ADD 3.0: Rethinking Drivers and Decisions in the Design Process

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SATURN 2015

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Outline

- Presentation
- Architectural design and types of drivers
- The Attribute Driven Design Method
- Design decisions
- Example
- Conclusion

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Speakers

- Rick Kazman
- Humberto Cervantes

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Learning Objectives

- At the end of the presentation, participants should be able to understand:
  - The different types of architectural drivers
  - What are design concepts and the decisions regarding their selection
  - What ADD is and how an architecture is designed iteratively using this method

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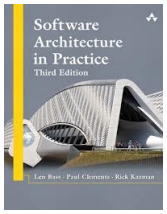
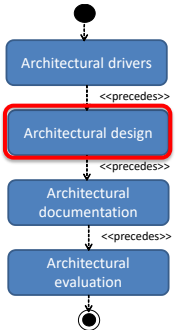
Software Architecture

- *The software architecture of a system is the set of structures needed to reason about the system, which comprise software elements, relations among them, and properties of both.*
- The architecture development lifecycle is divided in 4 phases, here we are interested in design





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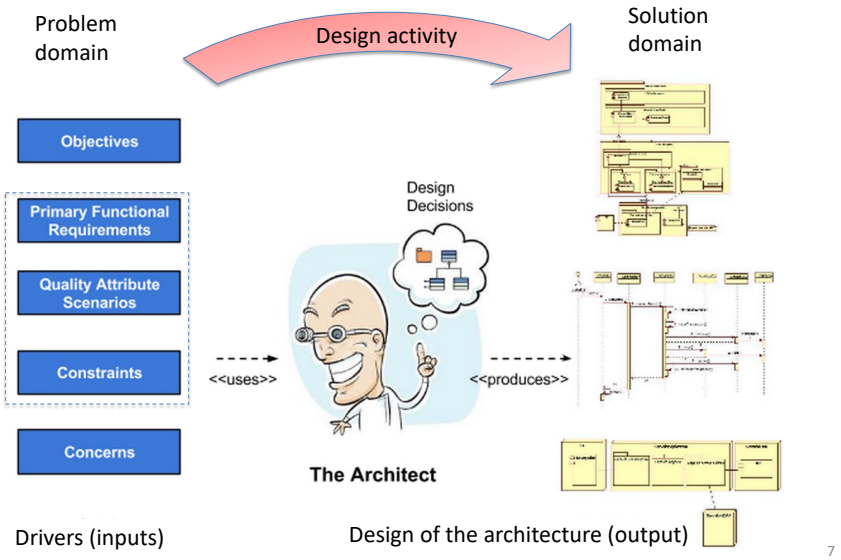
Architecture design



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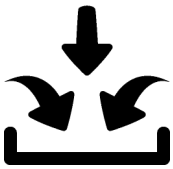
Architectural drivers

- They are a subset of the requirements that *shape* the architecture
  - Functional requirements
  - Quality attribute requirements
  - Constraints
- But other drivers include
  - The type of system that is being designed
  - Design objectives
  - Concerns



- These are the inputs to the design process

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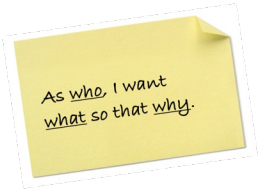
Functional drivers

- Functional drivers: typically involve primary functionality, i.e. functionality that directly supports the business goals



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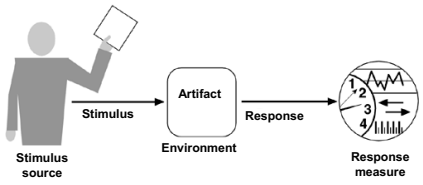
Quality attribute drivers

- Quality attributes are measurable characteristics of interest to users and developers
  - Performance, Availability, Modifiability, Testability, etc…
  - Can be specified using the scenario technique



An internal failure occurs in the system during normal operation. The system resumes operation in less than 30 seconds, and no data is lost.

  - Prioritized by the customer according to importance to the success of the system (H, M, L) and by the architect according to technical risk (H, M, L)

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Constraints

- Constraints are limitations or restrictions
  - They may be technical or organizational
  - They may originate from the customer but also from the development organization
  - Usually limit the alternatives that can be considered for particular design decisions
  - They can actually be your "friends"

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Types of systems

- Greenfield systems in novel domains
  - E.g. Google, Amazon, WhatsApp
  - Less well known domains, more innovative

- Greenfield systems in mature domains
  - E.g. "Traditional" enterprise applications, standard mobile applications
  - Well known domain, less innovative

- Brownfield systems
  - Changes to existing system

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Architecture design objectives

- Before you can begin you need to be clear about *why* you are designing. Your objectives will change what and how you design, e.g.
  - For a pre-sales proposal, which usually involves the rapid design of an initial solution in order to produce an estimate
  - For a custom system with established time and costs and which may not evolve much once released
  - For a new increment or release of a continuously evolving system

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Concerns

- Concerns represent design decisions *that should be made* whether or not they are stated explicitly as part of the goals or the requirements. Examples include:
  - Creating an overall logical and physical structure
  - Input validation
  - Exception management and logging
  - Communications
  - Deployment and updating
  - Data migration and backup
  - Organization of the codebase

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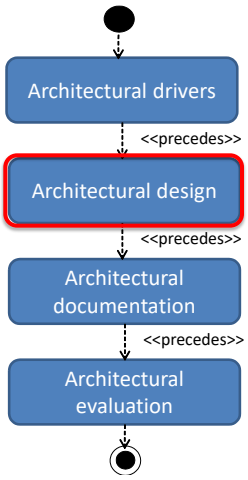
Architecture design methods

- There exist several architecture development methods
  - Viewpoints and Perspectives
  - Microsoft
  - Process of Software Architecting
  - ACDM
  - RUP
  - ADD
- Most of them cover the whole architecture lifecycle and provide few details on how to perform the design activity



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Why is a design method necessary?

- Architecture design is notoriously difficult to master
  - Many aspects need to be considered when making design decisions
  - It requires extensive knowledge of the domain and existing solutions
- However, design can (and should) be performed in a systematic way
  - To ensure that decisions are made with respect to the drivers.
  - To ensure that decisions are recorded and justified and to make the architect accountable for them
  - To provide guidance to less experienced people
- Otherwise, architecture design may end up being seen a mystic activity performed by gurus.

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Attribute Driven Design (ADD)

- ADD is an architecture design method "driven" by quality attribute concerns
  - Version 2.0 released November 2006
- The method promotes an iterative approach to design
- It provides a detailed set of steps for architecture design
  - enables design to be performed in a systematic, repeatable way
  - leading to predictable outcomes.

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ADD 2.0 Limitations

- Using ADD in practice has revealed some limitations in the original method

Limitation	Reason why this is a limitation
Inputs are just QA & functional requirements + constraints (step 0)	There are other inputs to design, such as the design objectives, and architecture concerns.
A single element of the system is decomposed in each iteration (step 2)	A design iteration may require decomposing several elements (e.g. several layers may need to be decomposed to support a use case).
The element to decompose is chosen before the drivers to be addressed (step 3)	Drivers to be addressed in an iteration are usually identified as the iteration begins.
Design concepts used to satisfy drivers only include patterns and tactics (step 4)	Architects design using not only conceptual primitives but also more concrete design primitives such as frameworks and reference architectures.
Initial documentation and analysis are not steps of the process itself	Not really a limitation since it is mentioned in ADD but only as part of one of the steps. This may not reinforce the idea that initial documentation is an important part of design.

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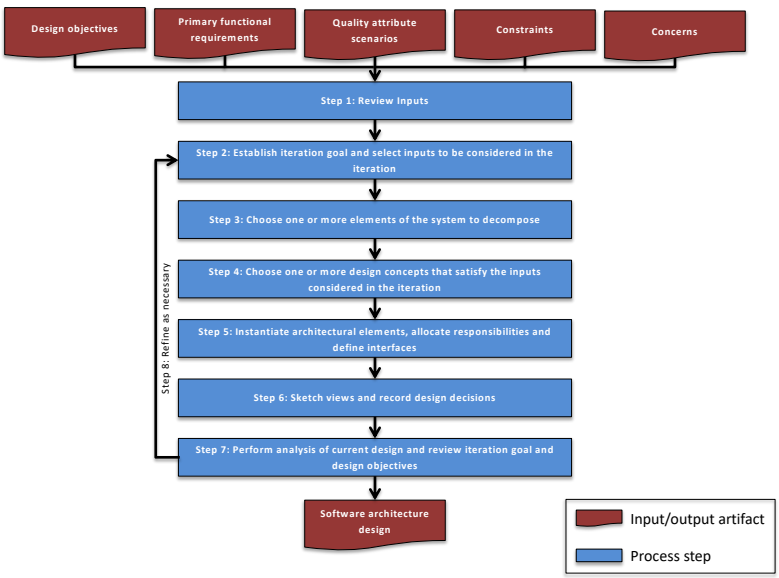
ADD 3.0



