Systems Architectures

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Architecture

- The word "architecture" is derived from the Greek word "architecton", which means master mason or master builder
- Webster's Dictionary defines architecture as:
- The art or science of designing or building structures
- The structure (in terms of components, connections, and constraints) of a product, process, or element – The Art of Systems Architecting
- An Architecture is the highest-level concept of a system in its environment - IEEE

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Architecture

- Architecture – The fundamental organization of a system embodied in its components, their relationships to each other and to the environment and the principles guiding its design and evolution - P141 Standard
- Systems Architecture – The fundamental and unifying system structure defined in terms of system elements, interfaces, processes, constraints, and behaviors – INCOSE SAWG
- Architecture – The organizational structure of a system of CSCIs, identifying its components, their interfaces and a concept of execution among them

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Architecture

- The architecture of a system defines its high-level structure, exposing its gross organization as a collection of interacting components.
- Components needed to model a software architecture include:
  - **Components, Connectors, Systems, Properties and Styles.**

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IT Architecture Concepts

- **Components**
  - The computational elements and data stores of the system
  - May have multiple interfaces, called ***ports***
  - ***Ports*** define a point of interaction between a component and its environment
- **Connectors**
  - Model interactions among components
  - Runtime perspective: connectors mediate the communication and coordination activities between components
  - Connectors may have interfaces that define the ***roles*** played by the participants in the interaction

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IT Architecture Concepts

- **Systems**
  - Graphs of components and connectors
  - Tend to be hierarchical – components and connectors may represent ***subsystems*** that have their own internal architectures
  - ***Bindings*** map the interfaces of one level of a system to another
- **Properties**
  - Represent the non-structural information about the parts of an architecture description
  - *Example:* a connector can be a function call, or a network interaction
  - Properties can be attached to any architectural element

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IT Architecture Concepts

- **Style**
  - An architectural style represents a family of related systems
  - Defines the design vocabulary (and constraints) for the components, connectors, ports, roles, bindings and properties.

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System Architect

- The architect is a member of the team that is responsible for designing and building a system
- The architect's contribution comes in the very early stages of the systems engineering process
  - When the operational concept is defined
  - The basic structure of the system is conceptualized
- A system architect, not only knows about the individual components, but also understands the interrelationships among the components

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Systems Architecting

- Systems Architecting has been defined as the process of creating complex, unprecedented systems
- Building systems in today's world is tenuous at best
  - Requirements of the marketplace are ill-defined
  - Rapidly evolving technology provides new services at a global level instantly
  - Uncertainty is increasing about they way the system will be used, the components that will be incorporated and the interconnections that will be made

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Systems Architecting - 2

- Generating a system architecture as part of the systems engineering process can be seen as a deliberate approach to deal with the uncertainty that characterizes these complex, unprecedented systems

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Traditional Approach to System Architecting

- Many methodologies have been developed to support a traditional system development model
  - Define the requirements
  - Consider several options
  - Emerge with a well-defined design through a process of elimination
  - Based on structured analysis and design

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Traditional Approach to System Architecting - 2

- Effective when the requirements are well defined and remain essentially constant during the system development period
  - Cannot handle change well
    - If the implementation of the system is long – on the order of years – the requirements change because of changing needs and new technology offers different alternatives and opportunities

