Software Architecture Fundamentals

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Course Overview

1. Software Architecture Fundamentals
2. Software Architecture Specification
3. Robust Design Strategies

Software Architecture Fundamentals

Chapter Overview

[1.1] The concept of architecture

[1.2] Software development lifecycle

[1.3] Architecture design phase

[1.4] Software architecture as artifact

[1.5] Technical implications

1.1 Architecture as a Concept

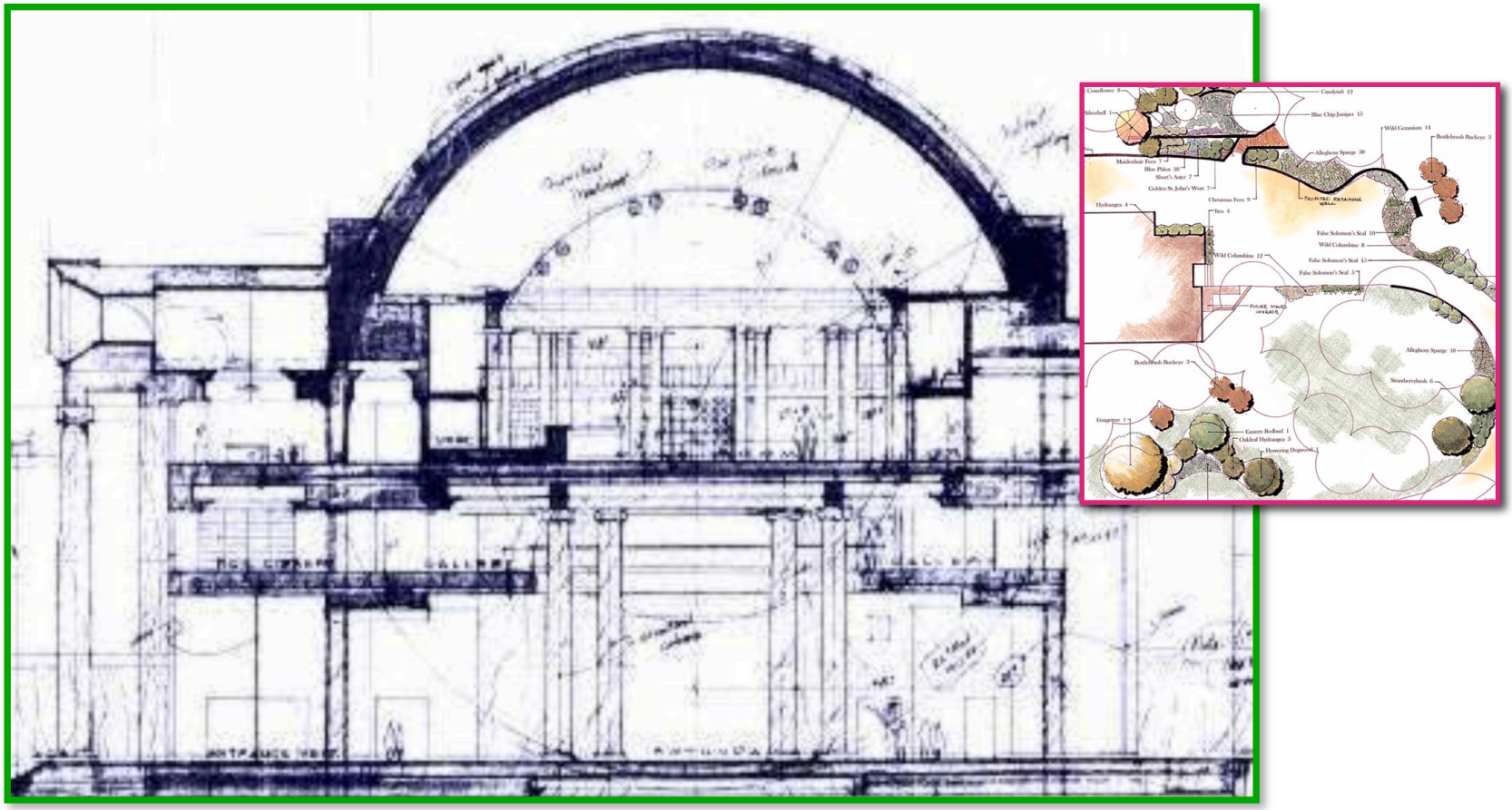
How general is the notion of architecture

