

System Integration & Architecture

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Lecture 1&2

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

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

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.**

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

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

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.

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

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 the way the system will be used, the components that will be incorporated and the interconnections that will be made

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

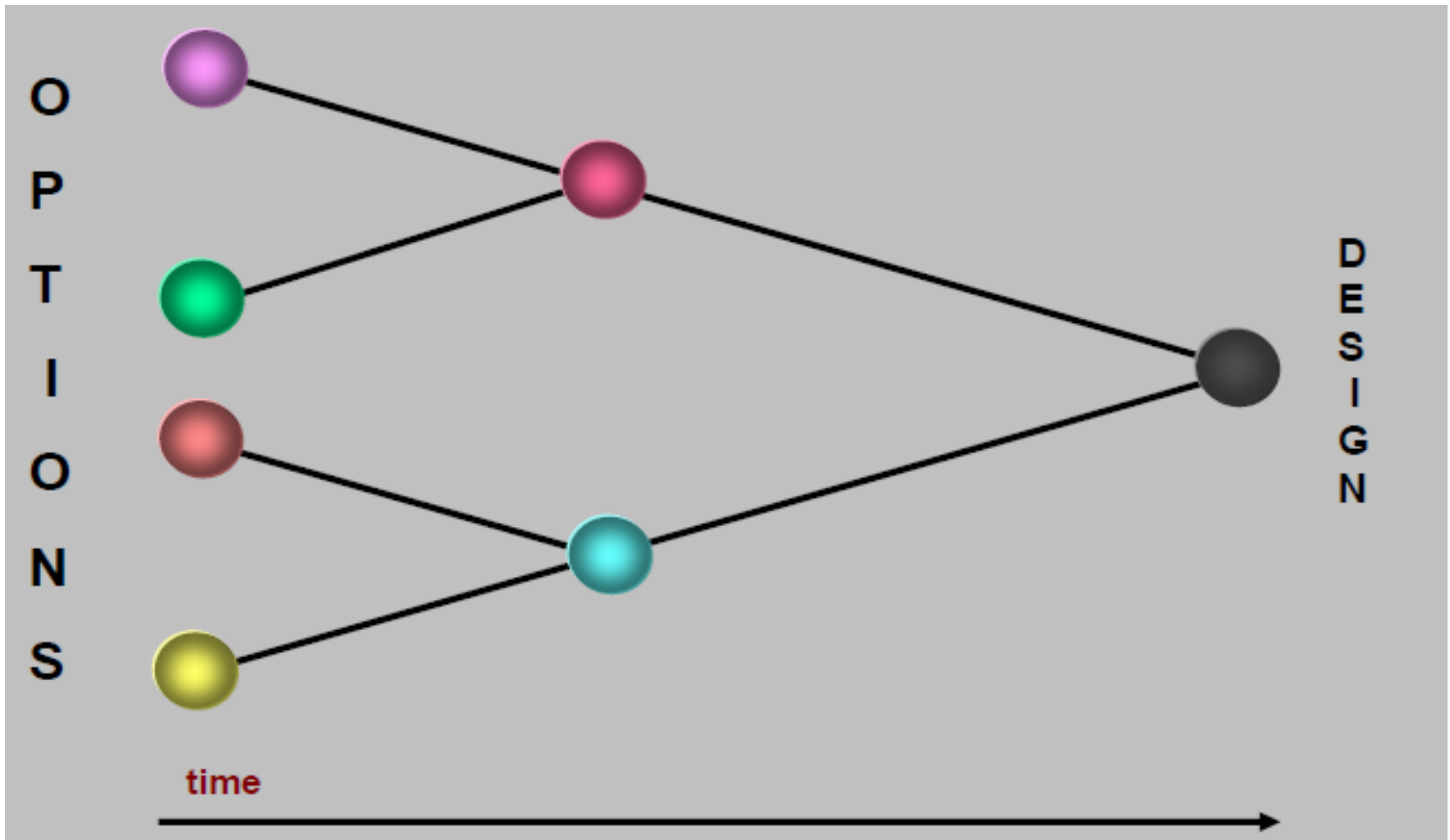
Traditional Approach to System Architecting