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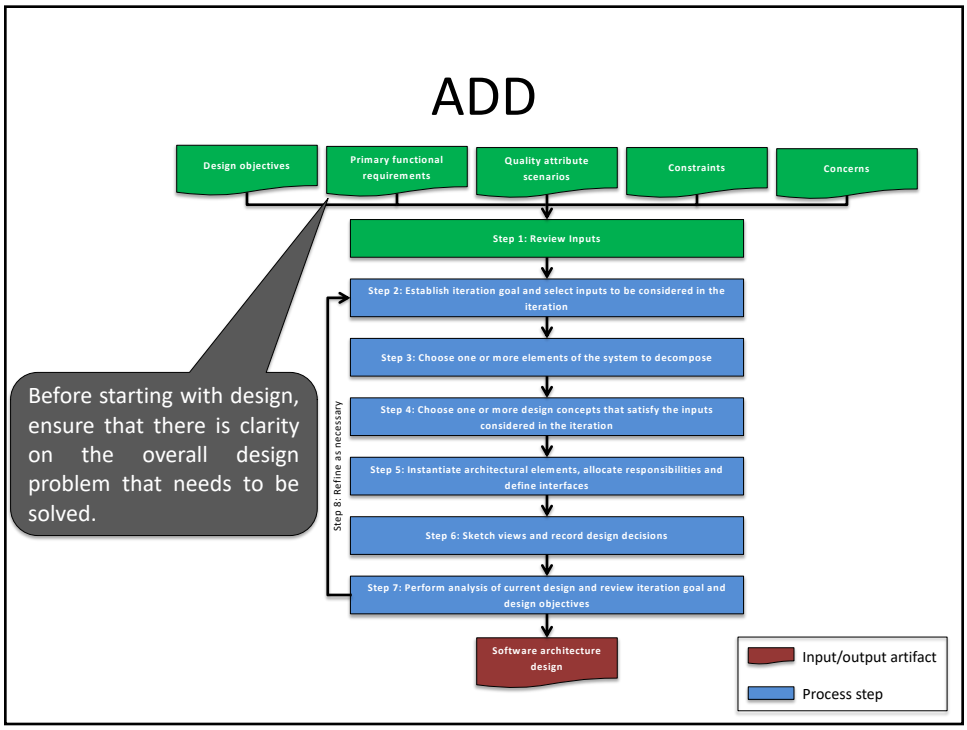
ADD
Design objectives
Primary functional requirements
Quality attribute scenarios
Constraints
Concerns
Step 1: Review Inputs
Step 2: Establish iteration goal and select inputs to be considered in the iteration
Step 3: Choose one or more elements of the system to decompose
Step 4: Choose one or more design concepts that satisfy the inputs considered in the iteration
Step 5: Instantiate architectural elements, allocate responsibilities and define interfaces
Step 6: Sketch views and record design decisions
Step 7: Perform analysis of current design and review iteration goal and design objectives
Step 8: Refine as necessary
Software architecture design
Input/output artifact
Process step
Before starting with design, ensure that there is clarity on the overall design problem that needs to be solved.

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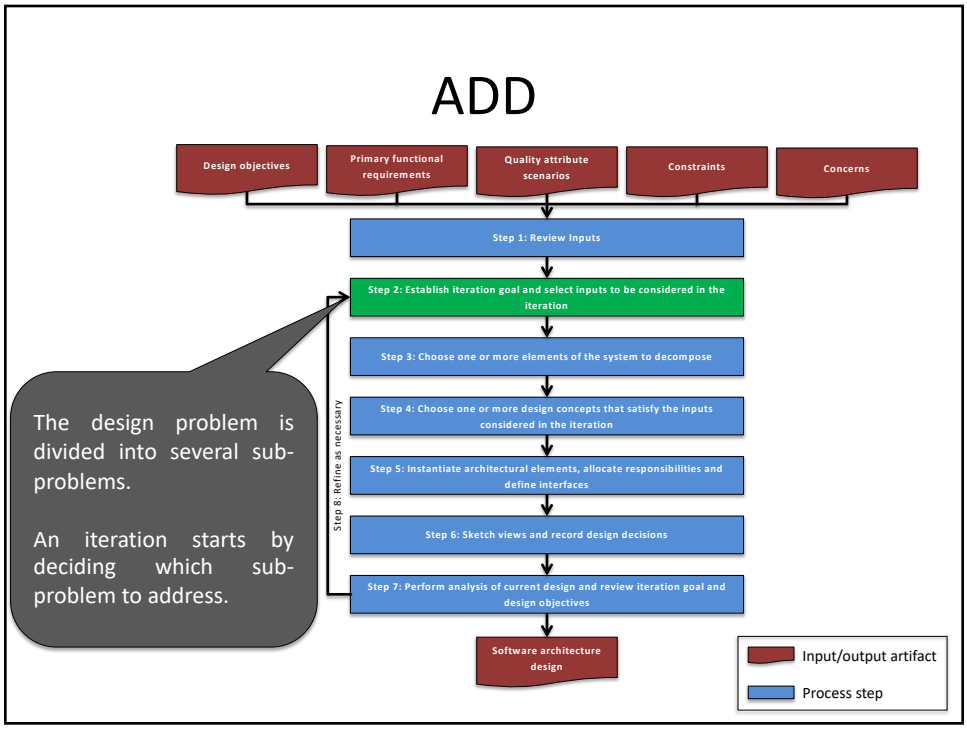
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Software architecture design
Input/output artifact
Process step
The design problem is divided into several sub-problems.
An iteration starts by deciding which sub-problem to address.

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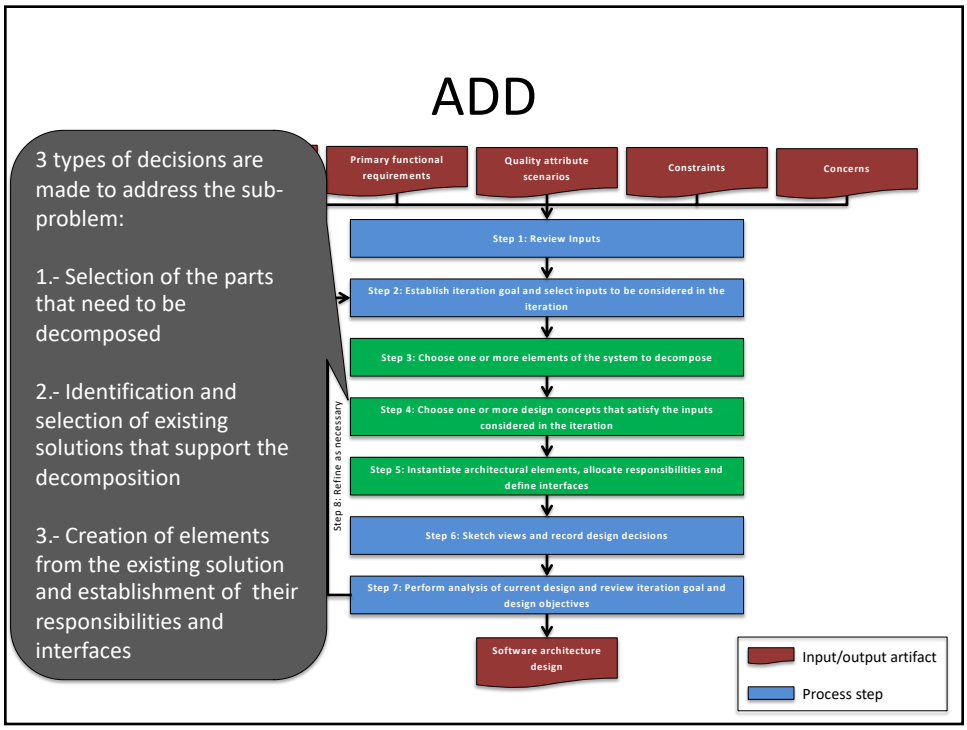
ADD
3 types of decisions are made to address the sub-problem:
1.- Selection of the parts that need to be decomposed
2.- Identification and selection of existing solutions that support the decomposition
3.- Creation of elements from the existing solution and establishment of their responsibilities and interfaces
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Input/output artifact
Process step

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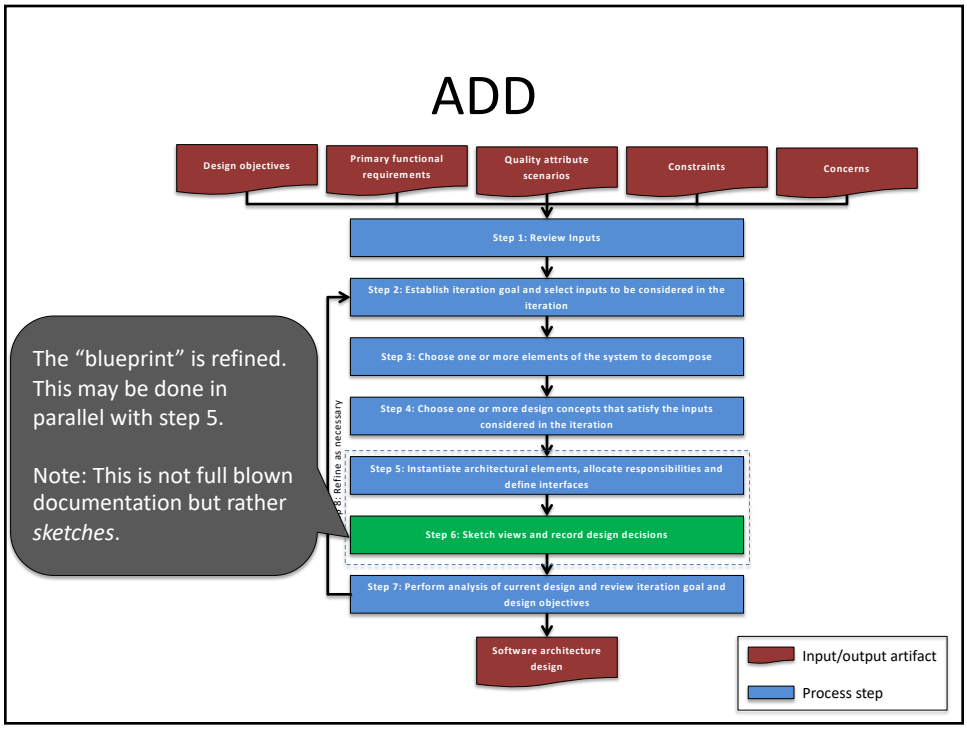
ADD
The “blueprint” is refined. This may be done in parallel with step 5.
Note: This is not full blown documentation but rather *sketches*.
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Software architecture design
Input/output artifact
Process step