- Architectural design
- Landscape architecture
- Architect of a policy of détente
- System architecture

Common Threads

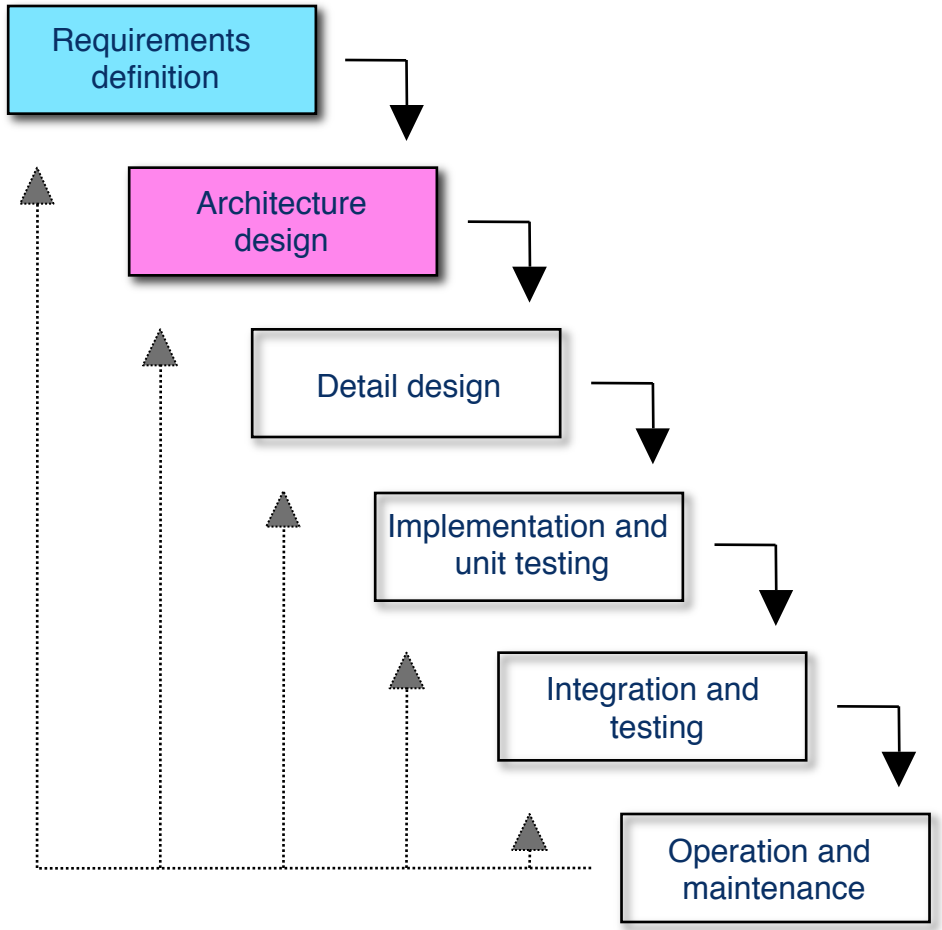
- Key organizational principle
  - integrative role
- Structure
  - explicit and visible
- Responsive to requirements
- Related to or shaping of function

Architectural Drawing



1.2 Software Development Lifecycle

- Two critical phases in software development
  - software requirements
  - software architecture

