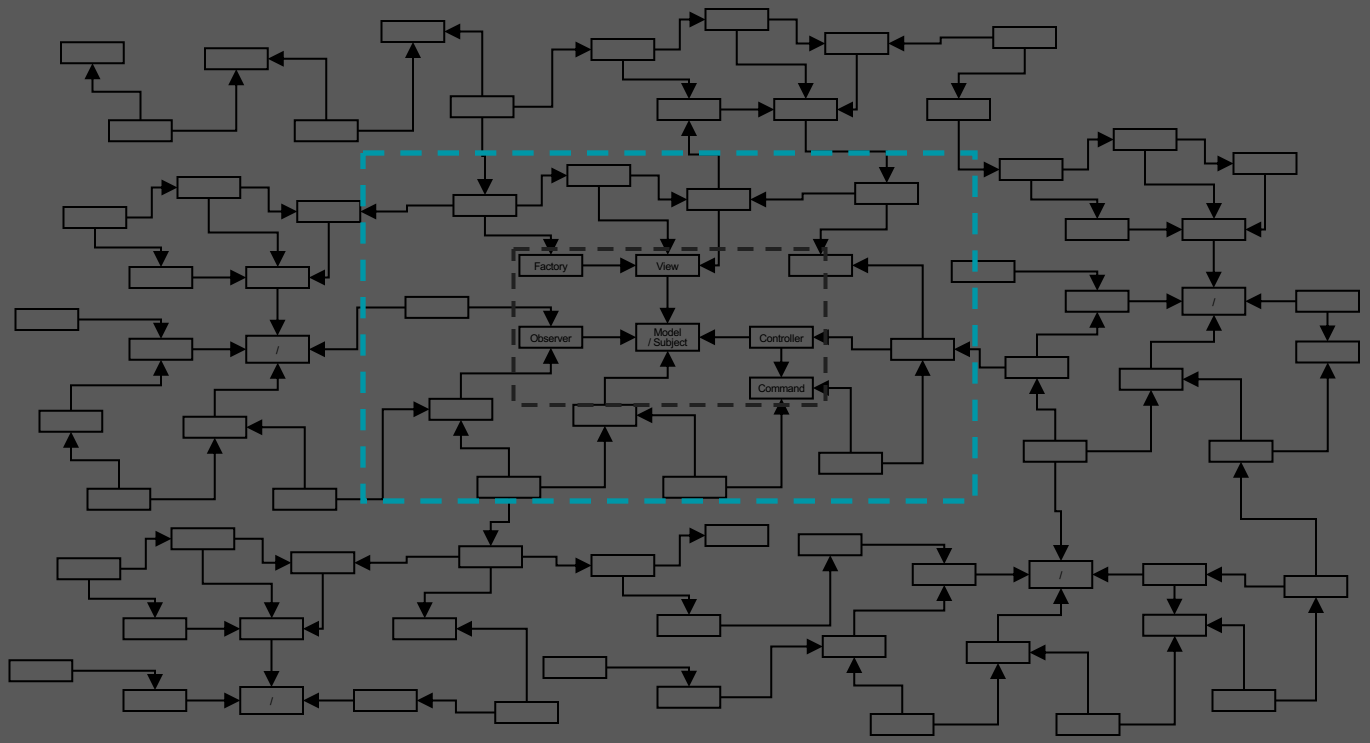
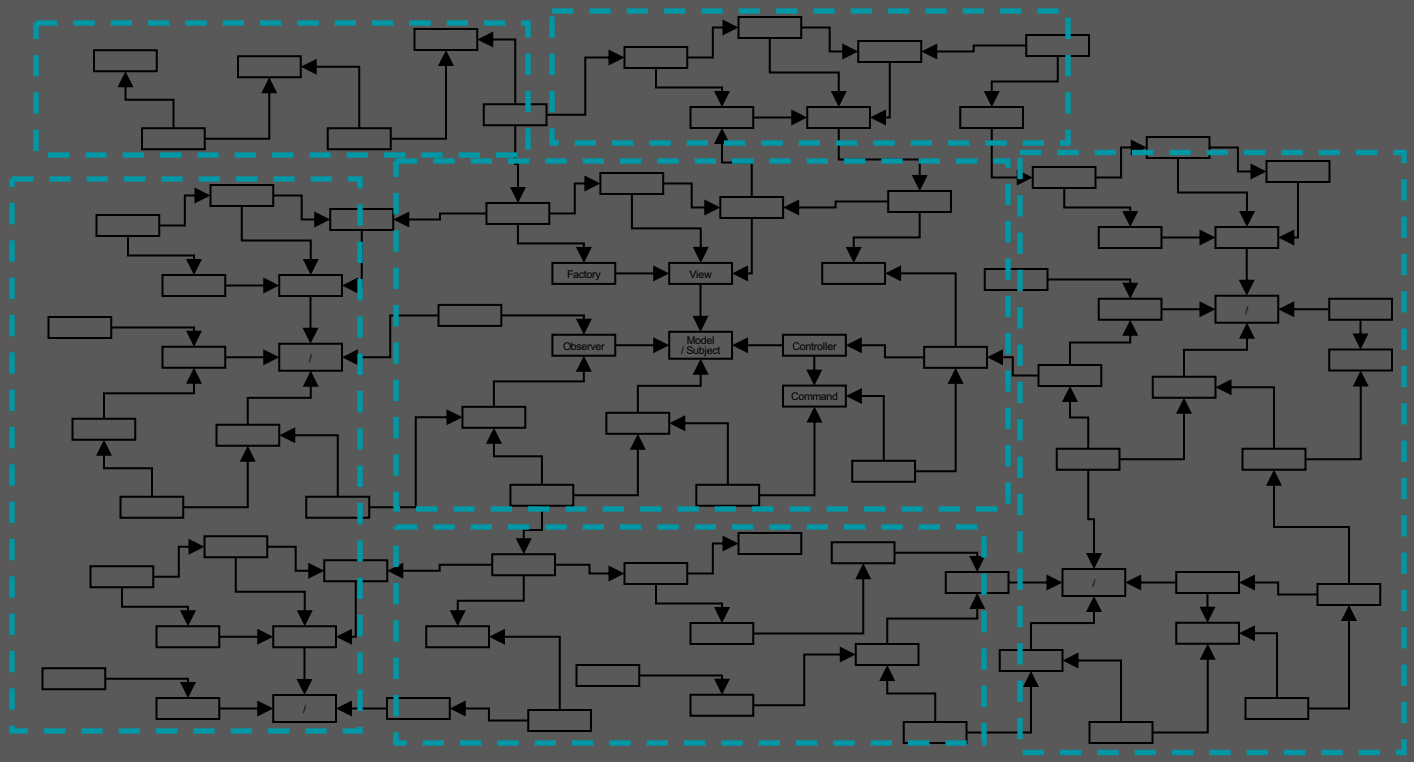