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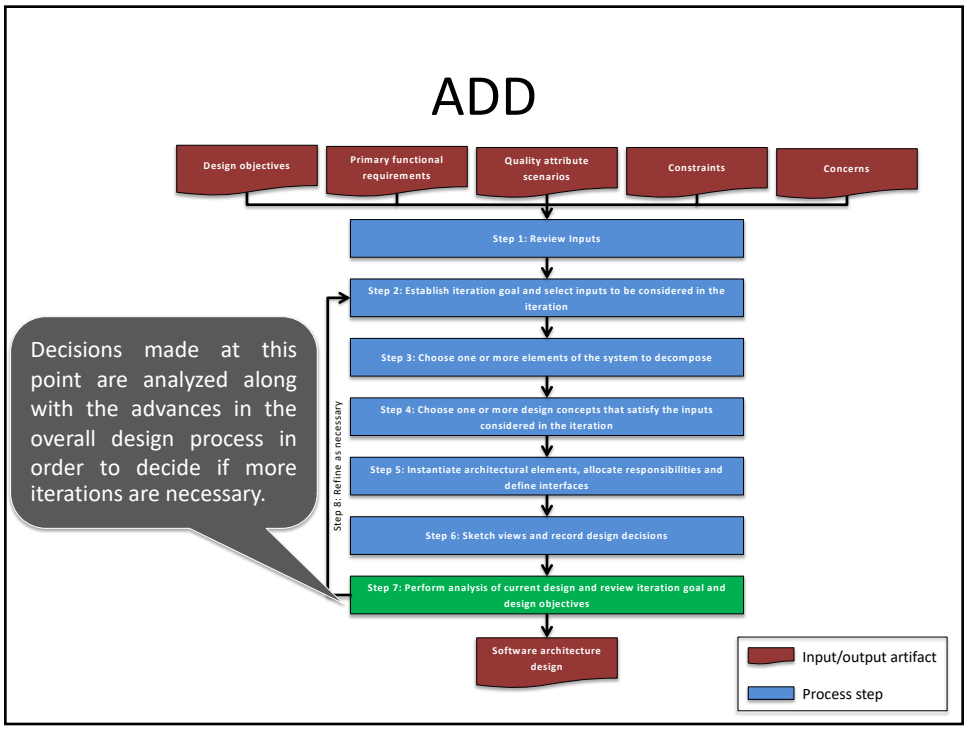
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Software architecture design
Decisions made at this point are analyzed along with the advances in the overall design process in order to decide if more iterations are necessary.
Input/output artifact
Process step

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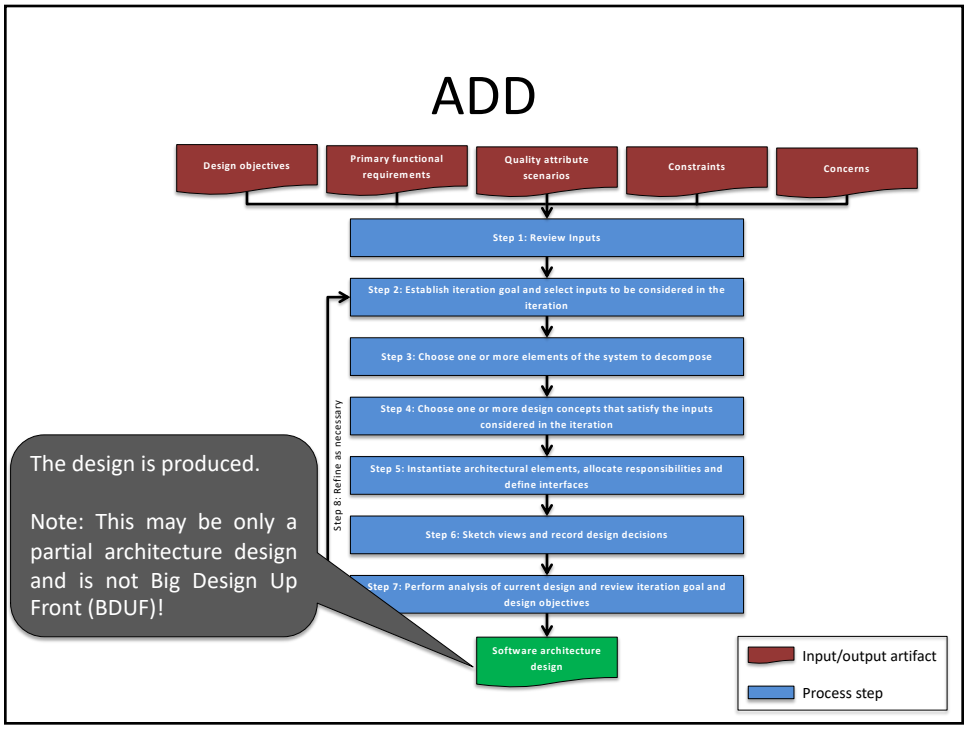
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Step 8: Refine as necessary
Software architecture design
The design is produced.
Note: This may be only a partial architecture design and is not Big Design Up Front (BDUF)!
Input/output artifact
Process step

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Design decisions

- The design process involves different making design decisions
  - Step 3: Selecting elements to decompose
  - Step 4: Choosing one or more design concepts that satisfy the inputs considered in the iteration
  - Step 5: Instantiating architectural elements, allocating responsibilities and defining interfaces

- Step 4 (selecting design decisions) can be particularly challenging…

Design Concepts

- Most sub-problems that are addressed during an iteration can be solved using existing solutions, i.e. *design concepts*
  - We want to avoid re-inventing the wheel
  - It is better (and faster) to use a proven solution to a problem for which we may not be experts
  - Creativity in design involves identifying, adapting and combining them
- There are several categories of design concepts, some are abstract and some more concrete. Here we consider:
  - Reference Architectures
  - Deployment Patterns
  - Architectural / Design Patterns
  - Tactics
  - Externally developed components (e.g. Frameworks)

VS.

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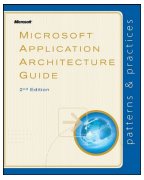
Reference Architectures

- They provide a blueprint for structuring an application. Examples for the enterprise application domain include
  - Mobile applications
  - Rich client applications
  - Rich internet applications
  - Service Applications
  - Web applications



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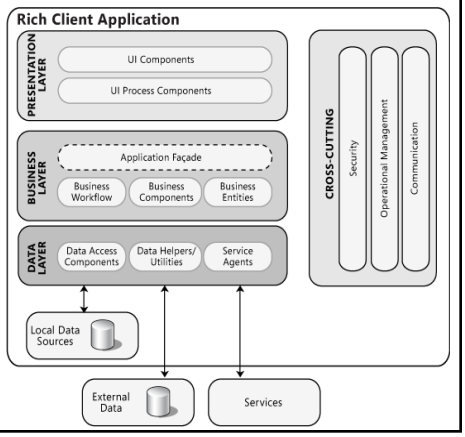

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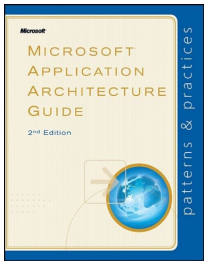
Deployment Patterns

- Deployment patterns provide guidance on how to structure the system from a physical standpoint. Good decisions with respect to the deployment of the software system are essential to achieve quality attributes such as availability.

- Examples
  - 2, 3, 4 and *n*-tier deployment
  - Load balanced cluster
  - Failover cluster
  - Private/public cloud
  - Etc…



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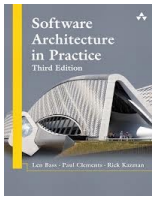
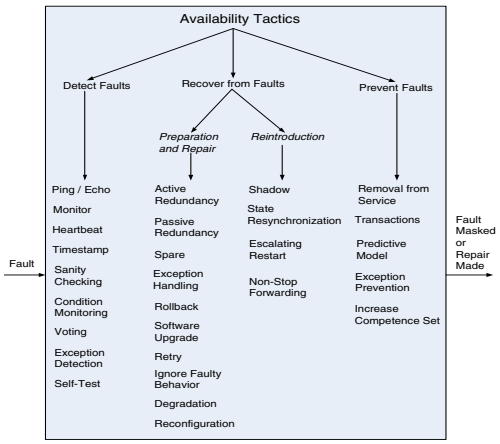
Tactics

- What are tactics?
  - Design decisions that influence the control of a quality attribute response.
- There are tactics categorizations for the quality attributes of:
  - Availability
  - Interoperability
  - Modifiability
  - Performance
  - Security
  - Testability
  - Usability





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Architectural / Design patterns

- Patterns are proven (conceptual) solutions to recurring design problems. Originated in building architecture.
- Many patterns exist (*thousands*), and they are documented across several pattern catalogs.
- It is difficult to draw a clear boundary between "design" and "architectural" patterns.

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Externally developed components

- These are reusable code solutions
  - E.g. Middleware, frameworks
- A Framework is a reusable software element that provides generic functionality, addressing recurring concerns across a range of applications.
  - Examples for Java:

Concern	Framework	Usage
Local user interface	Swing	Inheritance
Web UI	Java Server Faces (JSF)	XML, Annotations
Component connection	Spring	XML, Annotations
Security (authentication, auth)	Spring-Security	XML, Annotations
OO – Relational Mapping	Hibernate	XML, annotations

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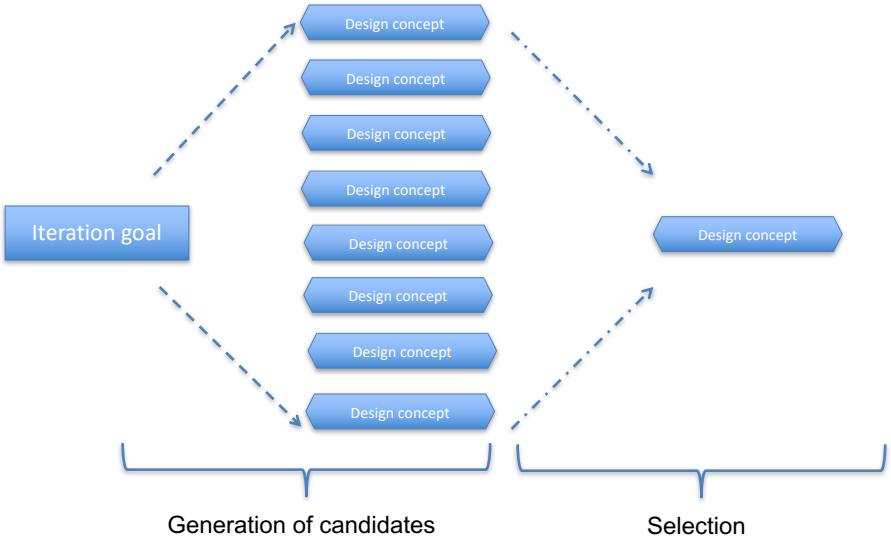
Selecting design concepts (step 4)