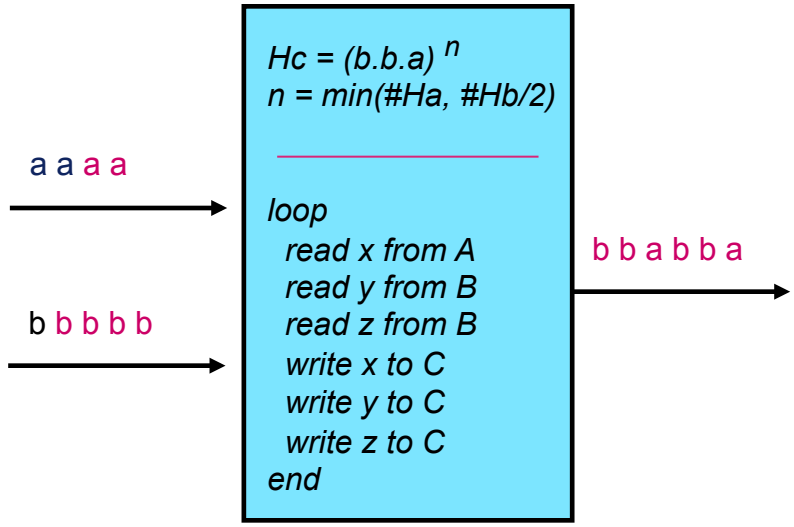


Architecture Design in Context

- Requirements definition
  - functional requirements — free of design biases
  - non-functional requirements — design constraints
  - analyzable from a functional perspective only
- Architecture design
  - overall organization of the system — technology specific
  - specifications for the individual components
    - interface, behavior, and performance parameters
  - analyzable at the functional and non-functional levels
- Detail design
  - internal mechanics of architectural components