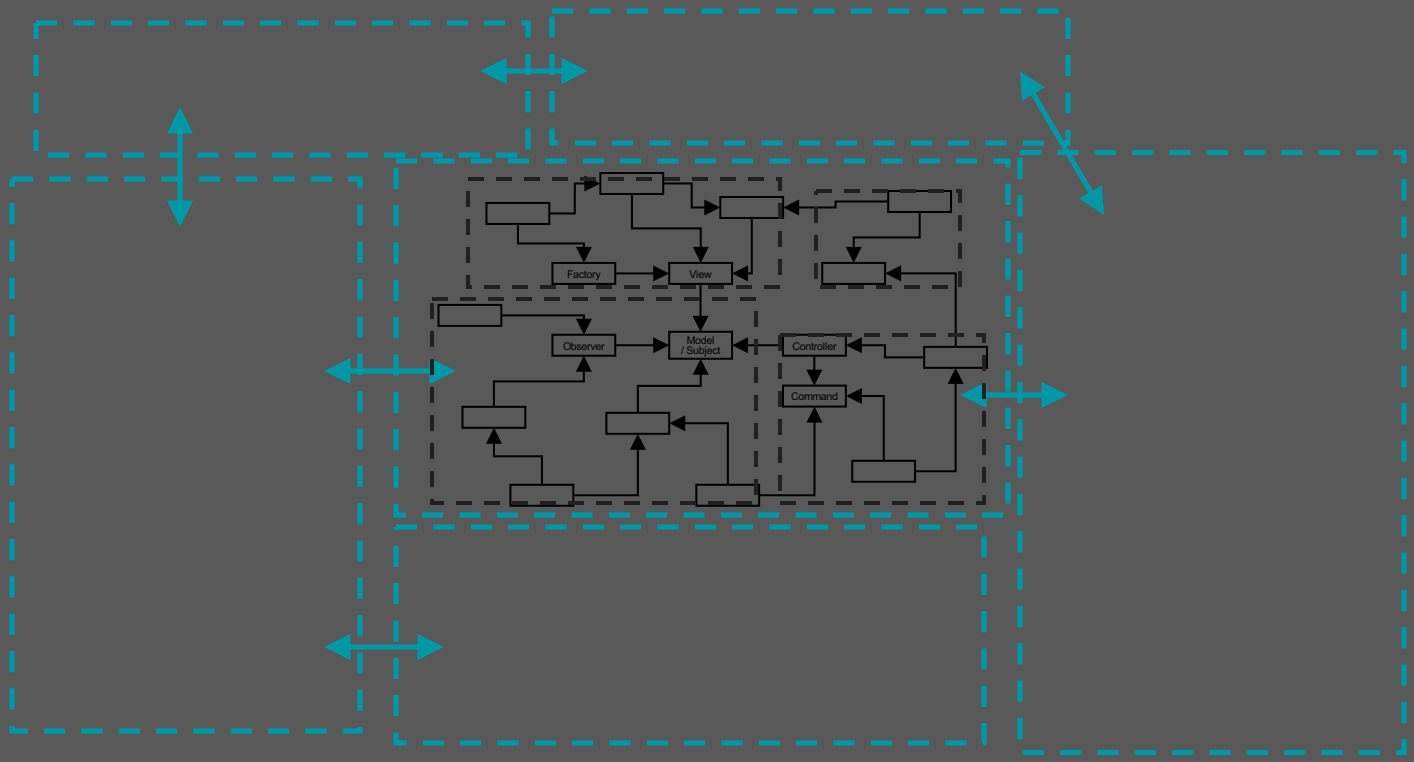
Design Patterns



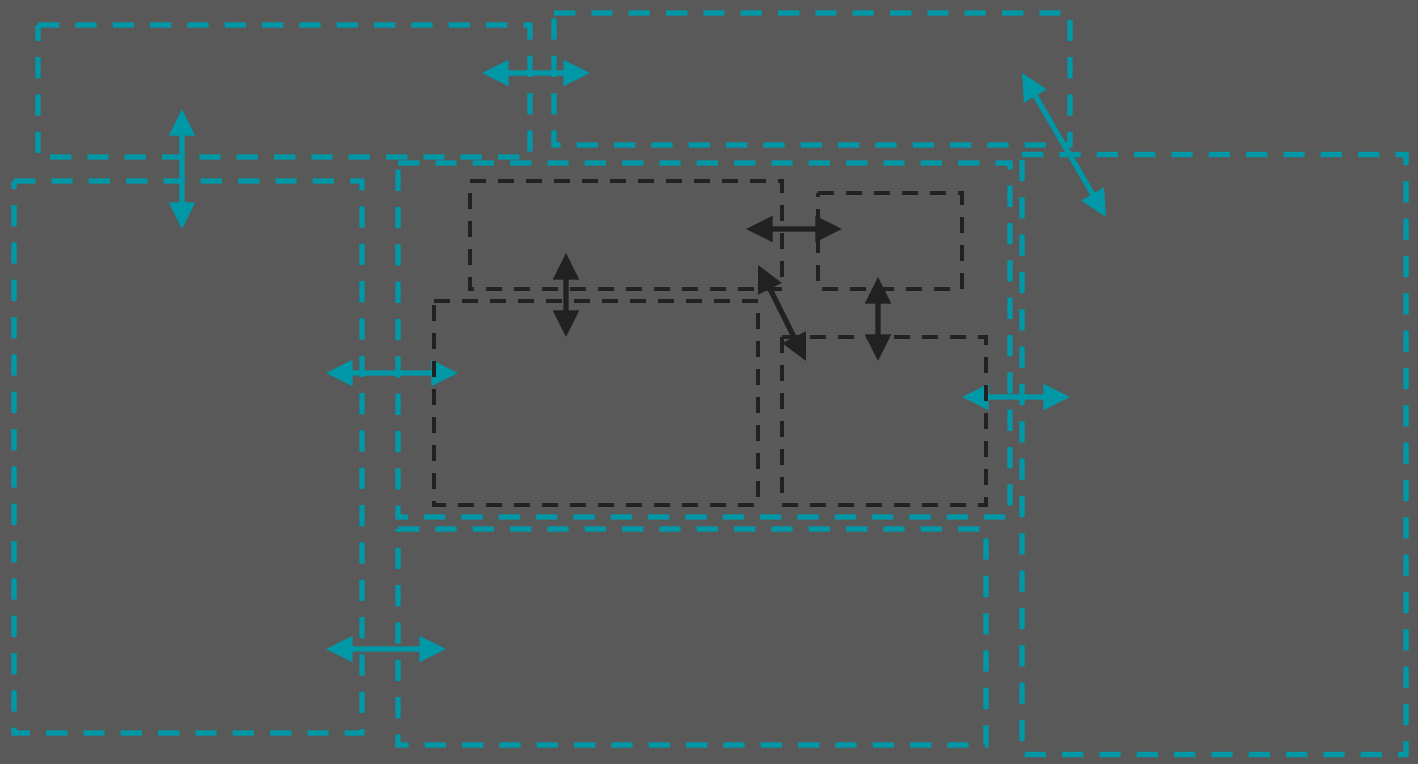
Architecture



Architecture



Architecture

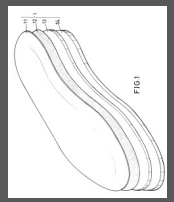


Architecture Documentation & Views

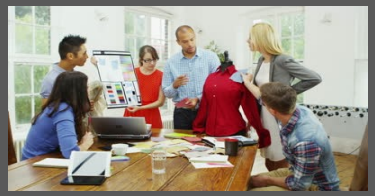
Architecture Disentangled

Architecture as structures and relations
(the ac

Architecture as documentation
(representations of the system)