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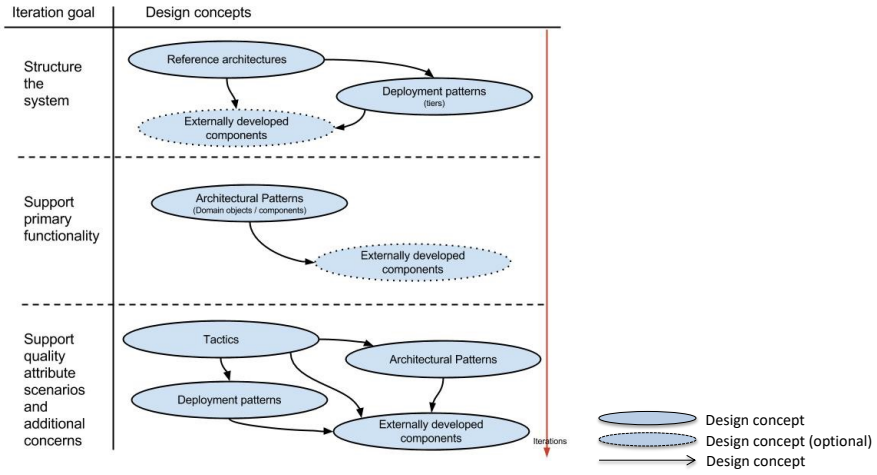
Selection roadmap

- Greenfield systems in mature domains



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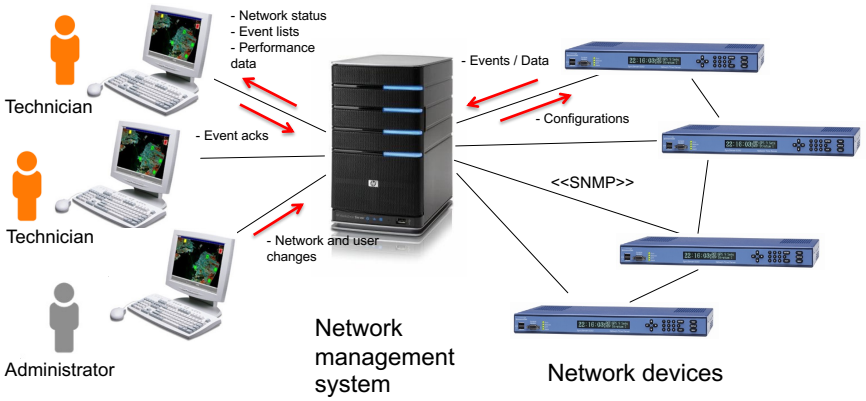
Example

- Network Management System “Marketecture” diagram



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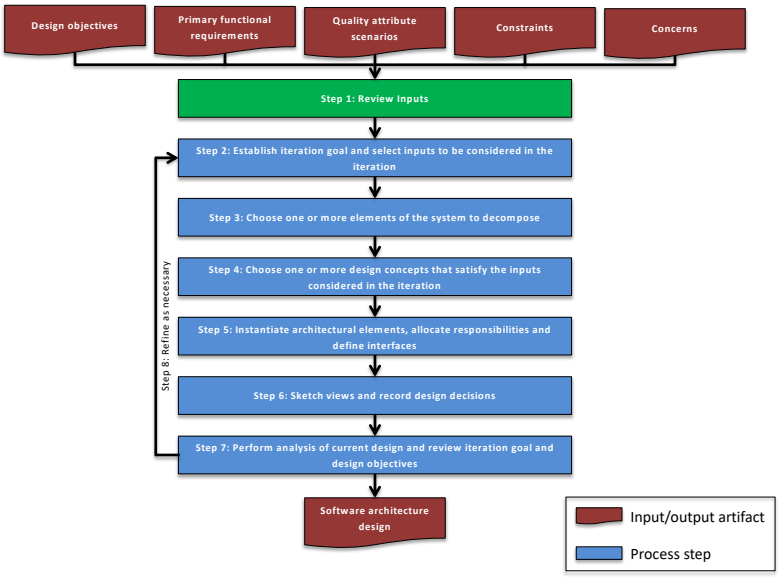

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Example

- Type Of System: Greenfield in mature domain
- Objective: Design in preparation for construction of an increment of the system
- Concerns
  - Structure the system
  - Organization of the codebase
  - Input validation
  - Exception management
  - …

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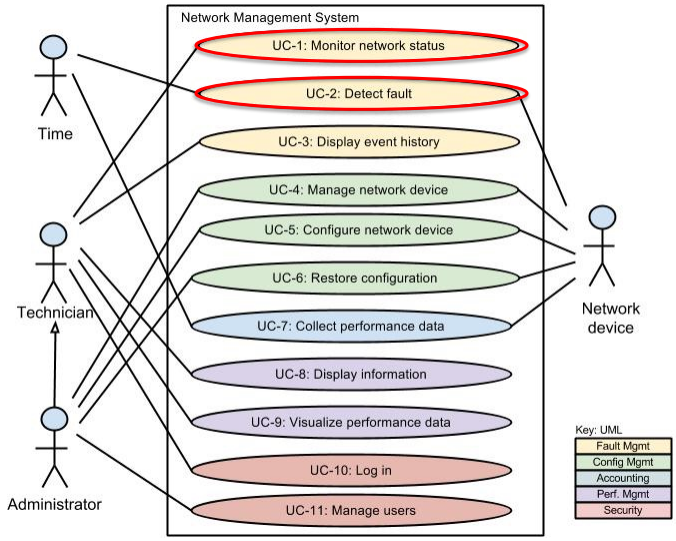
Use Cases



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Quality Attribute Scenarios

ID	Quality Attribute	Scenario	Associated use case	Priority
QA-1	Performance	Several network devices send traps to the management system at peak load. 100% of the traps are successfully processed and stored.	Detect network device fault (UC-2)	H, H
QA-2	Modifiability	A new network device management protocol is introduced to the system as part of an update. The protocol is added successfully without any changes to the core components of the system.	Configure network device (UC-5)	M, M
QA-3	Availability	A failure occurs in the management system during operation. The management system resumes operation in less than 30 seconds.	All	H, H
QA-4	Performance	The management system collects performance data from a network device during peak load. The management system collects all performance data within 5 minutes to ensure no loss of data.	Collect performance data (UC-7)	H, H
QA-5	Performance, Usability	A user displays the event history of a particular network device during normal operation. The list of events from the last 24 hours is displayed within 1 second.	Display Event history (UC-3)	H, M
QA-6	Security	A user performs a change in the system during normal operation. It is possible to know who performed the operation and when it was performed 100% of the time.	All	H, M

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Constraints

ID	Constraint
CON-1	A minimum of 50 simultaneous users must be supported.
CON-2	User workstations use the following operating systems: Windows, OSX, and Linux.
CON-3	An existing relational database server must be used.
CON-4	Network connection between users workstations and the server is unreliable
CON-5	Future support for mobile clients
CON-6	A minimum of 600 time servers must be supported (Initial deployment 100 time servers, 100 more / year during 5 years)
CON-7	Each time server sends, on average, 10 traps/hour.
CON-8	Performance data needs to be collected in intervals of no more than 5 minutes as higher intervals result in time servers discarding data.
CON-9	Events from the last 30 days must be stored
CON-10	The development team is familiar with Java technologies

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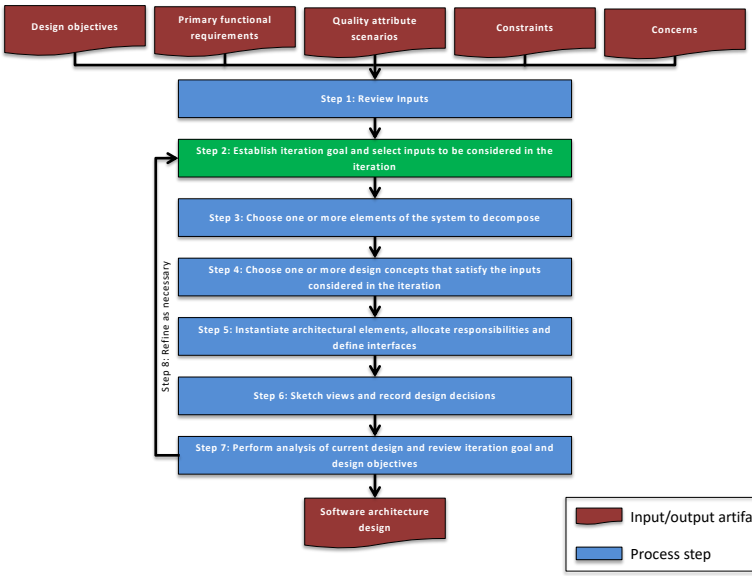
ADD: Iteration 1



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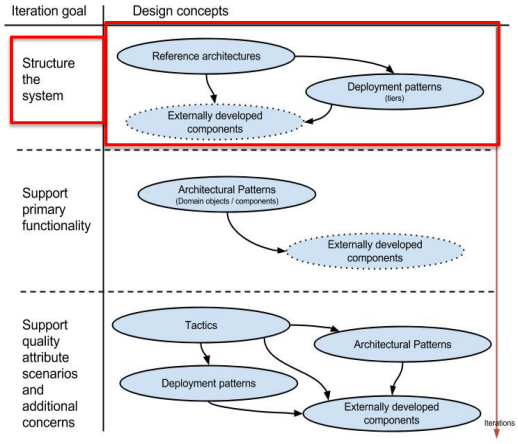
Iteration goal and inputs

- Iteration goal
  - Create an overall system structure
- Inputs to be considered
  - All