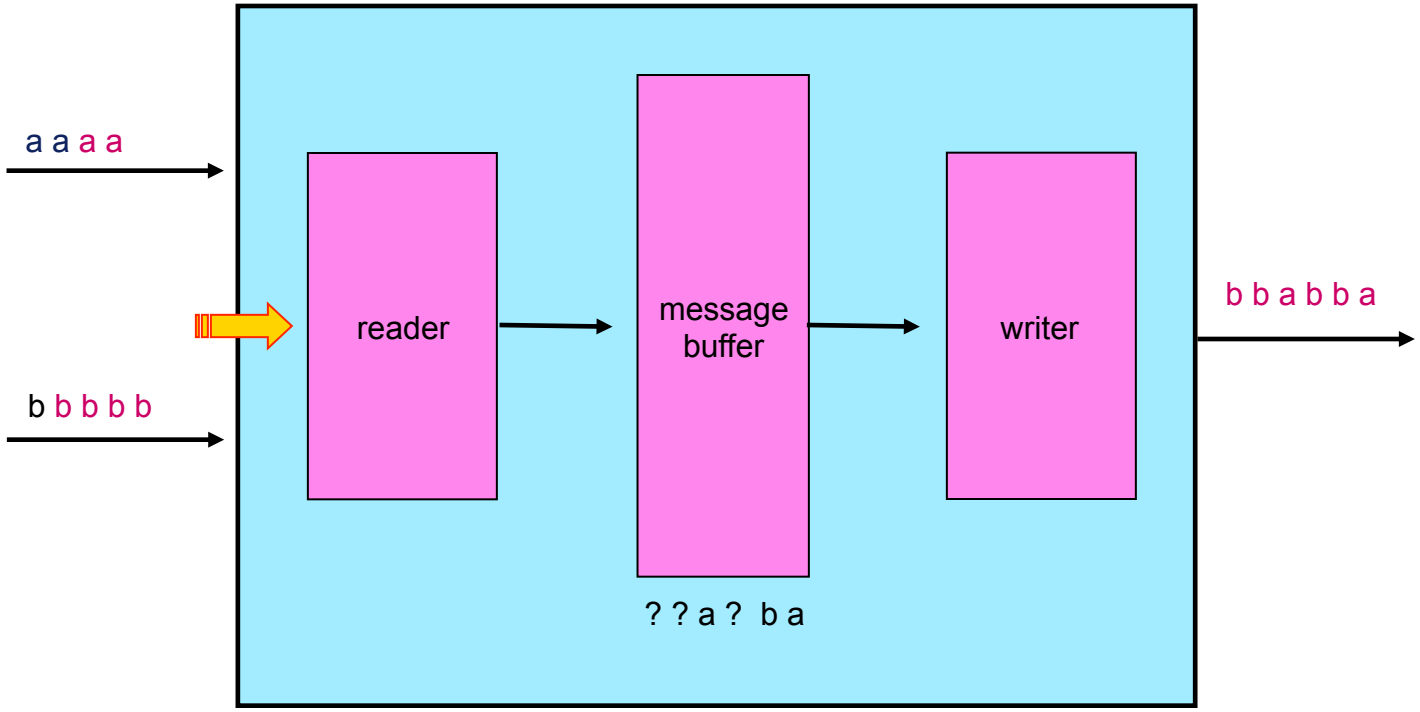
Message Merge

- Requirements definition
  - Build a message merger with inputs A and B and with output C
  - Functional requirements:
    - Release messages only in groups of three
    - A message from A must be followed by two from B
    - Preserve ordering among messages from the same input
  - Non-functional requirements
    - Messages have the following format ...
    - Message arrival generates an interrupt
    - Message arrival patterns obey …



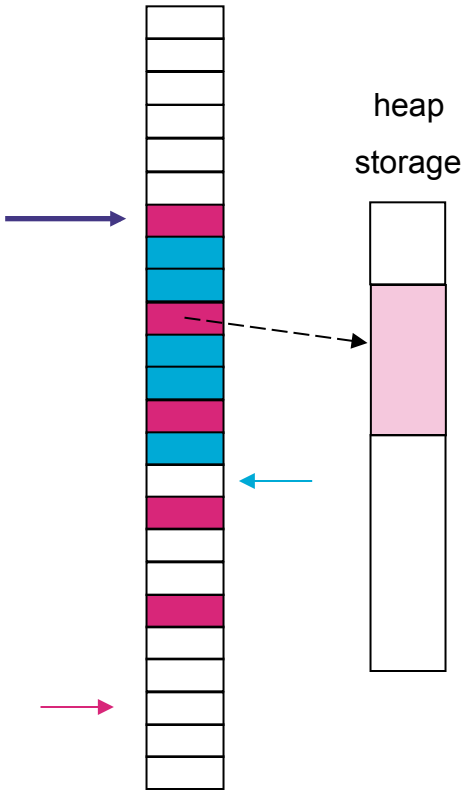
Message Merge

- Architecture design



Message Merge

- Detail design — message buffer
  - Interface
    - add message A or B
    - next cell
    - next message
  - Message pool
    - fixed size circular buffer
    - fixed size cells
    - three messages per cell
  - Message storage
    - heap storage



1.3 Architecture Design Phase

Technical goals

- Identify the principal components that make up the system and their (internal and external) interfaces
- Ensure compliance with respect to expectations captured in the requirements specification
- Understand, assess, and control risks
- Ensure predictability of the development process through accurate planning

Deliverables

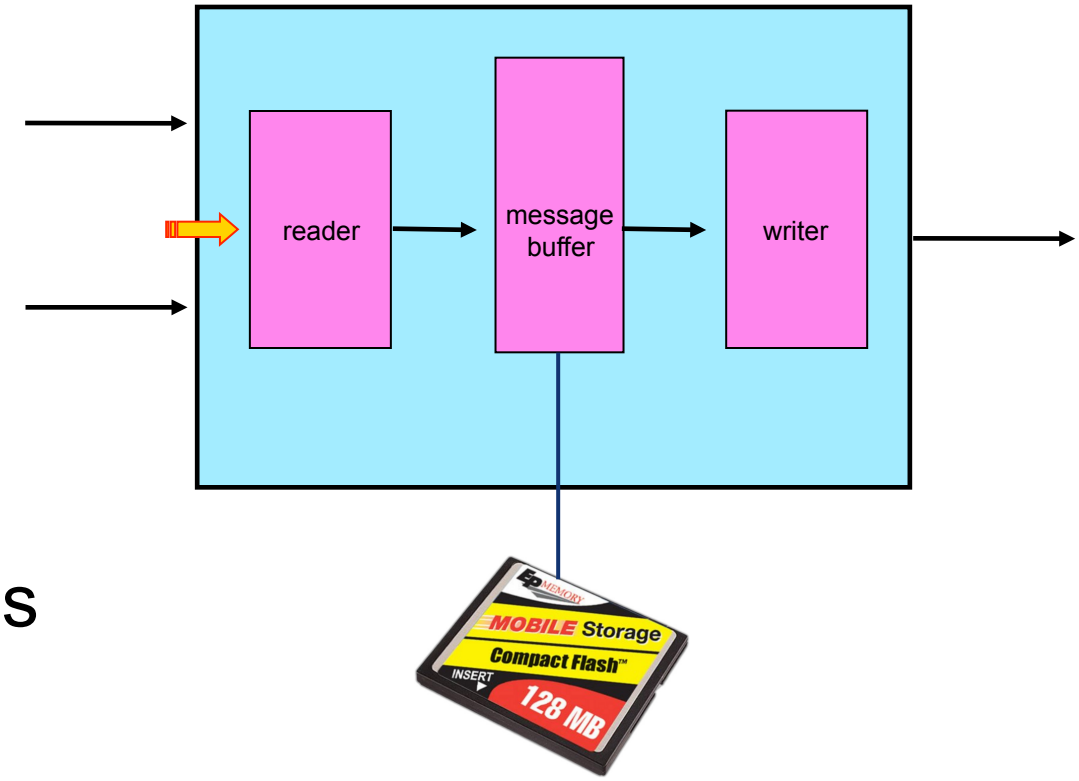
- Design diagram
  - including software to hardware allocation
- Component specifications
  - including binding specifications (COTS)
- Interface specifications
- Design analysis and evaluation
  - hazard analysis and modeling
  - risk assessment and containment
  - constraint evaluation and validation