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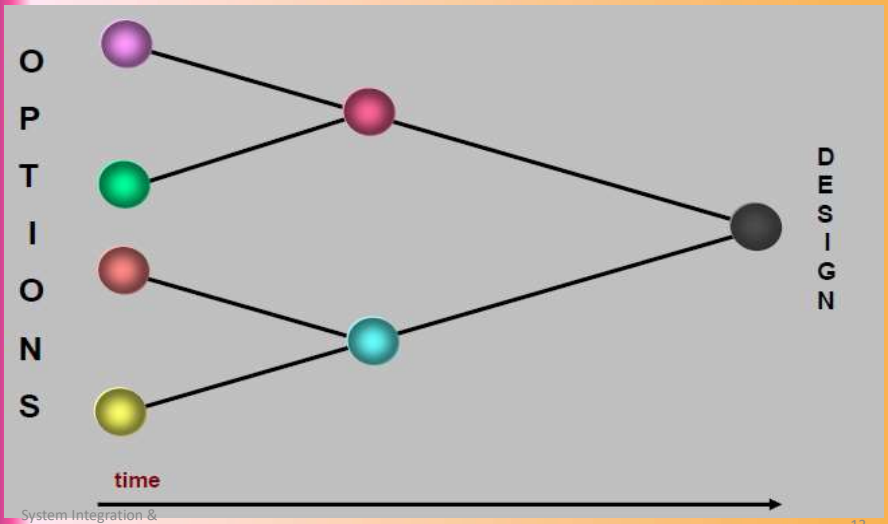
The Traditional Approach



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Evolutionary Approach

- New approach that is emerging with roots in software systems engineering
- Deals with uncertainty in requirements and in technology, especially for systems with a long development time and expected long life cycle
  - Evolutionary development
  - Build-a-little, Test-a-little
- Requirements are allowed to be more abstract and therefore subject to interpretation
- Alternative solutions are explored and pursued further as new technology options become available

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Evolutionary Approach - 2

- Intermediate designs are saved
- Some intermediate designs are implemented as prototypes but not operationally implemented while others are implemented in traditional ways
- Advantages of Object-Oriented approach:
  - Allows flexibility in the design as it evolves over time
- Disadvantages of Object-Oriented approach:
  - Requires some early elimination of technology alternatives in the absence of reliable information

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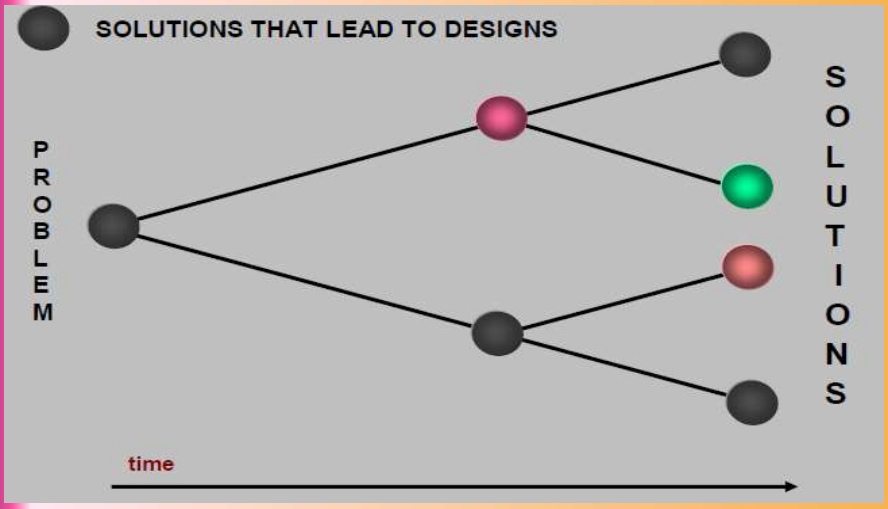
Evolutionary Approach



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Select, Build, and Field

- At any time in the development process, when there is a need to build a system, the available solution that best meets the current requirements is selected and implemented using any systems engineering approach