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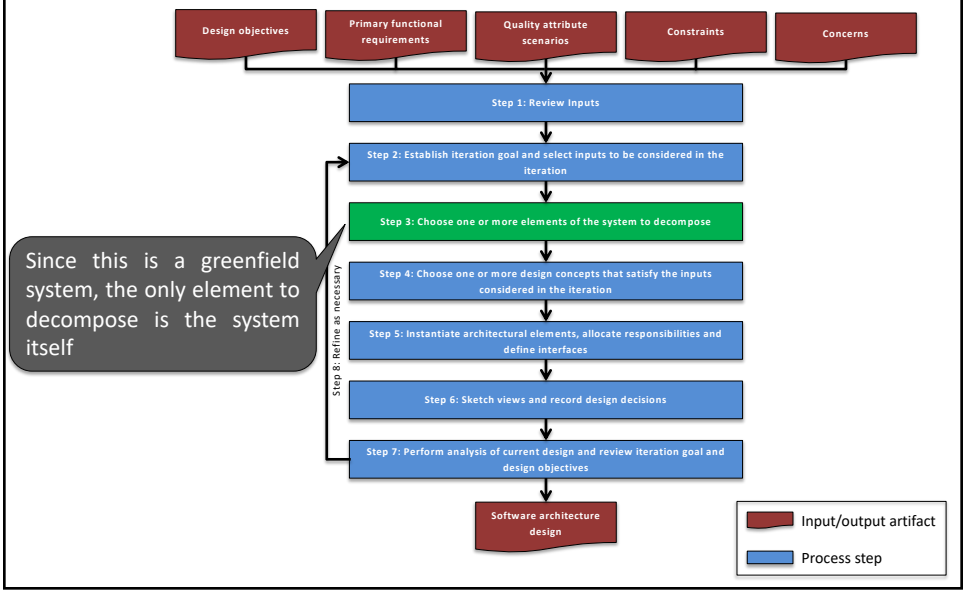

Since this is a greenfield system, the only element to decompose is the system itself

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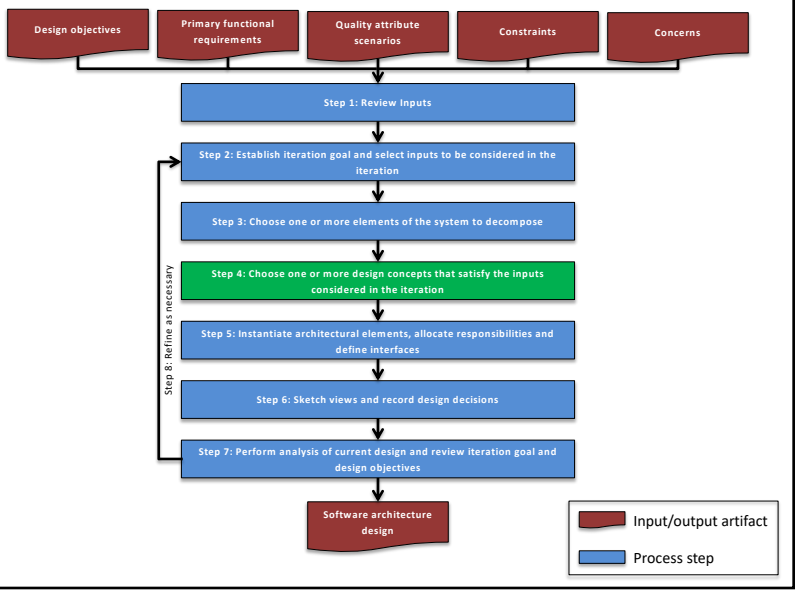
ADD: Iteration 1



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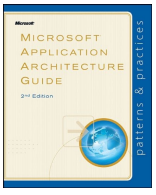
Selection of design concepts

- Reference architecture alternatives
  - Mobile applications
  - Rich client applications
  - Rich internet applications
  - Service Applications
  - Web applications

Source: https://msdn.microsoft.com/en-us/library/ee658107.aspx

- Distributed deployment patterns alternatives
  - 2 tier
  - 3 tier
  - 4 tier



Source: https://msdn.microsoft.com/en-us/library/ee658120.aspx

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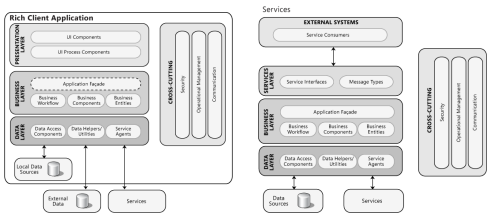
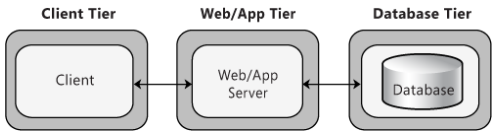
Design decisions

- Two reference architectures are chosen



Design decision	Rationale
Rich client application on the client side	- Supports rich user interface - Portability (CON-2)
Service application on the server side	- Support mobile clients in the future (CON-5)
3 Tier application	- Existing database server (CON-3)
…	…

- Distributed deployment patterns alternatives
  - 3 tier



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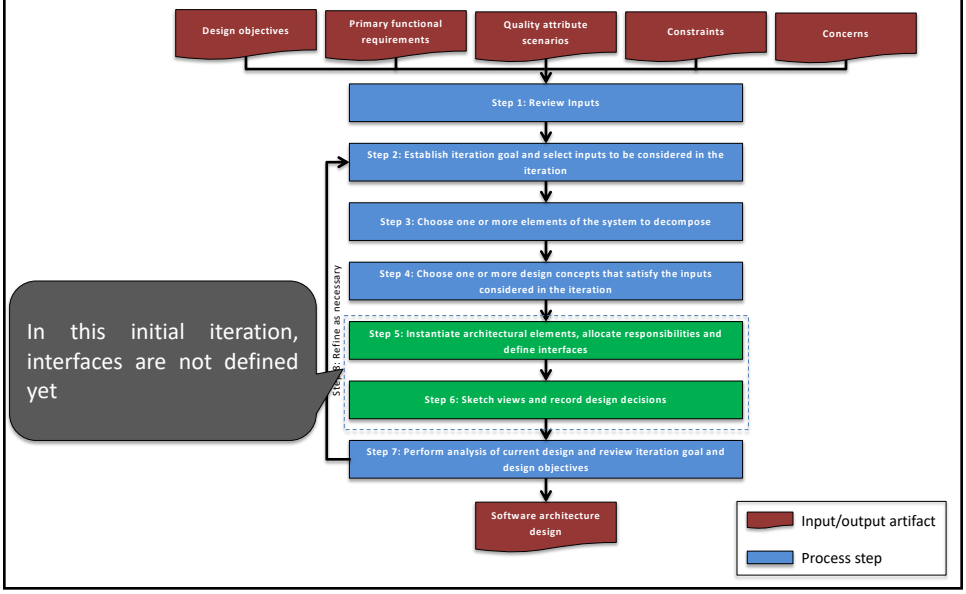
ADD: Iteration 1



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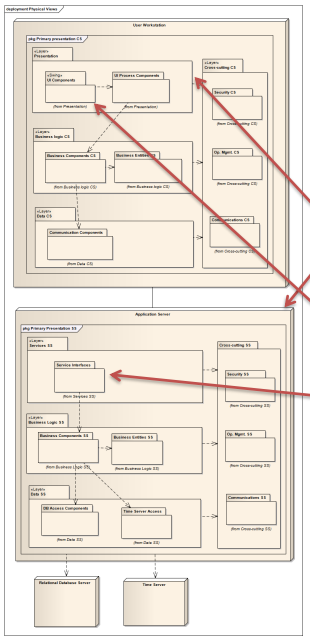

Step 5

Element	Responsibility	Properties
Application Server	- Hosts the elements of the service reference architecture - Connects to network devices - Connects to database server	OS = Centos
Presentation layer (Client side)	This layer contains components which control user interaction and use case control flow.	
UI Components (Client side)	These are components which render the user interface and receive user interaction.	
Service Interfaces	These is a group of components that expose services that are consumed by the clients	
…	…	

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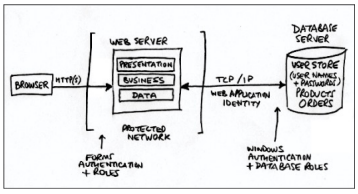
Documenting During Design

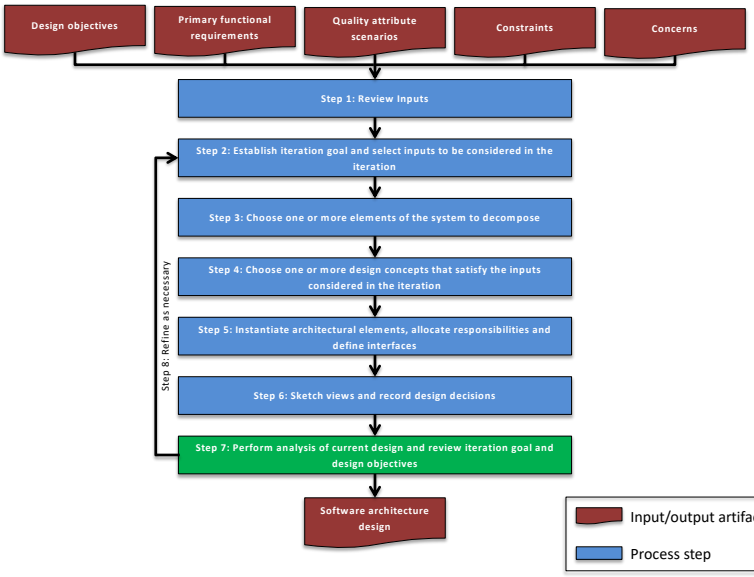
- As you instantiate design concepts you will typically create *sketches*. These are initial documentation for your architecture.
  - capture them and flesh them out later
  - if you use informal notation, be consistent
  - develop a discipline of writing down the *responsibilities* that you allocate to elements and *the relevant design decisions* that you have made