Formative Concerns

- Design space
  - non-functional requirements limit the range of options
  - hardware selection introduces new constraints
  - purchasing decisions can reshape the design
- Requirements/design trade offs may alter the design space
- Sufficient detail is achieved when all critical design considerations can be addressed

Message Merge Revisited

- Storage analysis
  - extra storage
    - needed?
    - available?
    - fast enough?
- Failure analysis
- Timing analysis
- Code size analysis



Ancillary Concerns

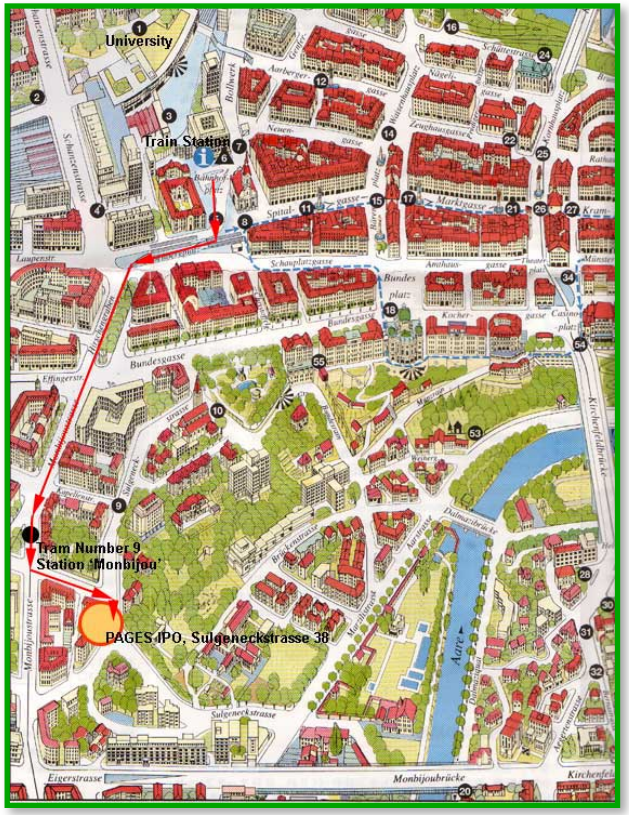
- Accurate planning requires the availability of a relatively complete architectural specification
- Idiomatic patterns of software organization are usually made evident by the design diagrams
- This facilitates design reuse and maintenance

1.4 Software Architecture as Artifact

- The architecture of a system is an abstract description of its structure and behavior
- The level of abstraction is chosen such that all critical design decisions are apparent and meaningful analysis is feasible
- A complete software architecture is usually specified by a combination of
  - design diagrams
  - component specifications