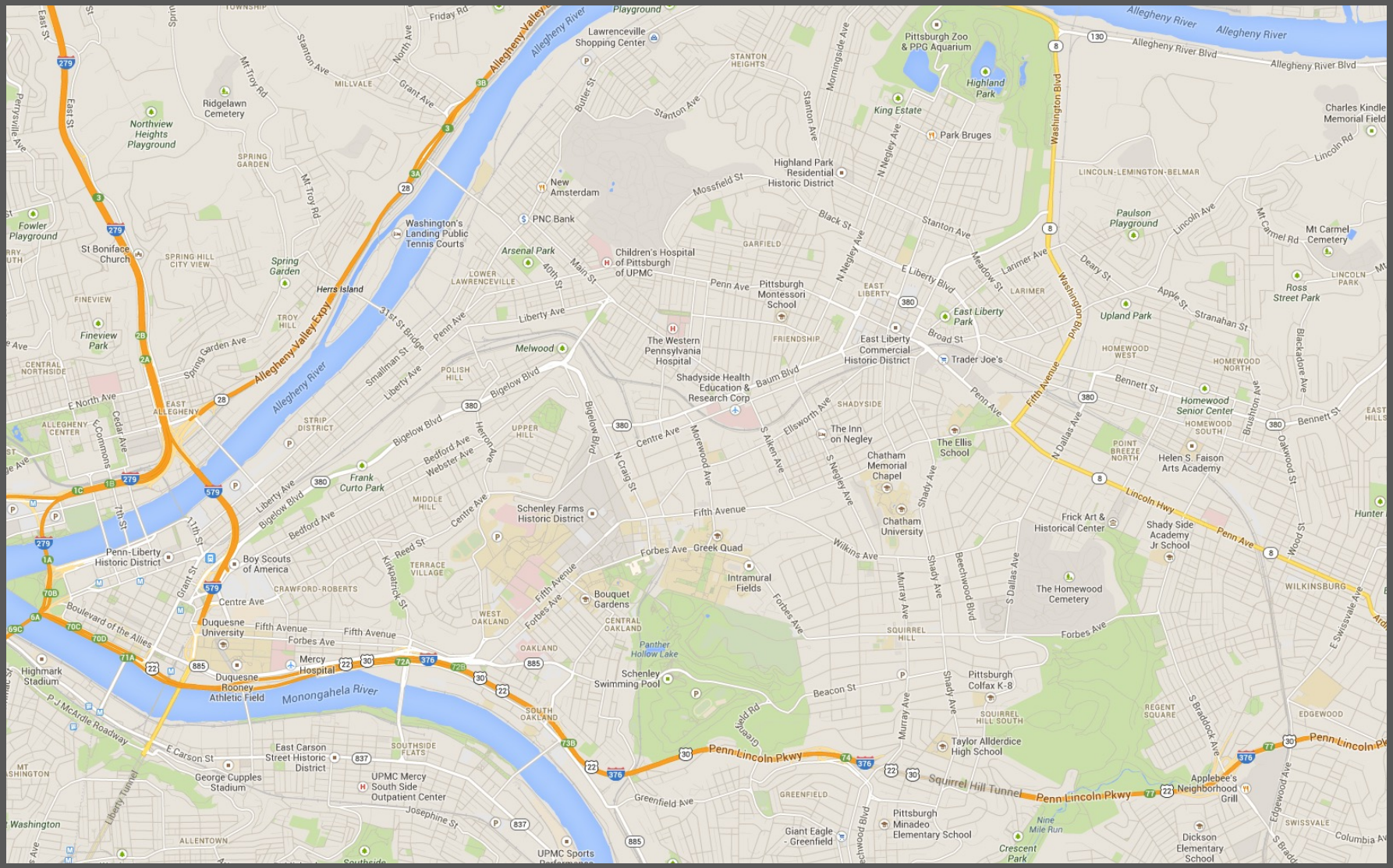


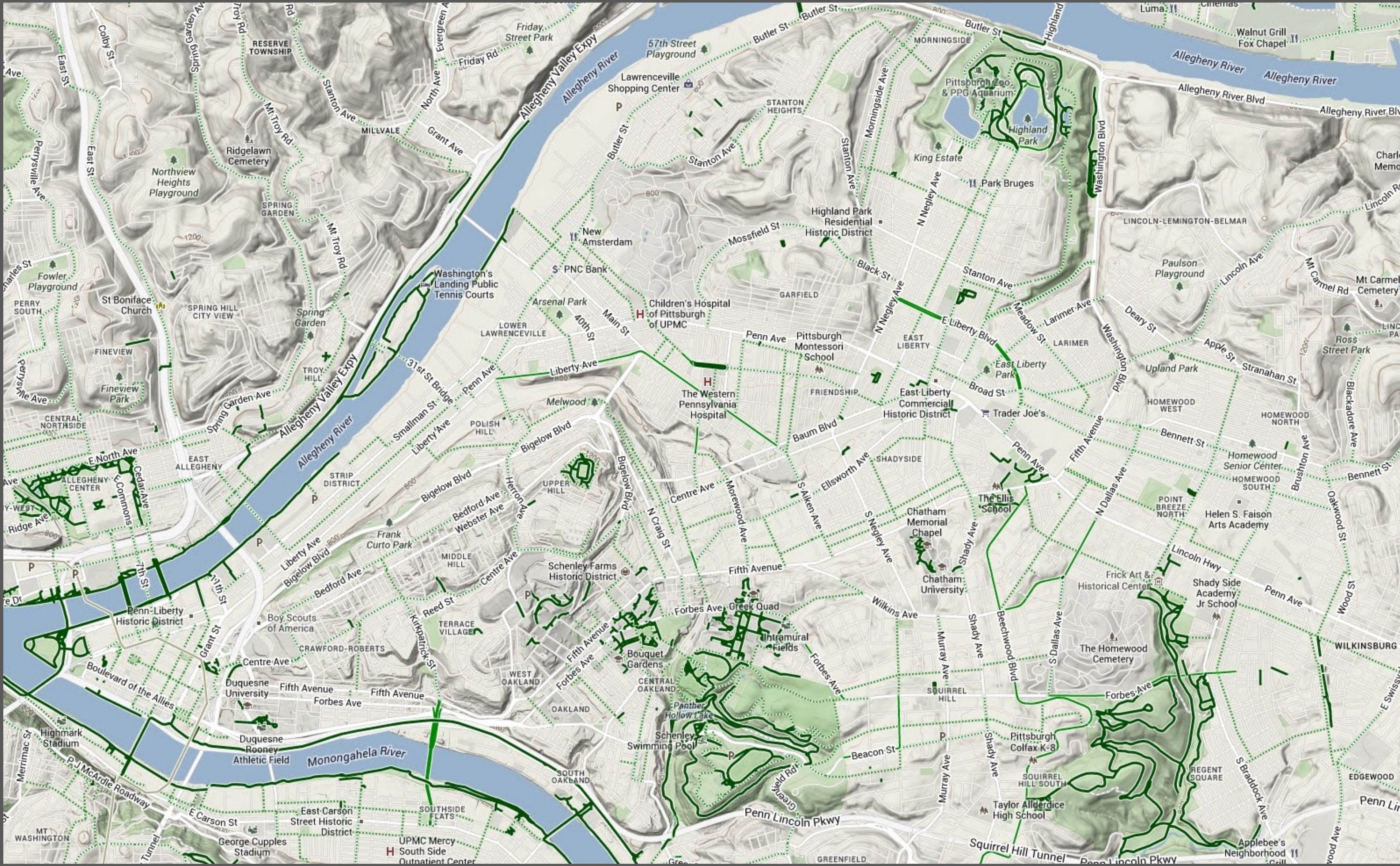
Architecture as (design) process
(activities around the other two)



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.


Allegheny River
Allegheny River Blvd
Pittsburgh Zoo & PPG Aquarium
Highland Park
Lawrenceville Shopping Center
Stanton Heights
Ridgelawn Cemetery
Northview Heights Playground
Millvale
Grant Ave
Stanton Ave
Mt Troy Rd
Spring Garden
Herrs Island
Allegheny Valley Expy
Washington's Landing Public Tennis Courts
New Amsterdam
PNC Bank
Arsenal Park
Children's Hospital of Pittsburgh of UPMC
Highland Park Residential Historic District
King Estate
Park Bruges
Mossfield St
Black St
Garfield
Penn Ave
Pittsburgh Montessori School
East Liberty
East Liberty Park
East Liberty Commercial Historic District
Trader Joe's
Paulson Playground
Lincoln-Lemington-Belmar
Mt Carmel Cemetery
Ross Street Park
Upland Park
Homewood West
Homewood North
Homewood Senior Center
Homewood South
Point Breeze North
Helen S. Faison Arts Academy
Shady Side Academy Jr School
Frick Art & Historical Center
The Ellis School
Chatham Memorial Chapel
Chatham University
The Inn on Negley
Shadyside
Shadyside Health Education & Research Corp
Baum Blvd
Centre Ave
Fifth Avenue
Forbes Ave
Greek Quad
Intramural Fields
Bouquet Gardens
Schenley Farms Historic District
The Homewood Cemetery
Wilkinsburg
Lincoln Hwy
Penn Ave
Washington Blvd
Fifth Avenue
Bigelow Blvd
Liberty Ave
Penn Ave
Melwood
The Western Pennsylvania Hospital
Polish Hill
Upper Hill
Middle Hill
Terrace Village
Crawford-Roberts
Strip District
Central Northside
East Allegheny
Fineview
Fineview Park
St Boniface Church
Spring Hill City View
Troy Hill
Lower Lawrenceville
Penn-Liberty Historic District
Boy Scouts of America
Frank Curto Park
Duquesne University
Mercy Hospital
Duquesne Rooney Athletic Field
Highmark Stadium
Monongahela River
Boulevard of the Allies
P.J. McArdle Roadway
East Carson Street Historic District
George Cupples Stadium
UPMC Mercy South Side Outpatient Center
Southside Flats
Allentown
Josephine St
UPMC Sports
Panther Hollow Lake
Schenley Swimming Pool
Central Oakland
West Oakland
Oakland
South Oakland
Squirrel Hill South
Squirrel Hill
Regent Square
Edgewood
Swissvale
Taylor Allderdice High School
Pittsburgh Colfax K-8
Pittsburgh Minadeo Elementary School
Dickson Elementary School
Applebee's Neighborhood Grill
Giant Eagle - Greenfield
Greenfield
Nine Mile Run
Crescent Park
Penn-Lincoln Pkwy
Squirrel Hill Tunnel
Beacon St
Greenfield Ave
Forbes Ave
Wilkins Ave
Bigelow Blvd
Liberty Tunnel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Stanton Ave
Lawrenceville Shopping Center
57th Street Playground
Friday Street Park
Millvale
Reserve Township
Ridgelawn Cemetery
Northview Heights Playground
Spring Garden
Fowler Playground
St Boniface Church
Spring Hill City View
Perry South
Fineview
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Greenfield
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Fire Zones & Firehouses
MAP KEY
Firehouse
Engine
Engine and Truck
Truck
Quint
Fire Zone
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District 2
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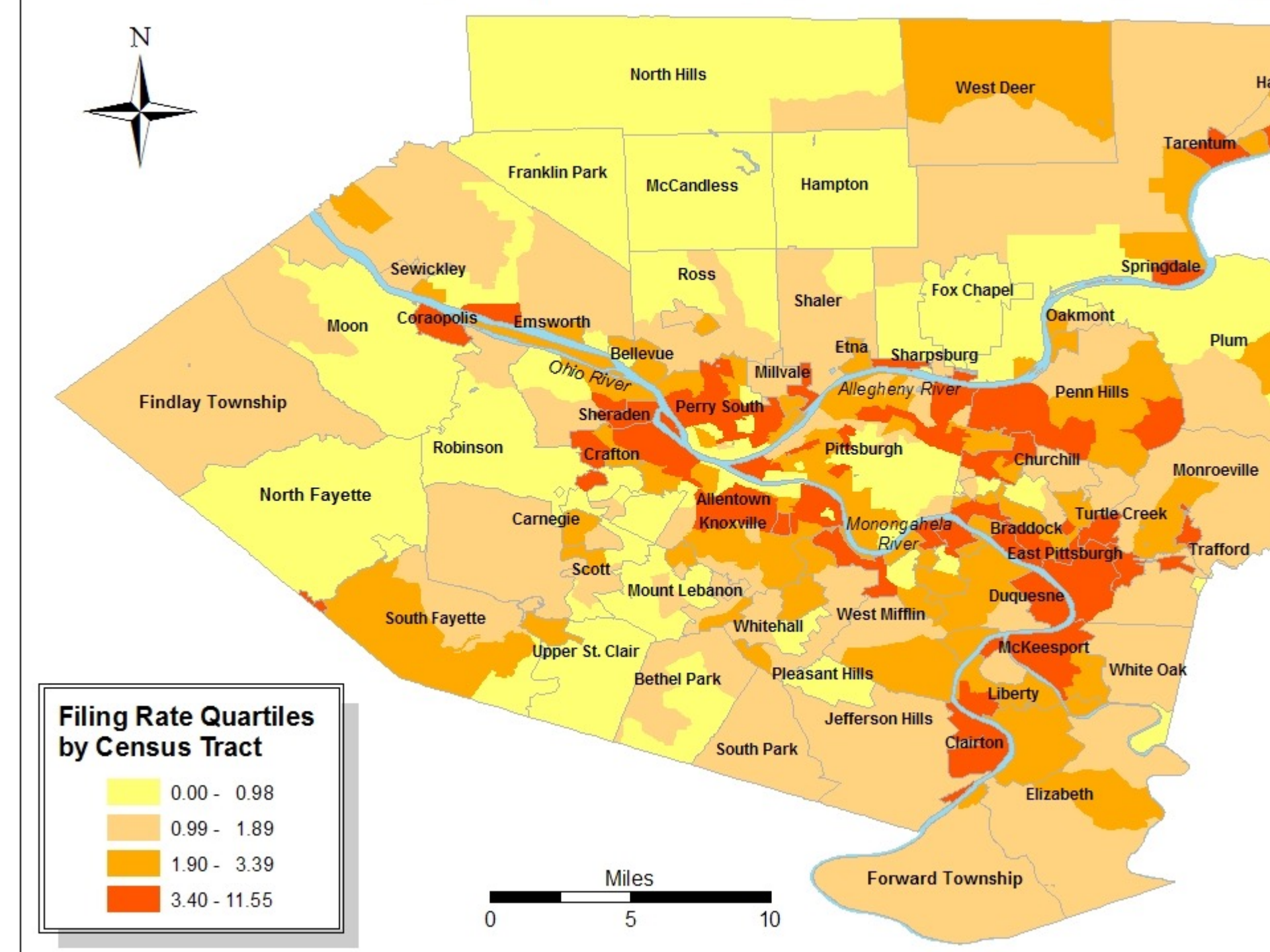
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North Hills
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Fox Chapel
Shaler
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Coraopolis
Emsworth
Plum
Bellevue
Etna
Sharpsburg
Millvale
Ohio River
Allegheny River
Findlay Township
Sheraden
Perry South
Penn Hills
Robinson
Crafton
Pittsburgh
Churchill
Monroeville
North Fayette
Allentown
Knoxville
Turtle Creek
Carnegie
Monongahela River
Braddock
East Pittsburgh
Trafford
Scott
Mount Lebanon
Duquesne
South Fayette
Whitehall
West Mifflin
McKeesport
Upper St. Clair
White Oak
Bethel Park
Pleasant Hills
Liberty
Jefferson Hills
Clairton
South Park
Elizabeth
Forward Township
Filing Rate Quartiles by Census Tract
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0.99 - 1.89
1.90 - 3.39
3.40 - 11.55
Miles
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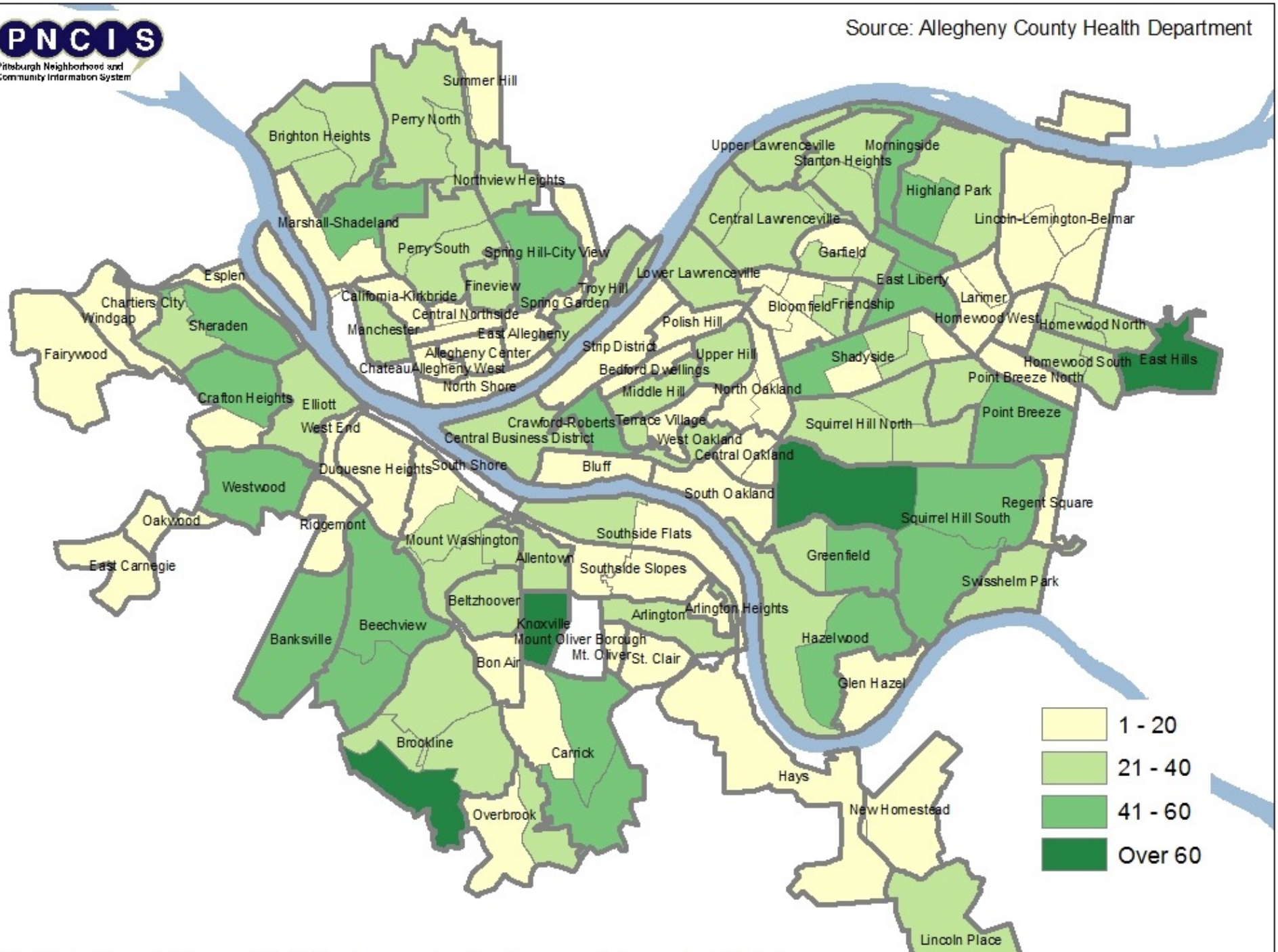
5
10