- 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

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

The Traditional Approach



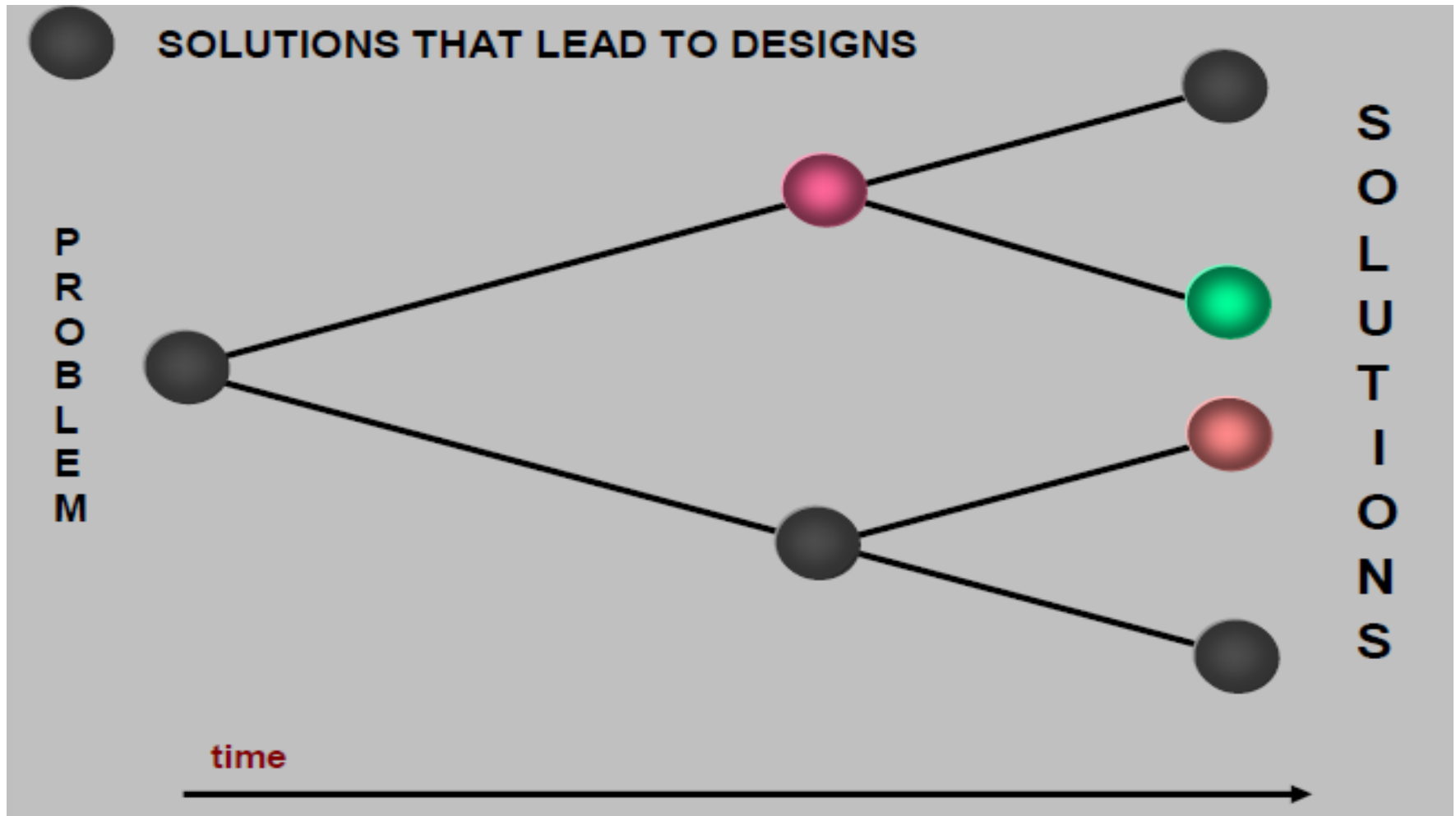
Evolutionary Approach

- 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

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