Design Diagram

- A design diagram is an abstraction of the system structure
- It is a map of the system organization at a particular level of abstraction
- It names of the principal system components and relations among them
- It hints at the operational behavior of the system (constrains what the system can do)
- It may provide implementation directives



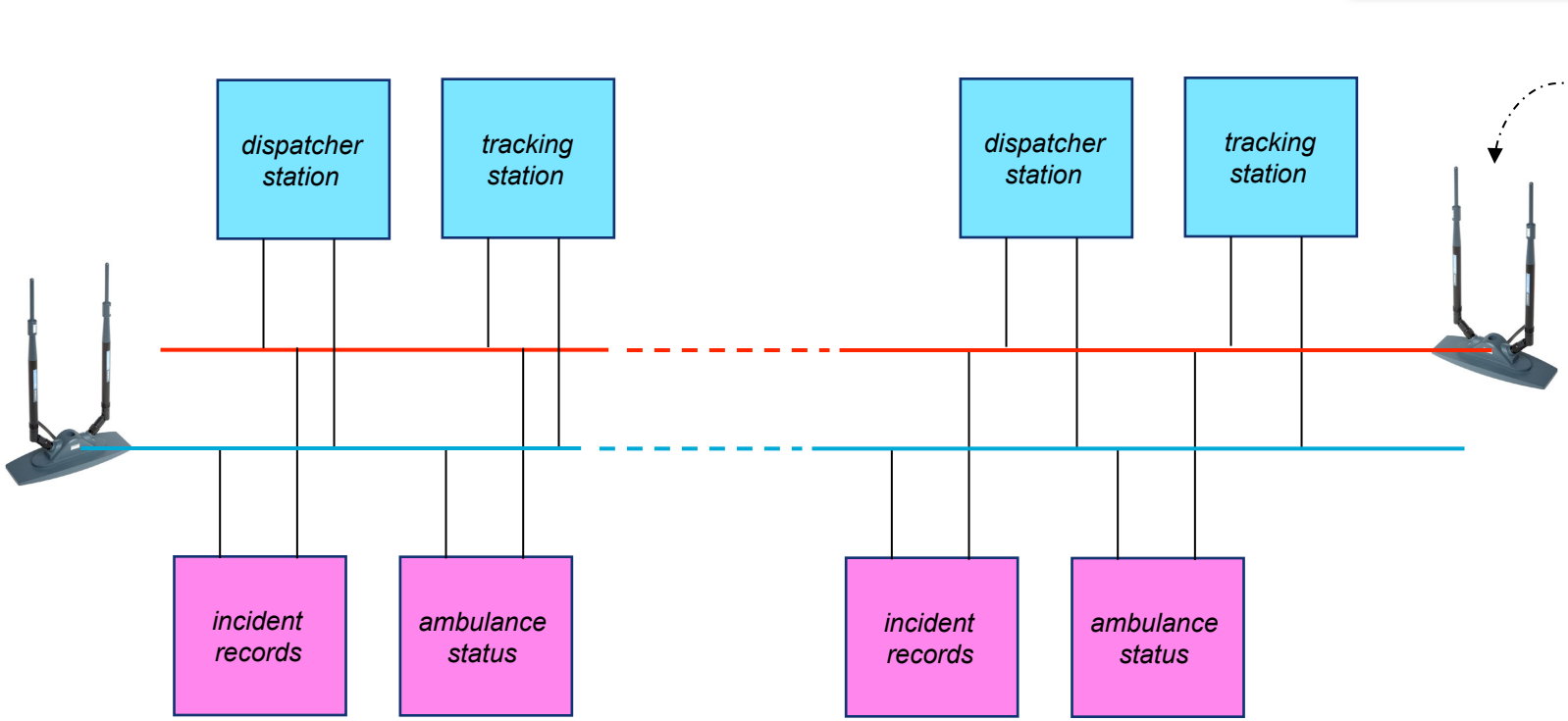
Design Diagram Caveats

- It is not an exact reflection of the code organization
- It is (by and large) independent of the syntax of any particular implementation language
- It is defined in terms of a set of constructs, selected by the designer, and believed to be implementable in the target language
- It has limited ability to express behavior
- It must be complemented by other specifications