PNCIS
Pittsburgh Neighborhood and Community Information System
Source: Allegheny County Health Department
Summer Hill
Perry North
Brighton Heights
Northview Heights
Marshall-Shadeland
Perry South
Spring Hill-City View
Esplen
Chartiers City
Windgap
Sheraden
Fairywood
California-Kirkbride
Fineview
Troy Hill
Spring Garden
Central Northside
Manchester
East Allegheny
Allegheny Center
Chateau
Allegheny West
North Shore
Crafton Heights
Elliott
West End
Duquesne Heights
South Shore
Westwood
Oakwood
Ridgemont
East Carnegie
Mount Washington
Allentown
Beltzhoover
Knoxville
Mount Oliver Borough
Mt. Oliver
Bon Air
Banksville
Beechview
Brookline
Carrick
Overbrook
Upper Lawrenceville
Morningside
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Homewood South
East Hills
Point Breeze North
Bedford Dwellings
Middle Hill
North Oakland
Point Breeze
Crawford-Roberts
Terrace Village
Squirrel Hill North
Central Business District
West Oakland
Central Oakland
Bluff
South Oakland
Regent Square
Squirrel Hill South
Southside Flats
Greenfield
Southside Slopes
Swisshelm Park
Arlington
Arlington Heights
Hazelwood
St. Clair
Glen Hazel
Hays
New Homestead
Lincoln Place
1 - 20
21 - 40
41 - 60
Over 60


Pittsburgh Zoo
Highland Park
Allegheny River
Allegheny Cemetery
Butler St
Stanton Ave
Chislett St
N Negley Ave
N Euclid Ave
Lake Dr
Washington Blvd
Larimer Ave
Lincoln Ave
Brushton Ave
Penn Ave
Liberty Ave
31st St
Smallman St
Spring Garden Ave
Pittview Ave
E Ohio St
East St
Troy Rd
N Charles St
Brighton Rd
River Ave
Spring Way
Bigelow Blvd
Webster Ave
Centre Ave
Baum Blvd
E Busway
Ellsworth Ave
Hamilton Ave
Bennett St
Mellon Park
West Park
Heinz Field
Clemente Park
Point State Park
Liberty Ave
Carson St
Pittsburgh
Duquesne University
Forbes Ave
2nd Ave
University of Pittsburgh
Carnegie Mellon University
Wilkins Ave
Homewood Cemetery
Wilkinsburg
Penn Ave
Forbes Ave
Schenley Park
Frick Park
S Braddock Ave
Ninemile Run
Josephine St
E Carson St
Southside Park
Arlington Ave
Liberty Tunnels
Saw Mill Run Blvd
Pat Busway
Becks Run Rd
Murray Ave
Hazelwood Ave
Calvary Cemetery
E Waterfront Dr
The Waterfront
E 8th Ave
Ann St
Johnston Ave
Munhall
Moore Park
Edgebrook Ave
Brookline Blvd
E Agnew St
Glass Run
Greensprin
279
28
579
376
22
885
51
837