- Recording during design ensures you won't have to remember things later…

52

ADD: Iteration 1



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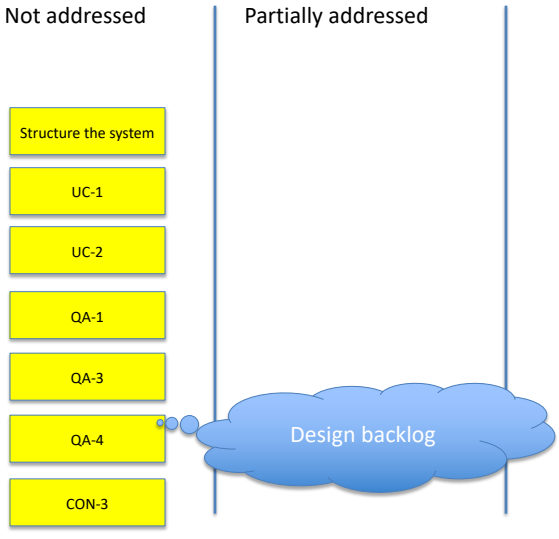
Step 7: Design Kanban board



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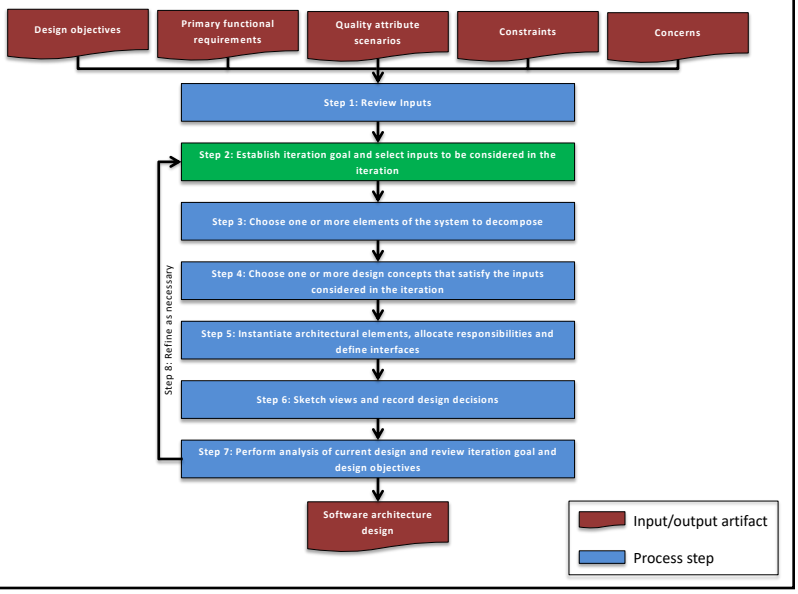
ADD: Iteration 2



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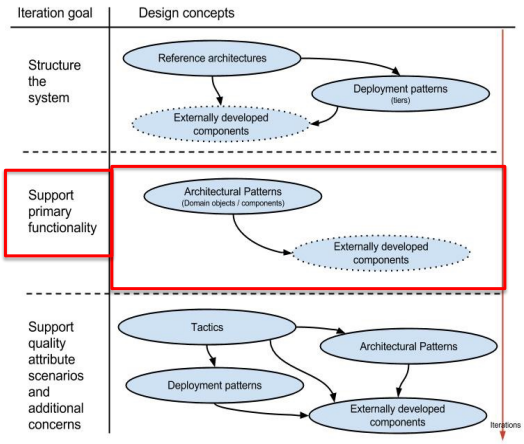
Iteration goal and inputs

- Iteration goal:
  - Identify the elements that support the primary functionality
- Inputs
  - Primary Use Cases



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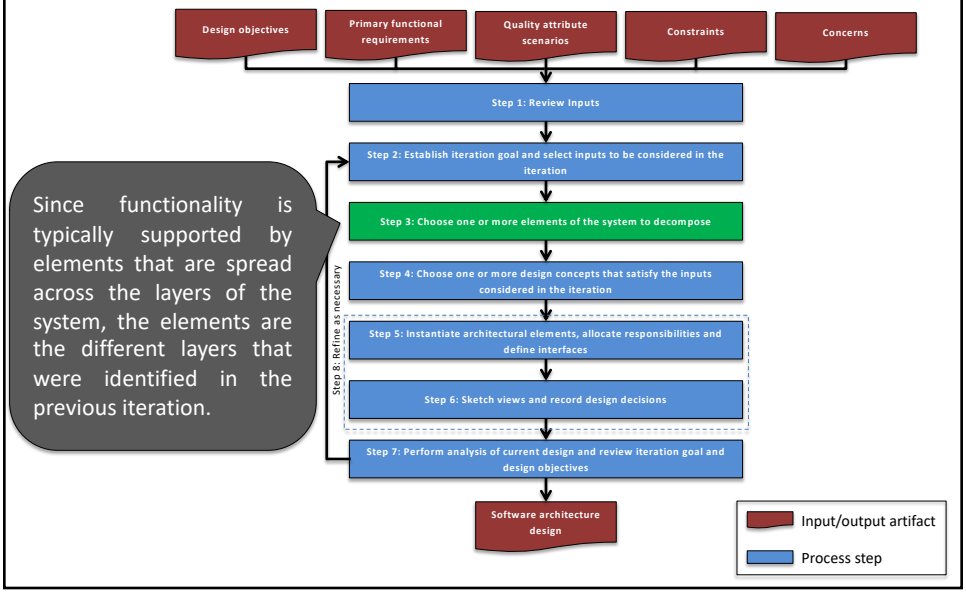
ADD: Iteration 2



Since functionality is typically supported by elements that are spread across the layers of the system, the elements are the different layers that were identified in the previous iteration.

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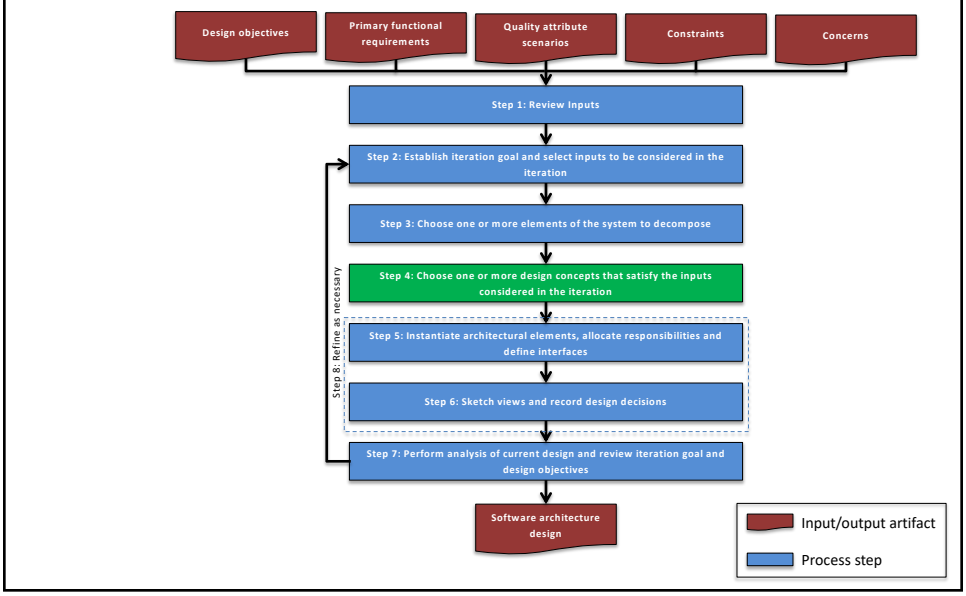
ADD: Iteration 2



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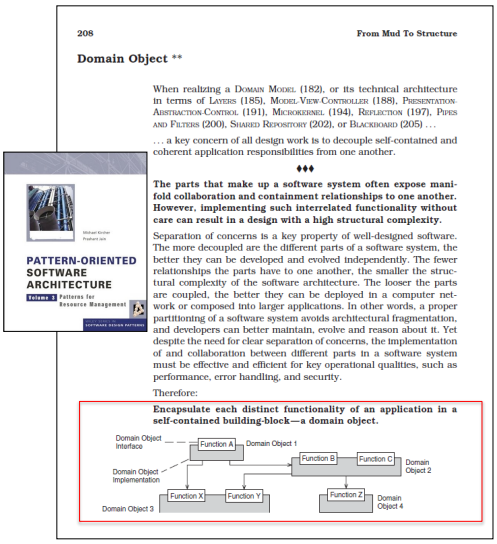
Selection of design concepts

- Design concepts
  - Domain objects
  - Externally developed components

Design decision	Rationale
Use domain objects (e.g. components) to decompose layers	Decomposition of the layers facilitates work assignment and associating technologies to components
Use Swing Framework for UI	Developers are familiar with this framework (CON-10)
Use Hibernate for OR Mapping	- CON-10 - New Database (not legacy)



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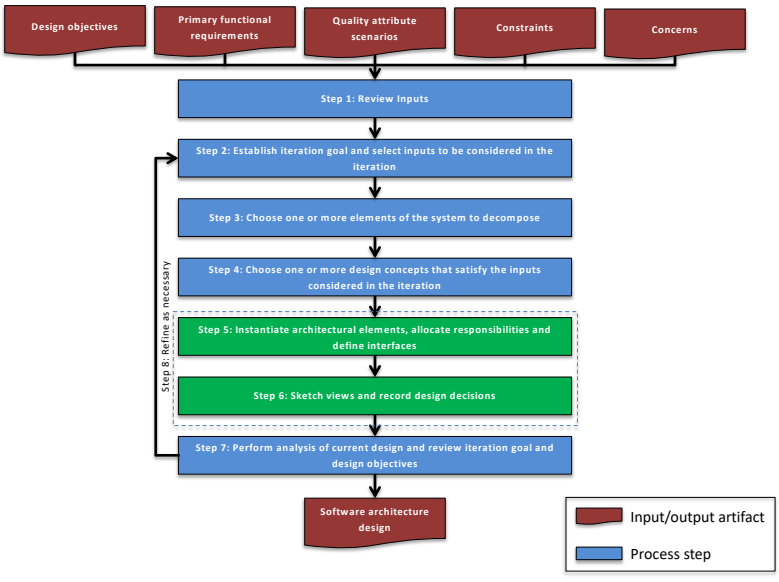
ADD: Iteration 2