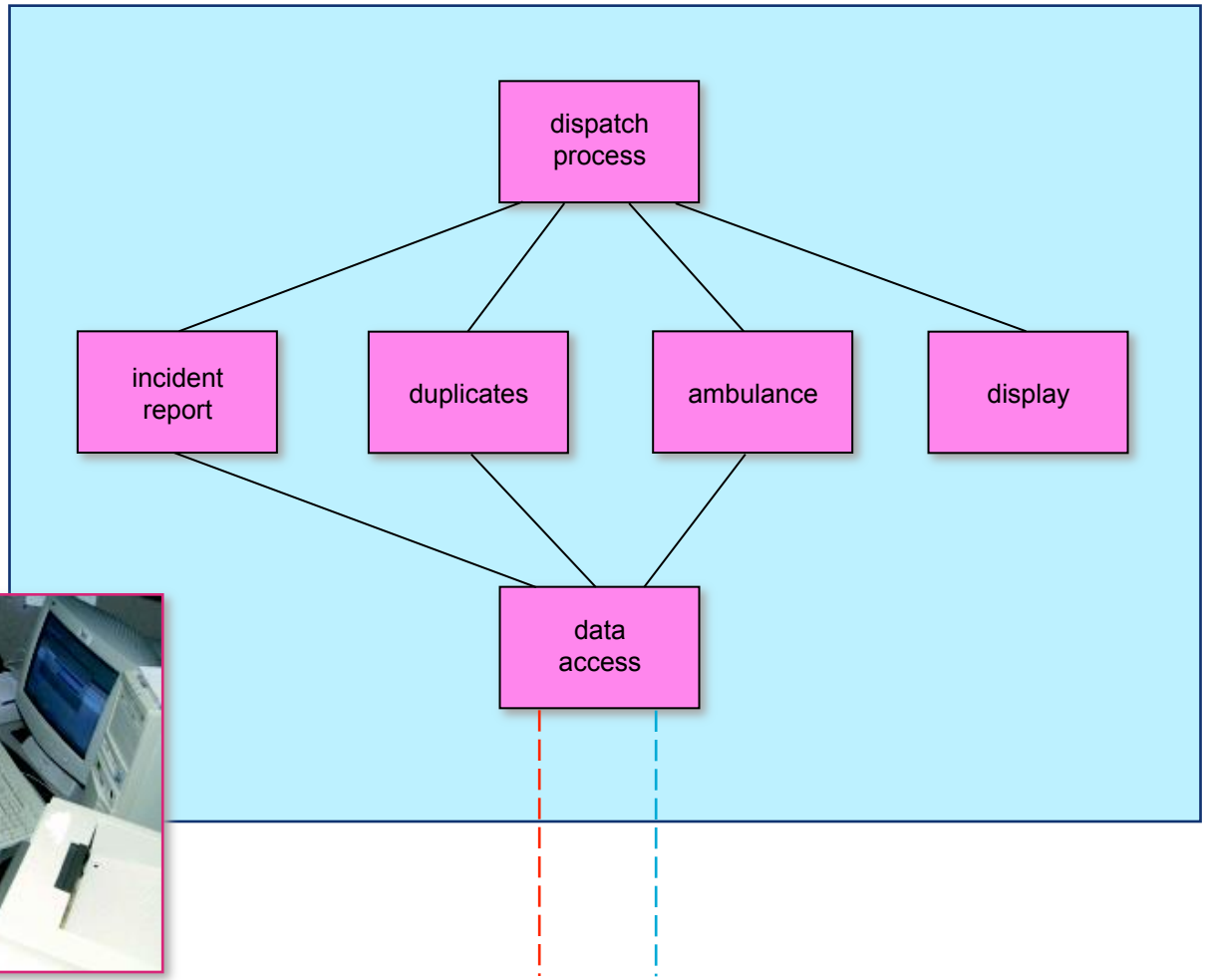
Design Diagram Role

- Important design instrument
  - captures key design decisions
    - components and their relations
    - system and underlying support
    - system and environment interactions
  - serves as an effective design communication vehicle
  - requires a low cost maintenance effort
  - is useful even after the fact
- Guides analysis and evaluation
- Facilitates project planning