Common Views in Documenting Software Architecture

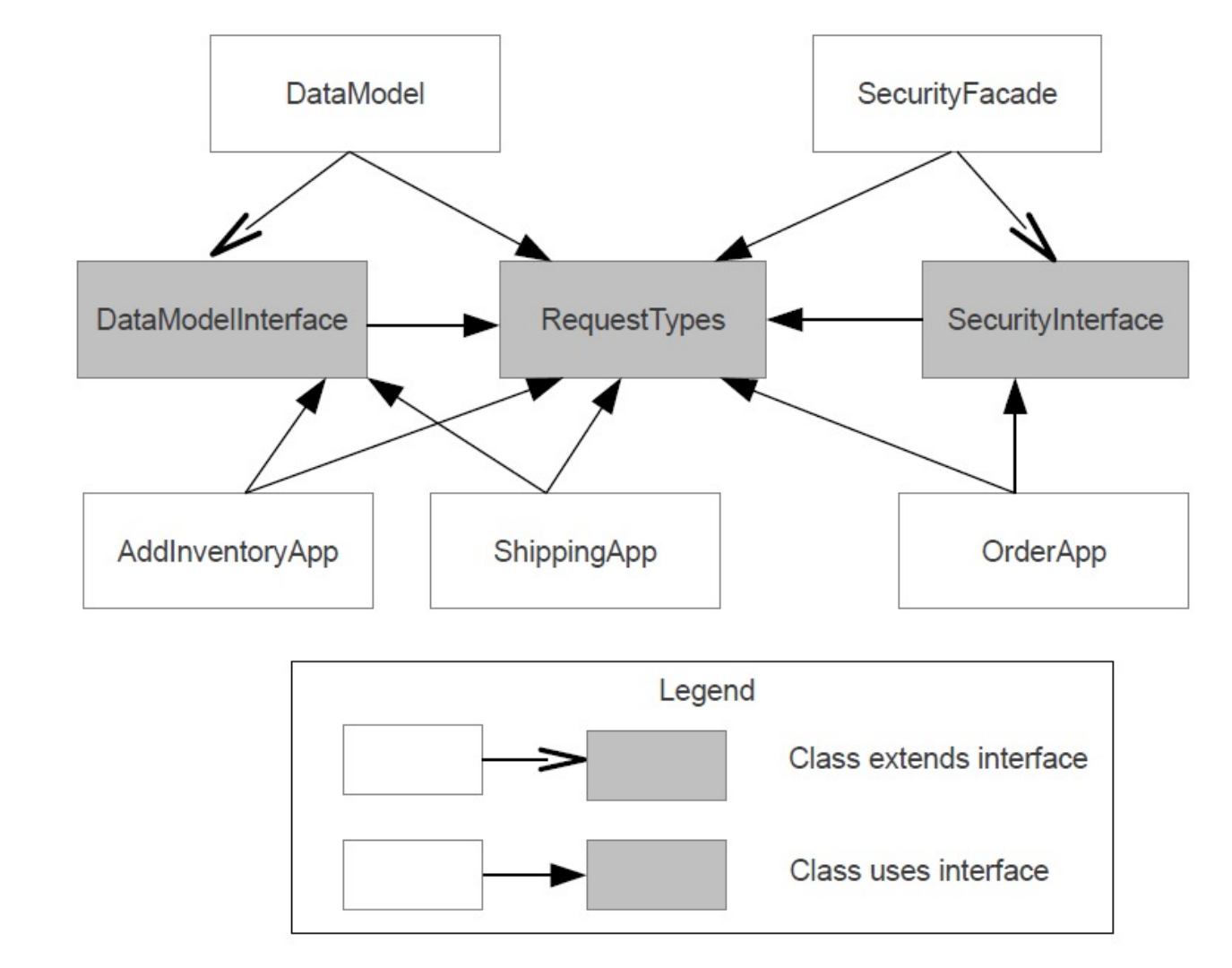
- Static View
  - Modules (subsystems, structures) and their relations (dependencies, …)
- Dynamic View
  - Components (processes, runnable entities) and connectors (messages, data flow, …)
- Physical View (Deployment)
  - Hardware structures and their connections