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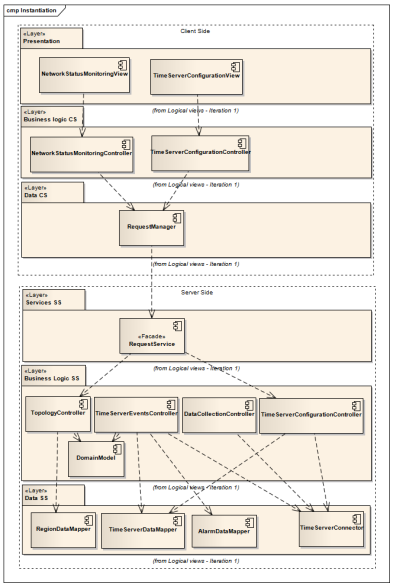
Step 5

- Logical view

Element	Responsibility	Properties
NetworkDeviceConnector	Communicate with network devices and isolate the rest of the system from specific protocol	
NetworkDeviceEventController	Process events that are received from the network devices	
Topology Controller	Provides access to the network topology information and changes in it	Type = stateless
Region Data Mapper	Manage persistence of Regions	Framework = Hibernate
NetworkStatusMonitoringView	Display the network topology and events that occur on the devices	Framework = Swing



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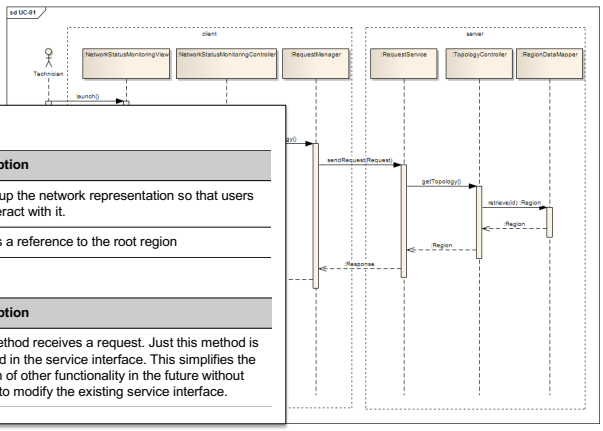
Step 5: Interfaces

- Once the elements have been identified, dynamic analysis allows interfaces to be defined
  - UC-1



NetworkStatusMonitoringContoller

Method name	Description
boolean initialize()	Opens up the network representation so that users can interact with it.
Region getRootRegion()	Returns a reference to the root region

RequestService:

Method name	Description
Response sendRequest(Request)	This method receives a request. Just this method is exposed in the service interface. This simplifies the addition of other functionality in the future without having to modify the existing service interface.

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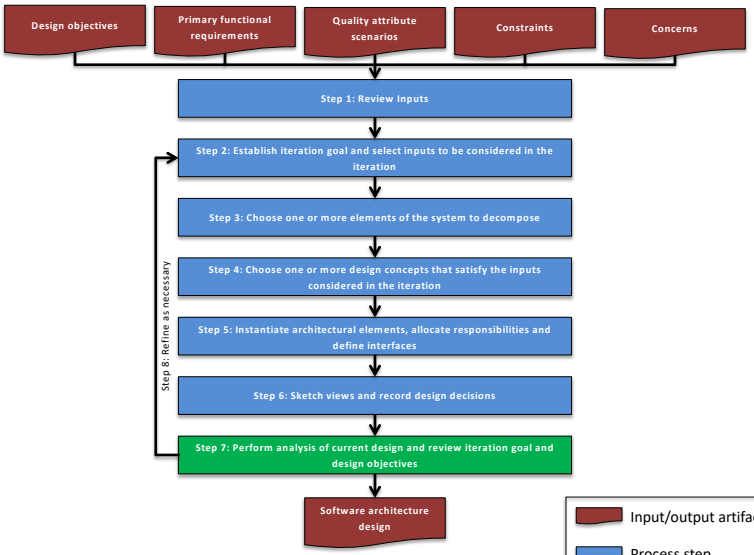
ADD: Iteration 2



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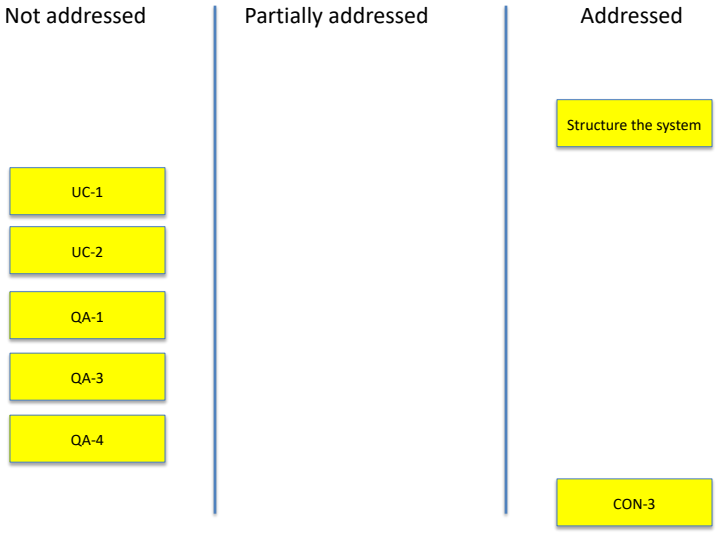
Step 7: Design Kanban board



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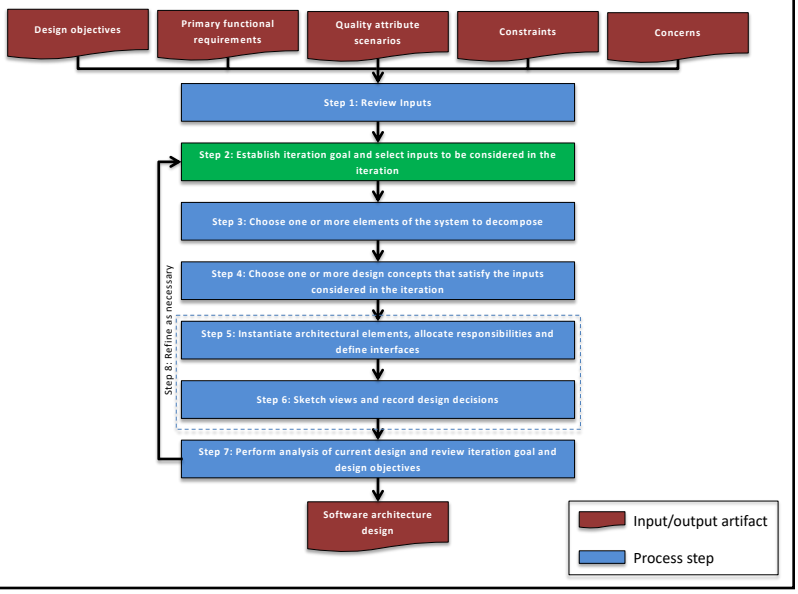
ADD: Iteration 3



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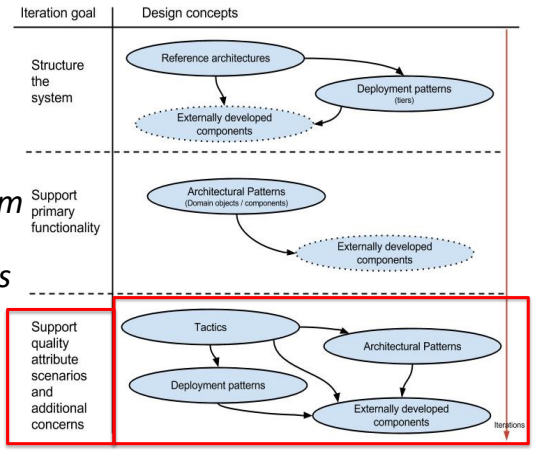
Iteration goal and inputs

- Iteration goal:
  - Address quality attribute QA-3: *A failure occurs in the network management system during operation. The system resumes operation in less than 30 seconds.*



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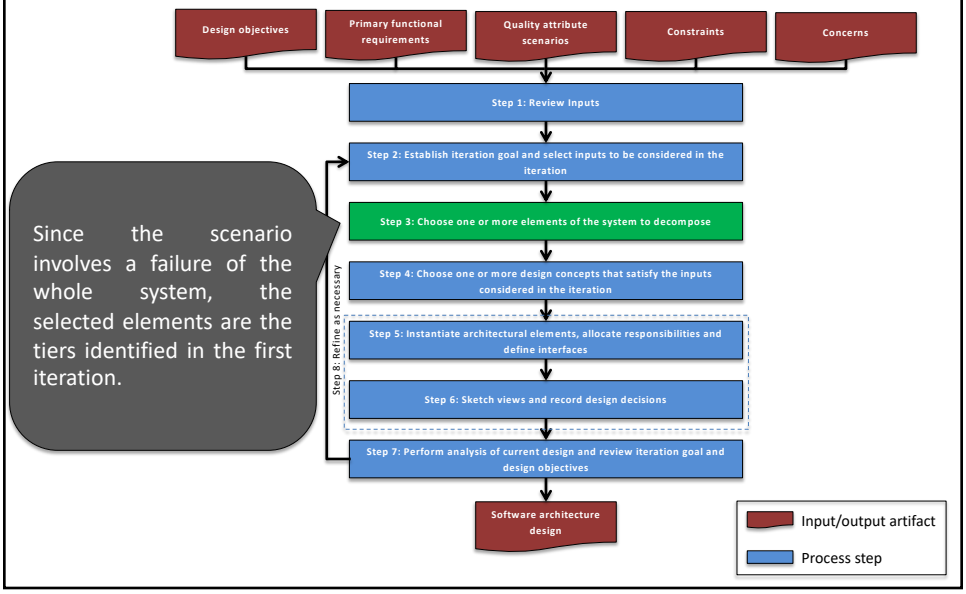
ADD: Iteration 3



Since the scenario involves a failure of the whole system, the selected elements are the tiers identified in the first iteration.