Ambulance Dispatch



Dispatcher Station



Dispatch Process Analysis

- Dependability
- Survivability
- Response time
- Storage requirements
- etc.
- Timeliness
- Duplicate dispatching
- Auditing capacity
- Ambulance status accuracy

Component Specifications

- Component specifications supply the details needed to provide a complete system description at this particular level of abstraction
  - interface syntax
  - interface semantics
- The structural and behavioral properties captured by the component specifications must be consistent with the design diagram

Incident Report

- State
  - dispatcher name and id
  - date and time
  - location
  - nature of the incident
  - caller id
- Methods
  - define location
  - …
- Semantics
  - …

incident report

Managing Complexity

- Multiple architectural views
  - different levels of abstraction
  - different perspectives
- Capturing assumptions
  - structure and interfaces (design diagram)
  - semantic invariants
- Behavior patterns
  - system and/or environment
  - specialized diagrams and other notations
    - overlaid specifications

1.5 Technical Implications

- Analysis and evaluation
  - functional requirements verification
  - constraints evaluation
    - direct assessment
    - investigative targets
- Project management
  - hazard and risk analysis
  - time, effort, and code size estimation
  - activity scheduling

Traceability

- Traceability is a property of the software development process
  - refers to the ability to relate elements of a specification to those design components that ensure their satisfiability
  - relations that are precise and narrow in scope simplify analysis
  - relations that are diffused often entail complex analysis
- Specifications may be
  - functional or non-functional
  - part of the system requirements or the byproduct of design
- Traceability is a useful tool, but not a substitute for verification
- Most traceability chains run through the software architecture
  - requirements to design
  - design to code

Traceability to Requirements

- Most functional requirements must be traceable to the architecture
- All non-functional system-level requirements must be traceable to the architecture
  - quality of service, real-time constraints, dependability, allocation to physical resources, etc.
- Most non-functional requirements that relate to physical components, coding processes, protocols, installation procedures, etc. bypass the architecture
- Even with tool support, documenting traceability is costly
- Requirements affecting large areas of the design
  - render traceability efforts meaningless
  - demand systematic analysis and verification

Traceability to Code

- The software architecture is an abstraction of the code organization
  - most traceability between code and architecture requires no additional documentation
  - explicit traceability is required in some cases
    - abstract communication and coordination mechanisms
    - implementation directives
    - code elements and design elements that do not have one to one correspondence
    - non-functional requirements imposed by the design
- Requirements/code traceability is derived from the composition of two traceability mappings
  - requirements/architecture
  - architecture/code

Review Process

- The software architecture must be analyzed and evaluated by the design team
  - functional correctness
  - constraints satisfiability
  - system life-cycle issues
- Reviews
  - perform quality assurance
  - acquire measurement and evaluation data
  - exercise control
  - ensure cost effectiveness of the software development process
    - by cutting down on rework
    - by preventing error propagation to successive phases

Secondary Objectives

- Education
- Expertise development

- Project continuity
- Project visibility

- Motivation
- Standards enforcement
- Exposure of the design rationale

Review Styles

Reviews are a product adoption process

- Working session
- Walkthrough
- Inspection
- Project review
- Audit

Project Review Strategy

- Introduce the context
  - build expectations and a mental map for the audience
  - build a bridge to the system's mission
  - fully explain the interfaces
- Explain the structure
  - introduce the major system components
  - when subsystems are defined, follow the structure top-down and depth-first
- Explain the behavior
  - use a fixed repertoire of processing scenarios and predefined variations

Project Review Strategy

- Review the individual component specifications
  - relate the explanations to the selected repertoire of processing scenarios
- Justify the design
  - discuss properties critical to correct system execution
  - identify hazards and demonstrate their impossibility
- Perform other narrowly focused reviews
  - critical issues often warrant separate in depth reviews

Conclusions

- Software architecture
  - is key to any software development effort
  - is critical for ensuring the success of the undertaking
    - technically
    - managerially
  - ties to requirements in one direction and to implementation and testing in the other
  - is important to develop and maintain even after the fact