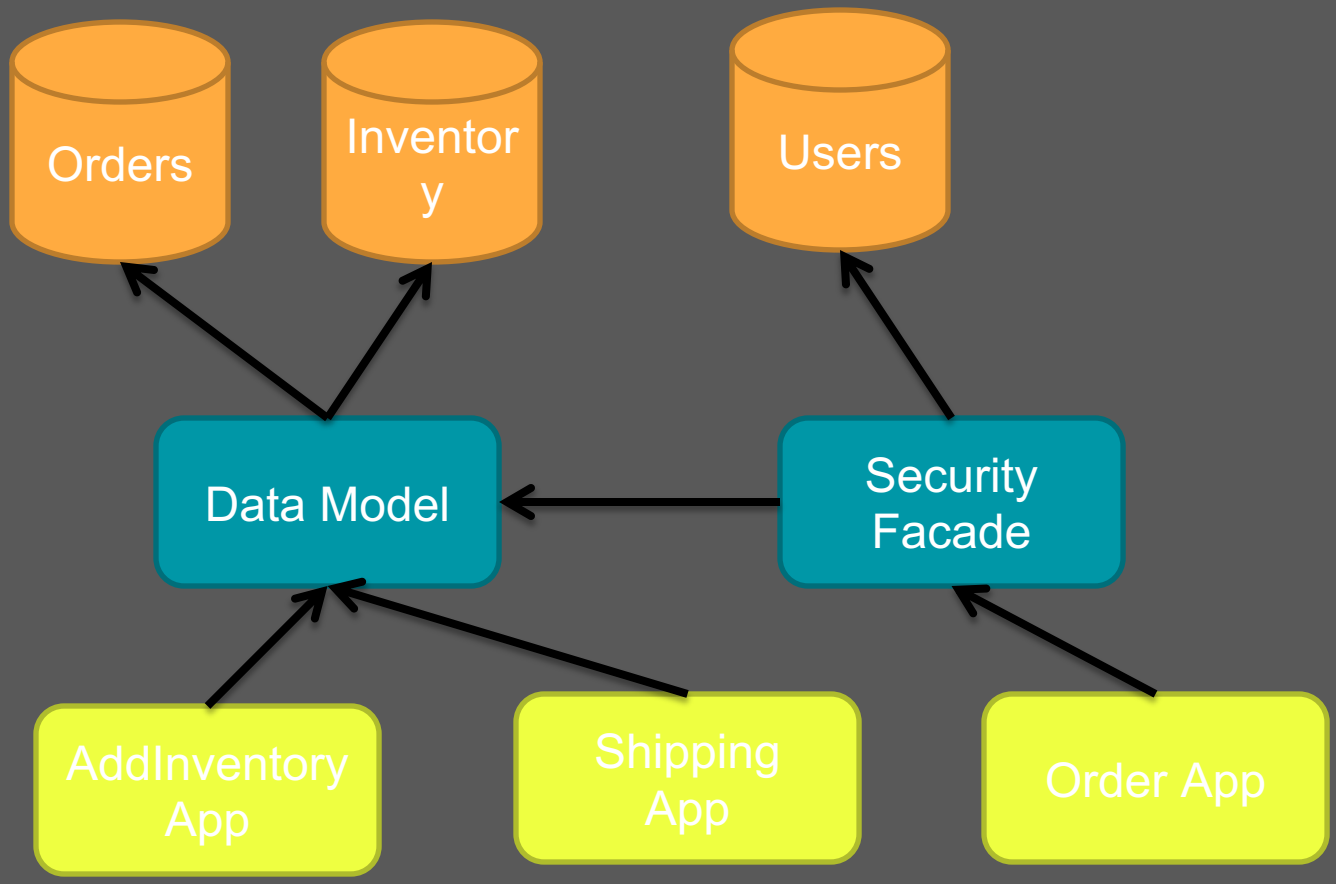
Views and Purposes

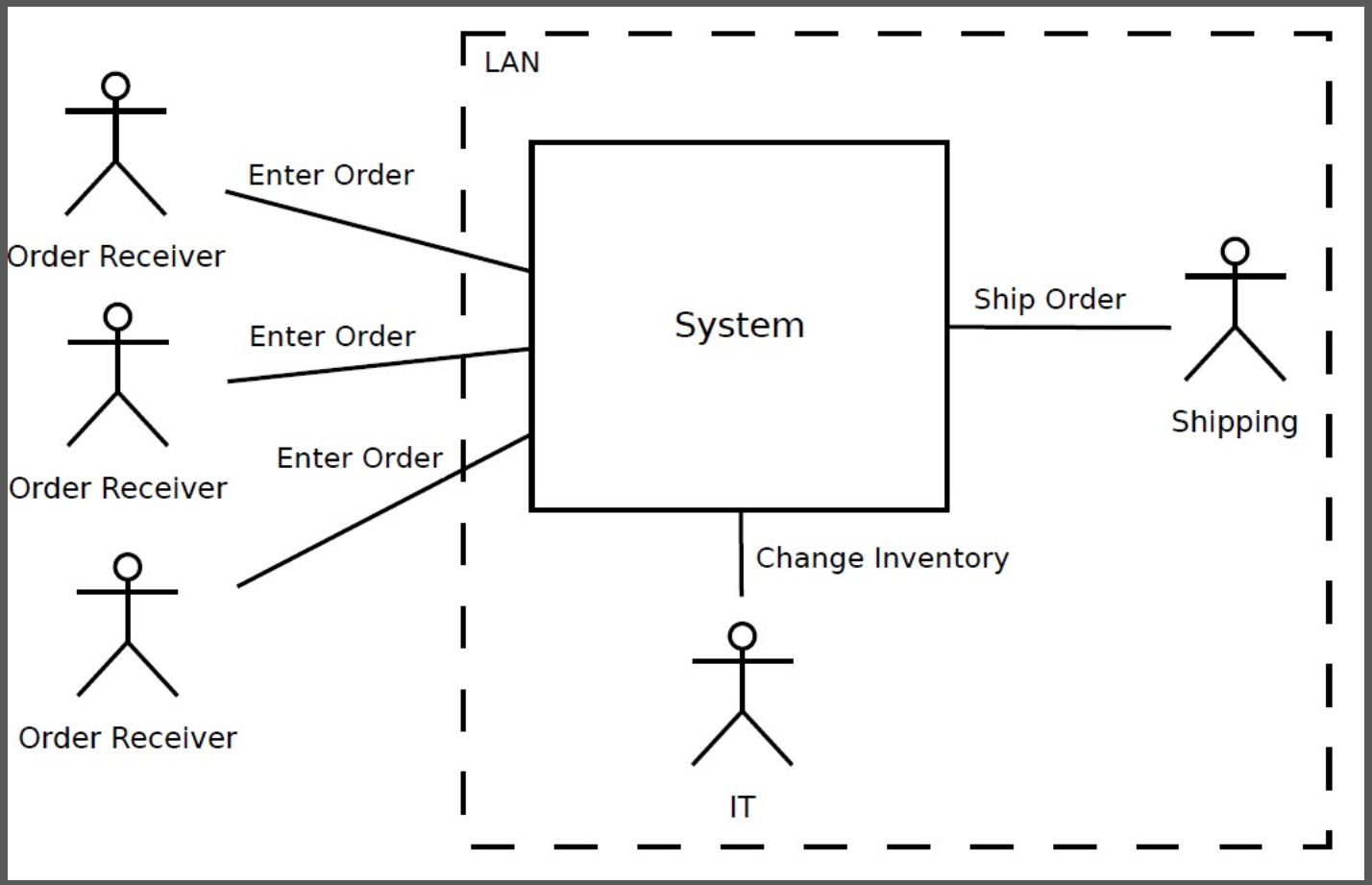
Every view should align with a purpose

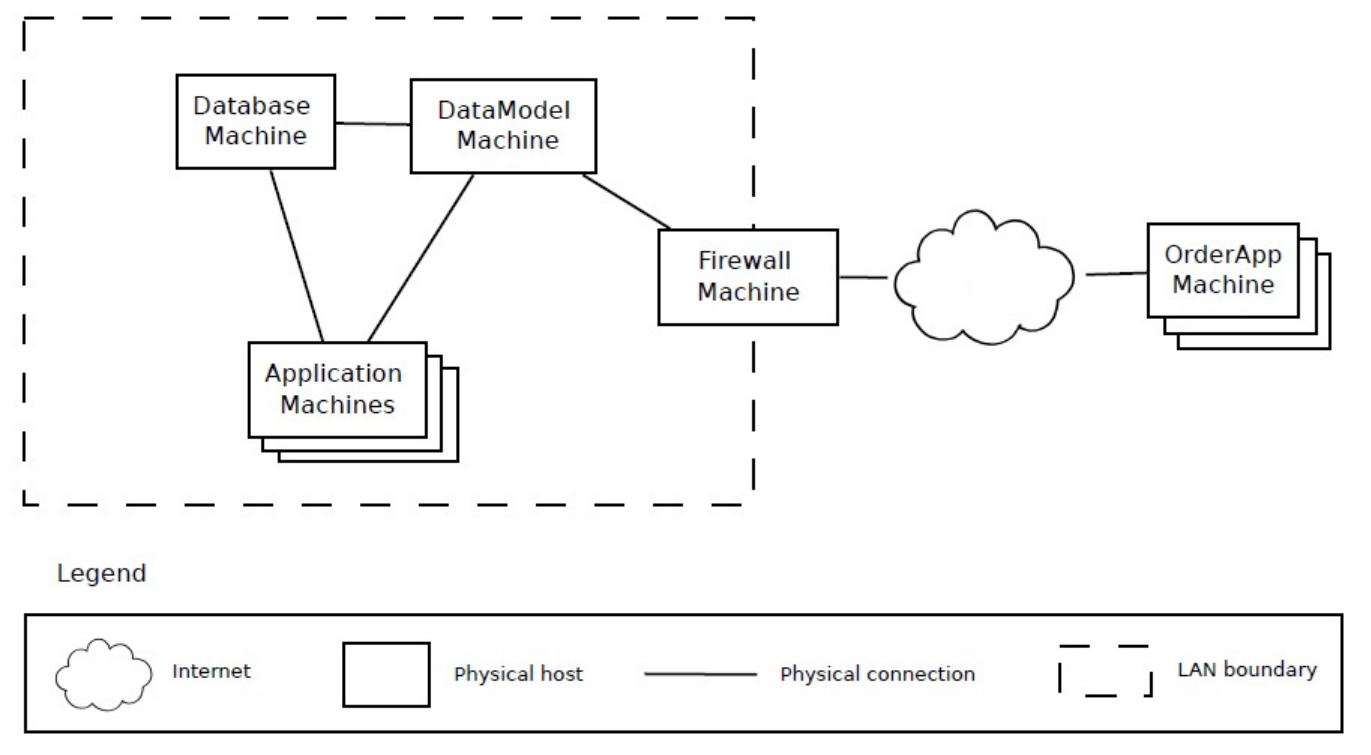
Different views are suitable for different reasoning aspects (different quality goals), e.g.,

- Performance
- Extensibility
- Security
- Scalability
- …


DataModel
SecurityFacade
DataModelInterface
RequestTypes
SecurityInterface
AddInventoryApp
ShippingApp
OrderApp
Legend
Class extends interface
Class uses interface


Orders
Inventor
y
Users
Data Model
Security
Facade
AddInventory
App
Shipping
App
Order App


LAN
Enter Order
Order Receiver
Enter Order
Order Receiver
Enter Order
Order Receiver
System
Ship Order
Shipping
Change Inventory
IT


Database Machine
DataModel Machine
Firewall Machine
OrderApp Machine
Application Machines
Legend
Internet
Physical host
Physical connection
LAN boundary