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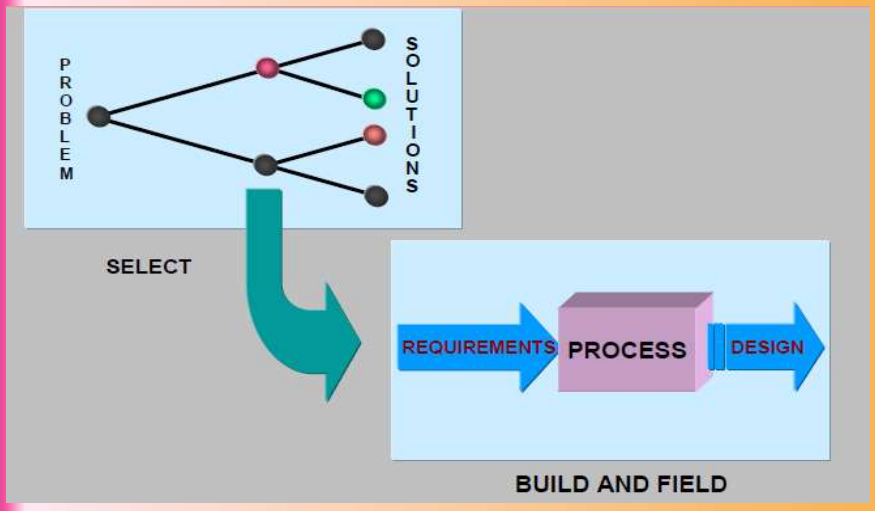
Select, Build, and Field



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The Challenge of Coping With Change

- If the implementation is long, then the situation shown next prevails, with the unfortunate consequences that very little, if any, from the work on Option A is used for Option B

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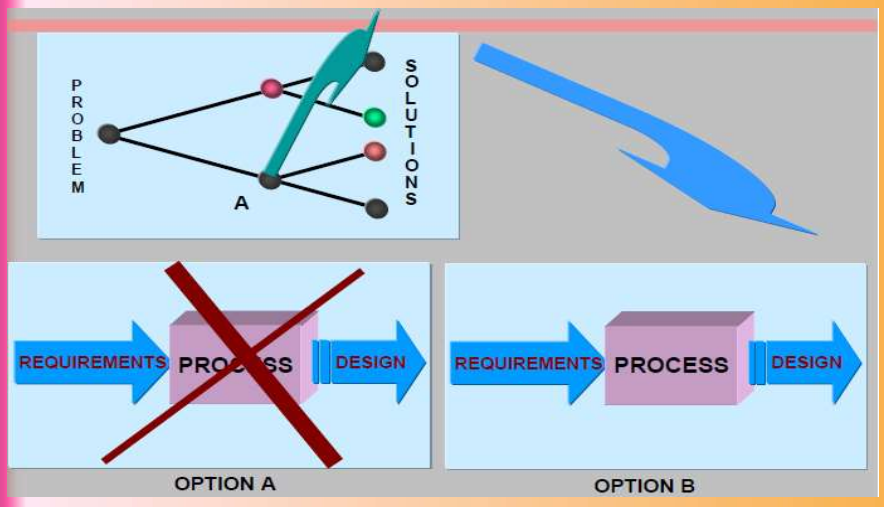
The Challenge of Coping With Change



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How to Define an Architecture

- Defining an architecture, especially of an information system, requires the following items to be described:
  - Processes exist that need to take place in order that the system accomplish its intended functions
  - The individual processes transform either data or materials that "flow" between them
  - The processes or activities or operations follow rules that establish the conditions under which they occur
  - The components that will implement the design (hardware, software, personnel, and facilities must be described)

How to Define an Architecture - 2

- Define the Functional Architecture
  - A functional architecture is:
    - A set of activities or functions that are arranged in a specific order and when activated, achieves a set of requirements
    - Divide and allocate the functional requirements into different sub-functions and modes of operation

How to Define an Architecture - 3

- Define the Physical Architecture
  - A physical architecture is:
    - A representation of the physical resources
    - Expressed as nodes that constitute the system and their connectivity
    - Expressed in the form of links

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How to Define an Architecture - 4

- Define the technical architecture
  - A minimal set of rules governing the arrangement, interaction, and interdependence of the parts or elements that must ensure that a conformant system satisfies a specified set of requirements
  - Provides the framework upon which engineering specifications can be derived, guiding the implementation of the system
  - Analogous to the building code that provides guidance for new buildings to be able to connect to the existing infrastructure by characterizing the attributes of that infrastructure