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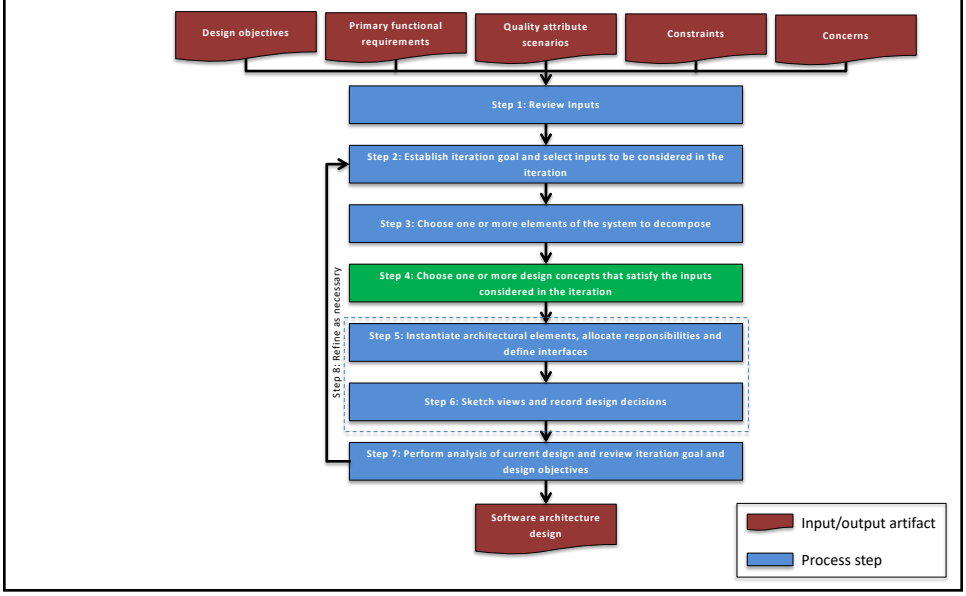
ADD: Iteration 3



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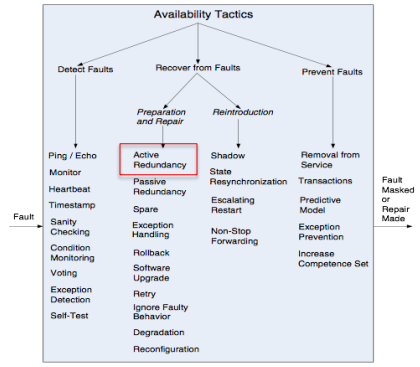
Step 4

- It is recommended to start with tactics and from there go to patterns or technologies



Design decision	Rationale
Introduce active redundancy by replicating the application server and other critical components such as the database	By replicating the critical components, the system can withstand the failure of one of the replicated elements without affecting functionality.
Implement redundancy using Apache + mod_proxy	Apache serves as the point of entry, mod_proxy serves as load balancer

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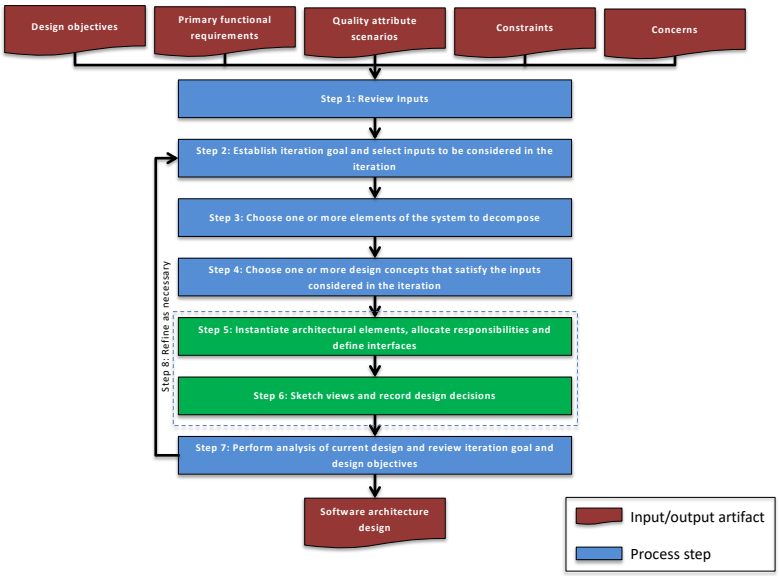
ADD: Iteration 3



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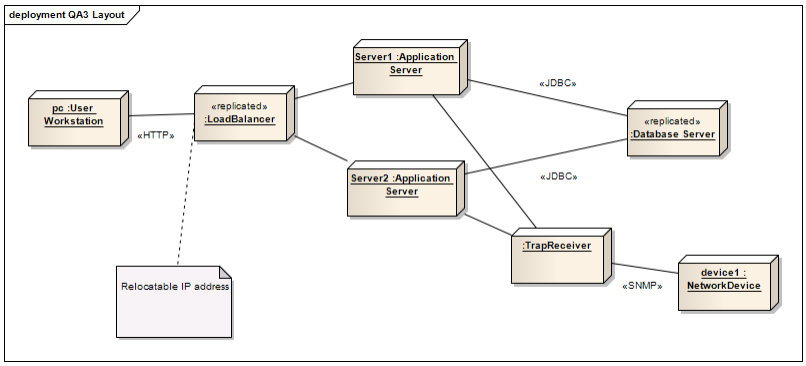
Step 5



Element	Responsibility	Properties
TrapReceiver	Receive traps from network devices, convert them into events and put these events into a message queue	Framework = SNMP4J
…	…	…

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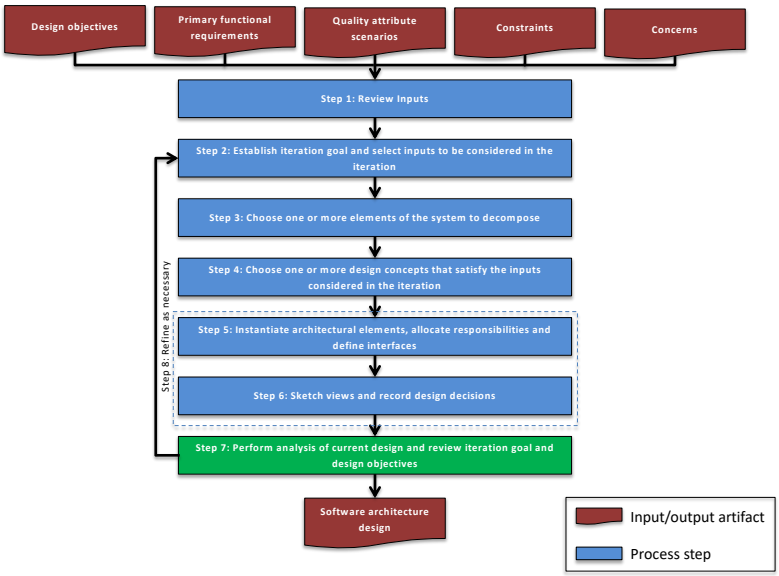
ADD: Iteration 3



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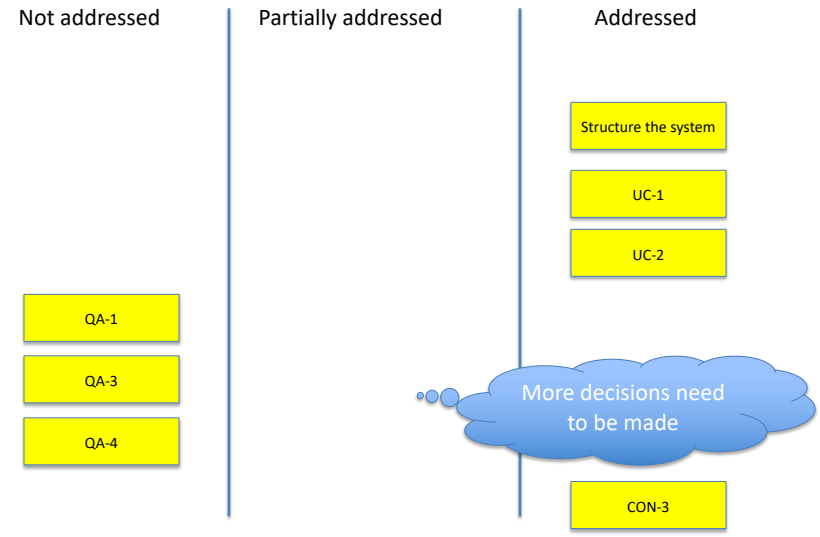
Step 7: Design Kanban board



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Design Process Termination Criteria

- The design process continues across several iterations:
  - until design decisions have been made for all of the driving architectural requirements (design goal reached); or
  - until the most important technical risks have been mitigated; or
  - until the time allotted for architecture design is consumed (not very desirable!).

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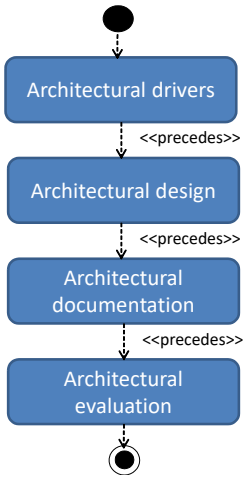
Additional aspects

- Creating prototypes as part of the design process is recommended
- Creating documentation and performing architectural evaluation can be performed more easily if the ADD steps were performed systematically



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Summary

- Architecture design transforms drivers into structures.
- Architectural drivers include functional requirements, quality attributes and constraints but also objectives, concerns and the type of system
- ADD is a method that structures architecture design so it may be performed systematically.
- Design concepts are building blocks from which the design is created. There are several important types: Reference Architectures, Deployment patterns, Architectural Patterns, Tactics, and Externally developed components such as frameworks.
- ADD can be performed in an agile way by using initial documentation (sketches) and a design kanban board to track design advancement

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Thank you

- **Questions?**

- Rick Kazman kazman@sei.cmu.edu
- Humberto Cervantes hcm@xanum.uam.mx

- Don’t miss the *Smart Decisions: An Architecture Design Game* session! (Wednesday, 11:00)

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