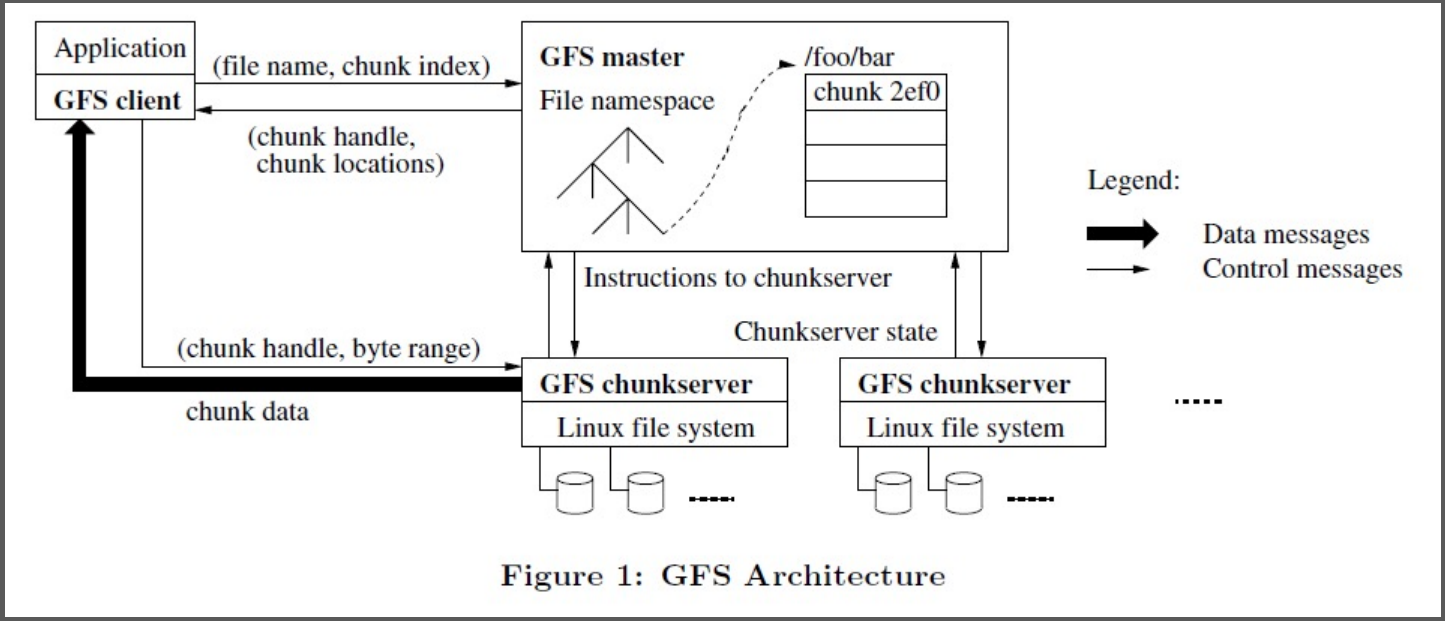


Figure 1: GFS Architecture

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

Examples of Architecture Descriptions

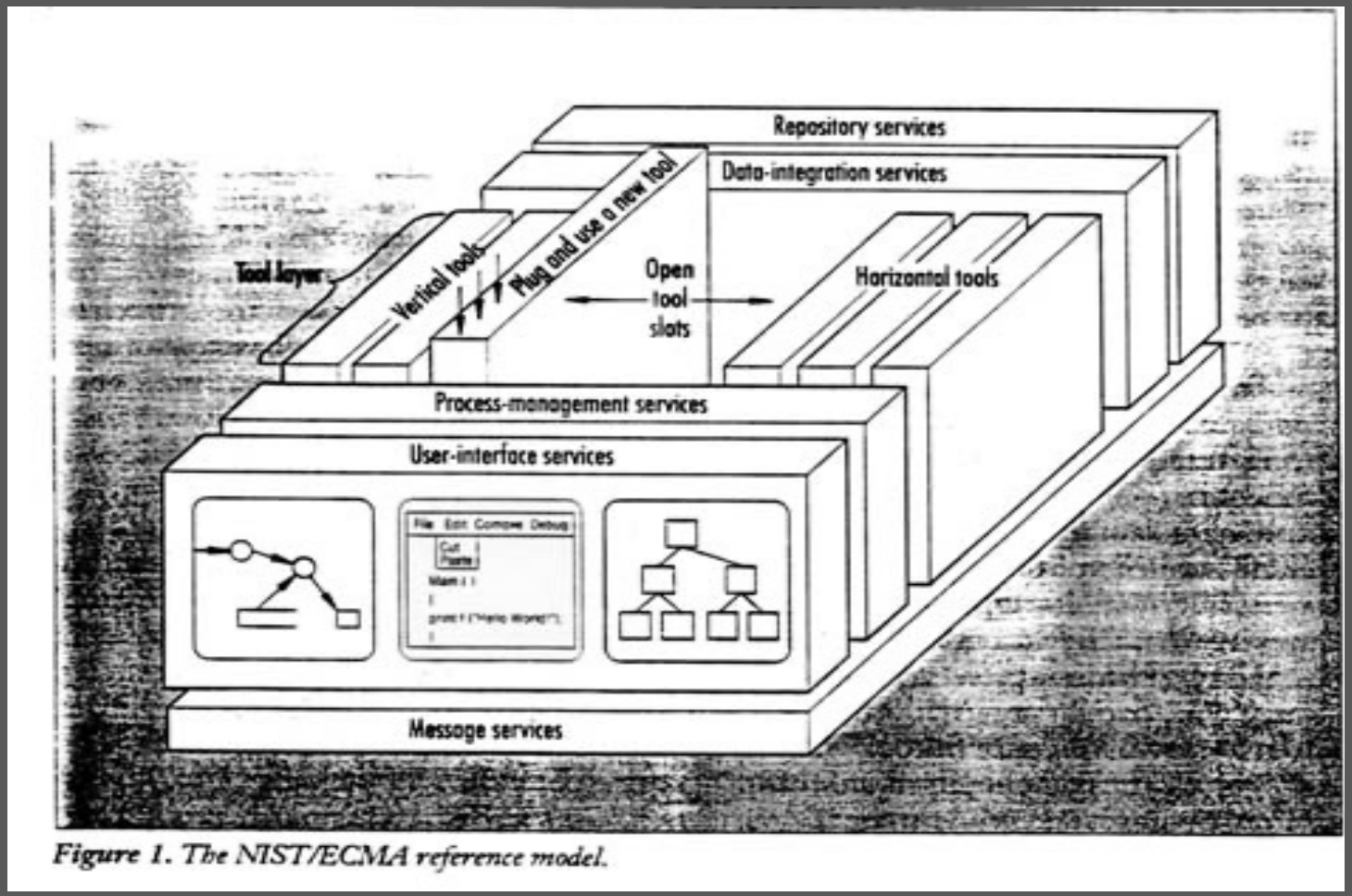


Figure 1. The NIST/ECMA reference model.

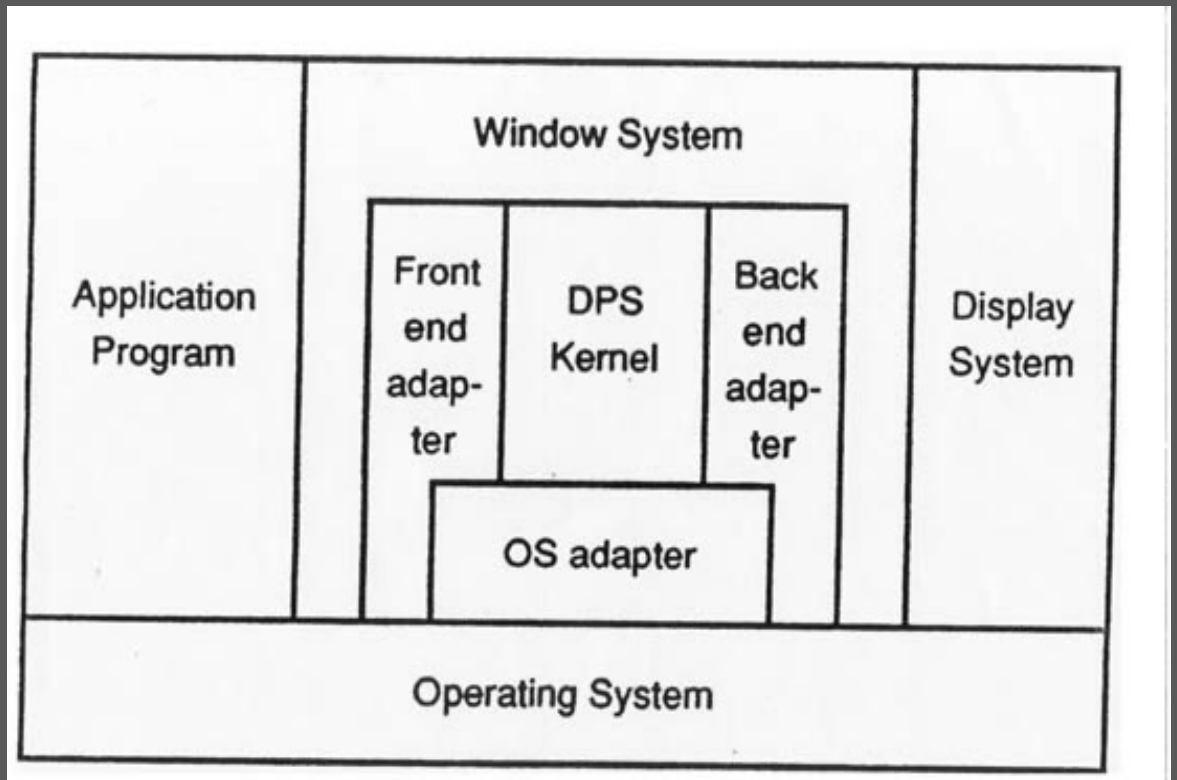


Figure 2. Display PostScript interpreter components.

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

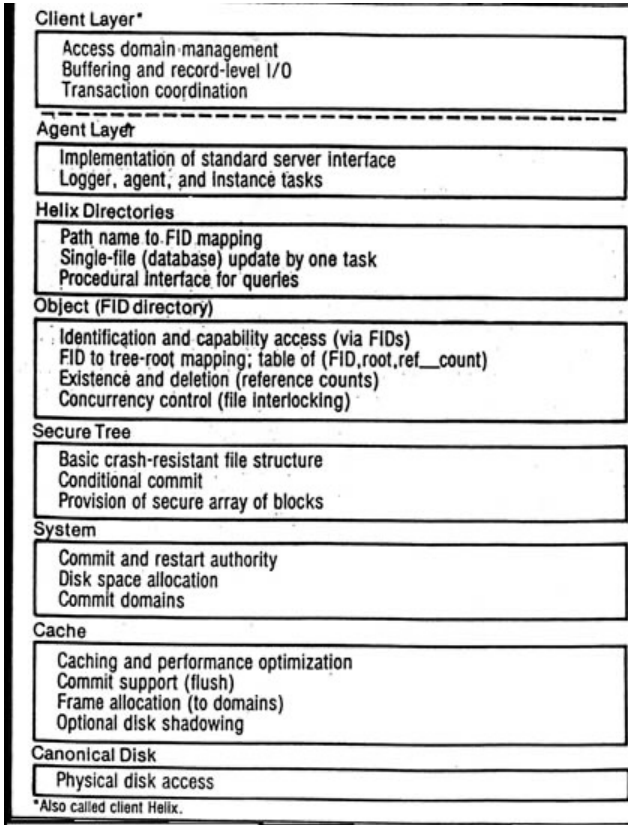


Figure 2. Abstraction layering.