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Operational Concept

- An important task in the architecture development process is to define the operational concept
  - A concise statement that describes how the goal will be met
  - How will the system look and act in the operational environment
- Operational Concept Definition Parts
  - How the system operates
  - Where in the operating environment the system will be distributed
  - How long the system must operate
  - How effective the system's performance must be

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Operational Concept - 2

- An operational concept is a shared vision from the perspective of the system's stakeholders of how the system will be:
  - Developed
  - Produced
  - Deployed
  - Trained
  - Used and maintained
  - Refined
  - Retired

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Operational Concept - 3

- The operational concept includes a collection of scenarios – one for each group of stakeholders for each relevant phase of the system's lifecycle
  - Each scenario addresses one way that a particular stakeholder will want to use, deploy, fix, etc., the system and how the system will respond to a produce a desired end
  - Scenario - a sequence of events which might occur that includes the interaction of the product with its environment and users, as well as the interaction among its product components

Executable Model

- The functional, physical, and technical architectures are static representations that attempt to describe the dynamic behavior of the architecture
- In order to analyze the behavior of the architecture and evaluate the performance characteristics, an executable model is needed

Architecture Development Process

- The architecture development process consists of three phases:
  - Analysis Phase – The static representatives of the functional and physical architectures are obtained using the operational concept to drive the process and the technical architecture to guide it
  - Synthesis Phase – The static constructs are used, together with descriptions of the dynamic behavior of the architecture to obtain the executable operational X-architecture (X = executable property)
  - Evaluation Phase – Measures of performance (MOP) and measures of effectiveness (MOE) are obtained

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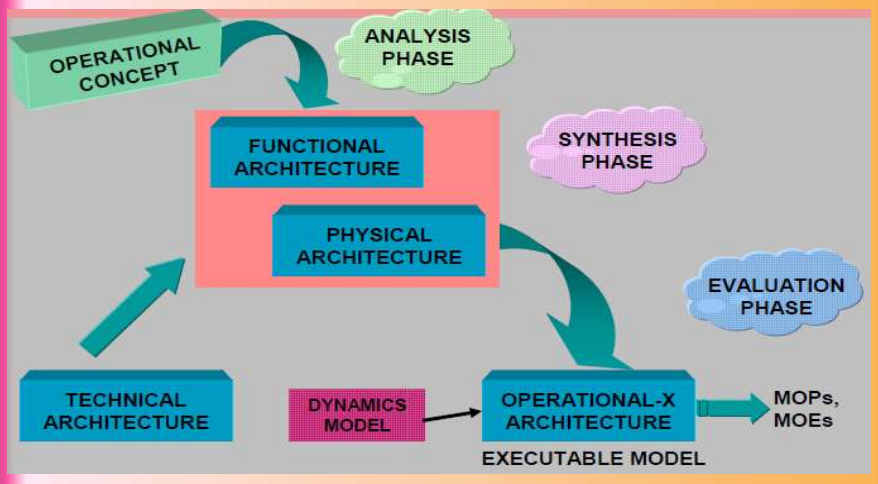
The Three-Phase Process of Architecture Development



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Summary

- Architecture – The fundamental organization of a system embodied in its components, their relationships to each other and to the environment and the principles guiding its design and evolution
- A system architect, not only knows about the individual components, but also understands the interrelationships among the components

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Summary - 2

- A functional architecture is:
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- A physical architecture is:
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Summary - 3

- An important task in the architecture development process is to define the operational concept
  - A concise statement that describes how the goal will be met
  - How will the system look and act in the operational environment
- A technical architecture is a minimal set of rules governing the arrangement, interaction, and interdependence of the parts or elements that must ensure that a conformant system satisfies a specified set of requirements

Summary - 4

- The functional, physical, and technical architecture are static representations that attempt to describe the dynamic behavior of the architecture
- In order to analyze the behavior of the architecture and evaluate the performance characteristics, an executable model is needed