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

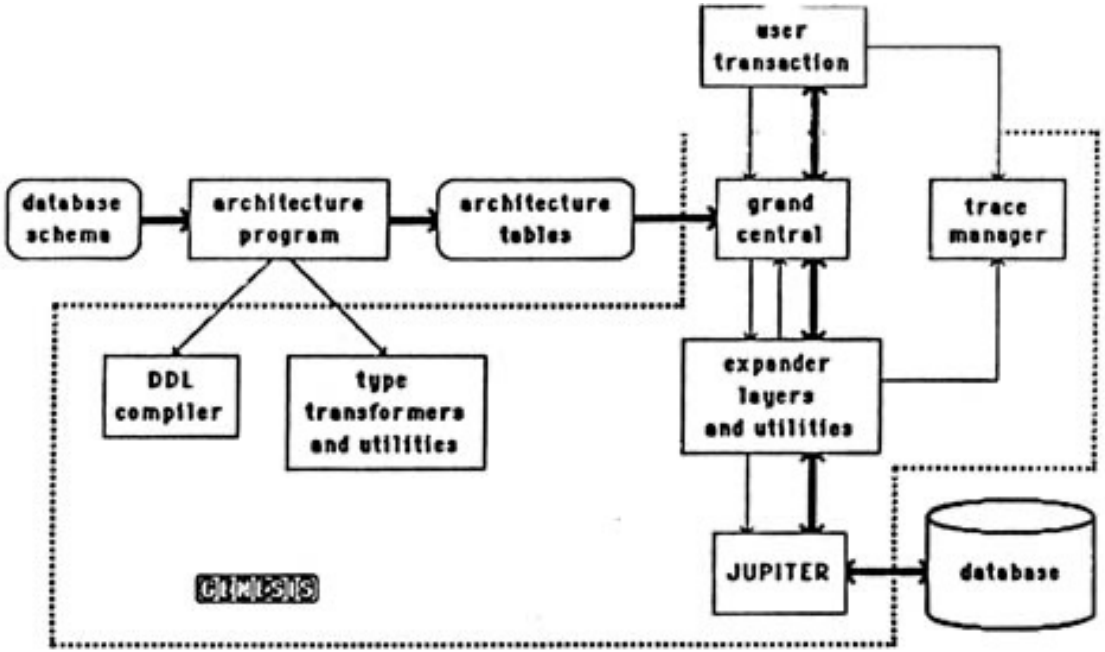
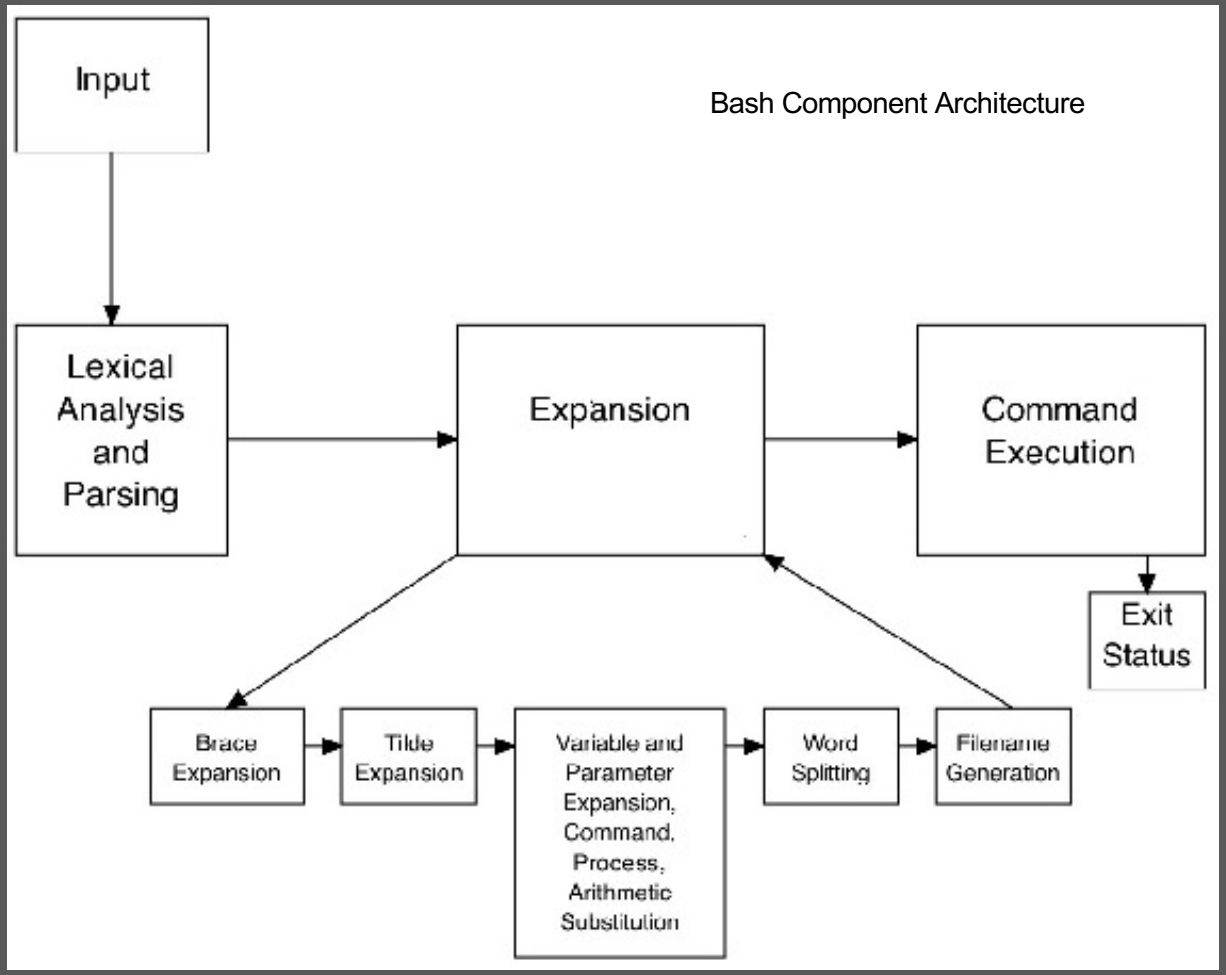
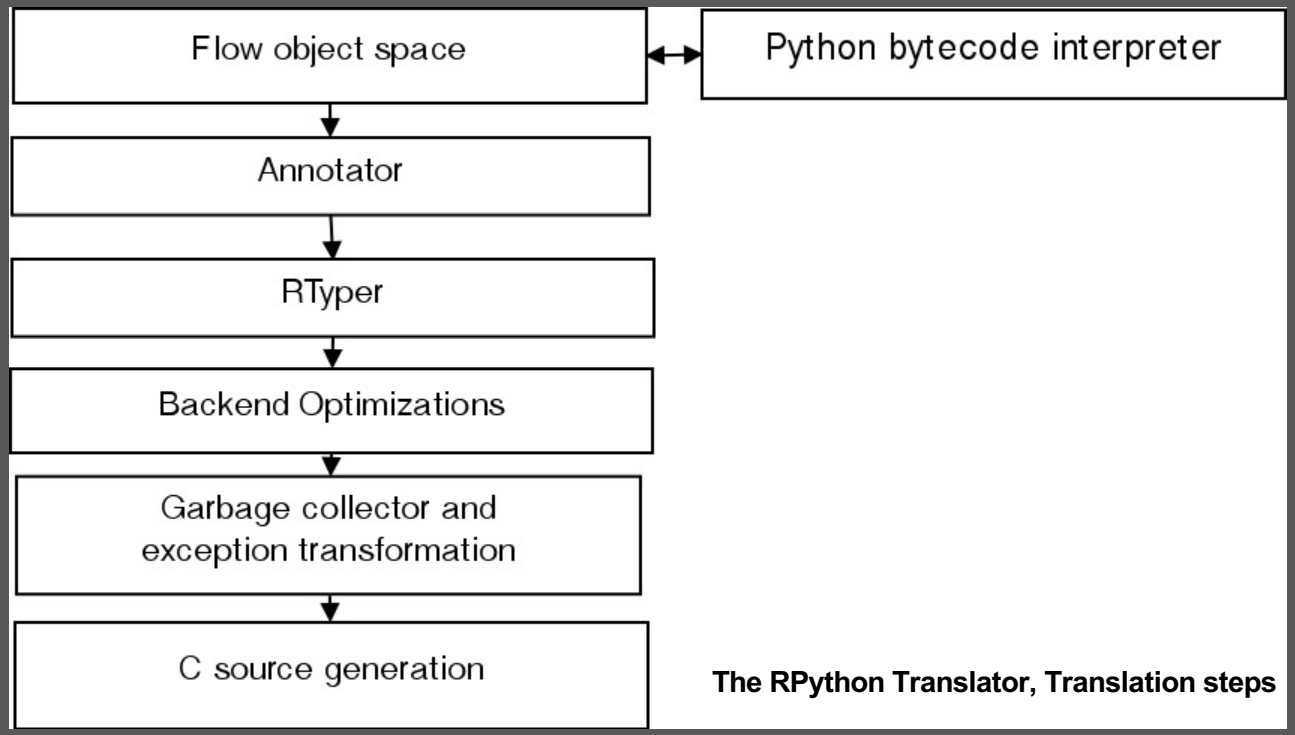


Figure 3.1 The Configuration of the GENESIS Prototype

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,

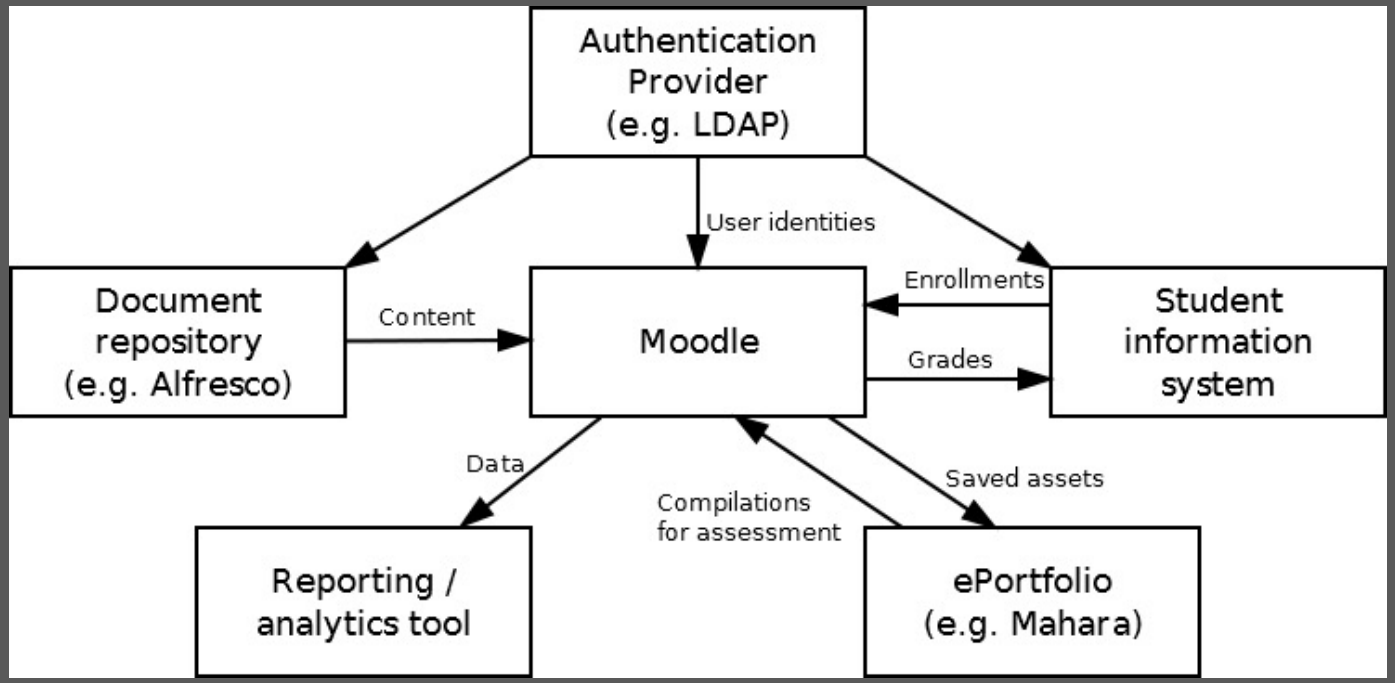


Example source:
http://www.aosabook.org



The RPython Translator, Translation steps

Example source:
http://www.aosabook.org



Moodle: Typical university systems architecture – Key subsystems

Example source:
http://www.aosabook.org

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

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