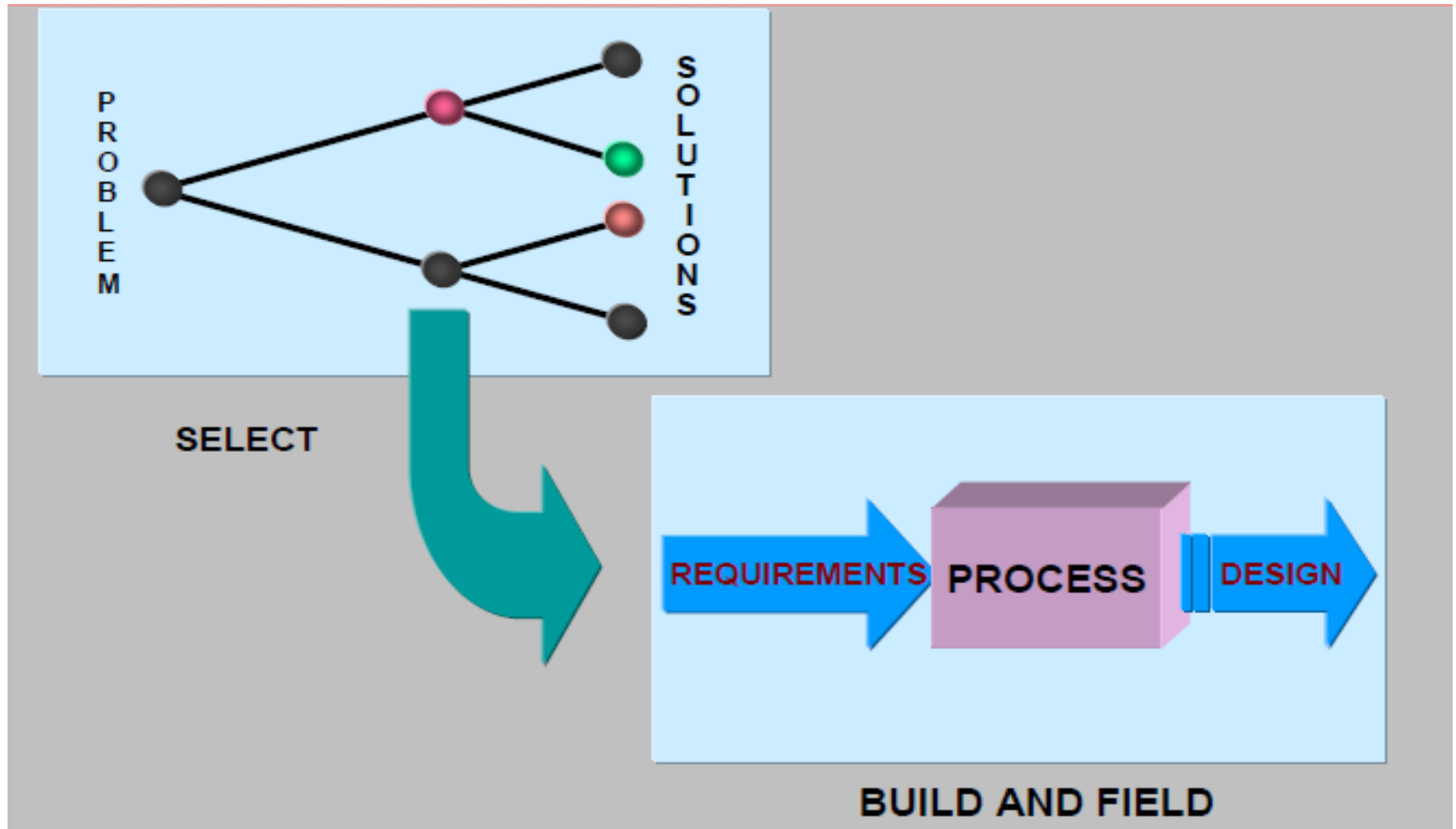
Evolutionary Approach



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

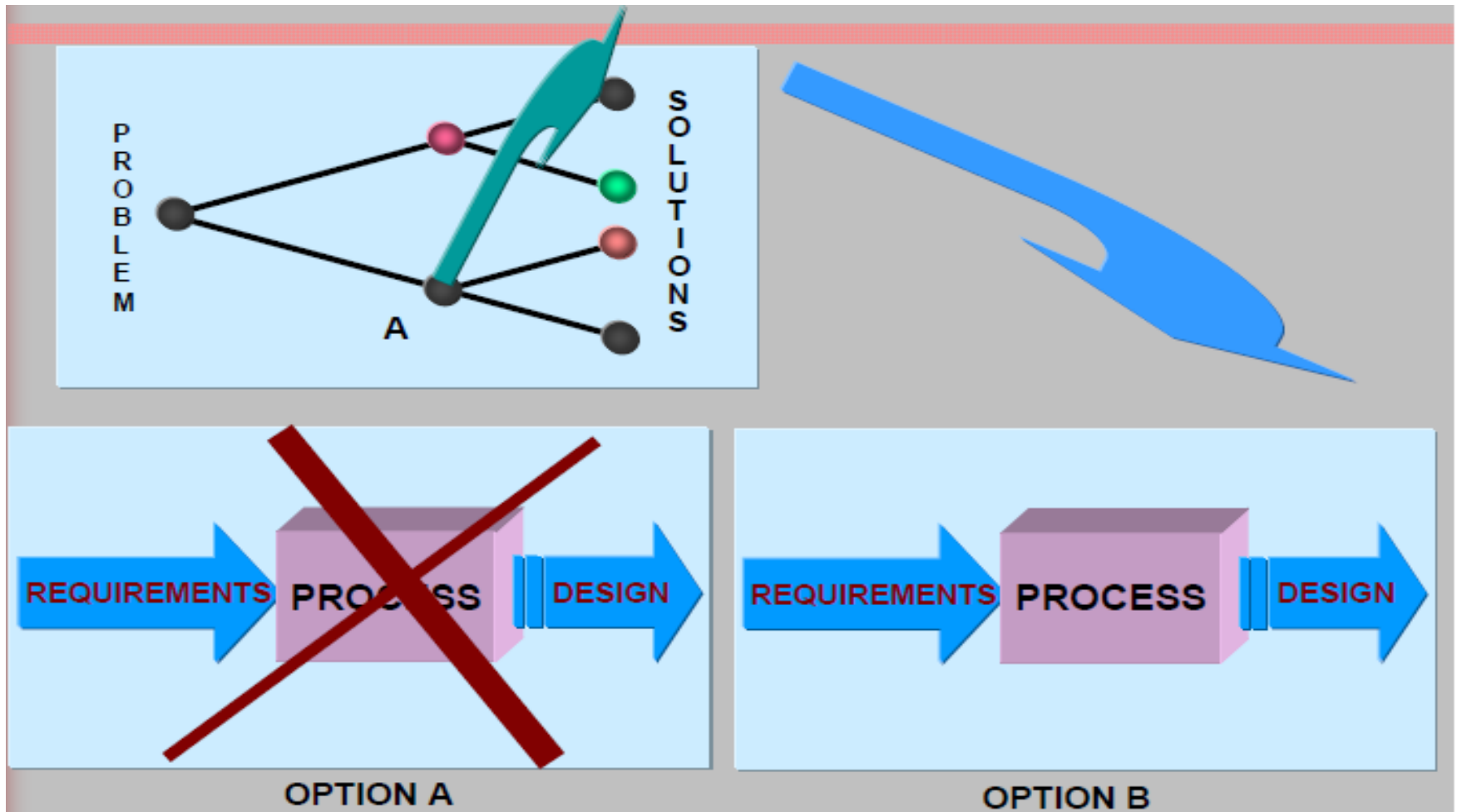
Select, Build, and Field



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

The Challenge of Coping With Change



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

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

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

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

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

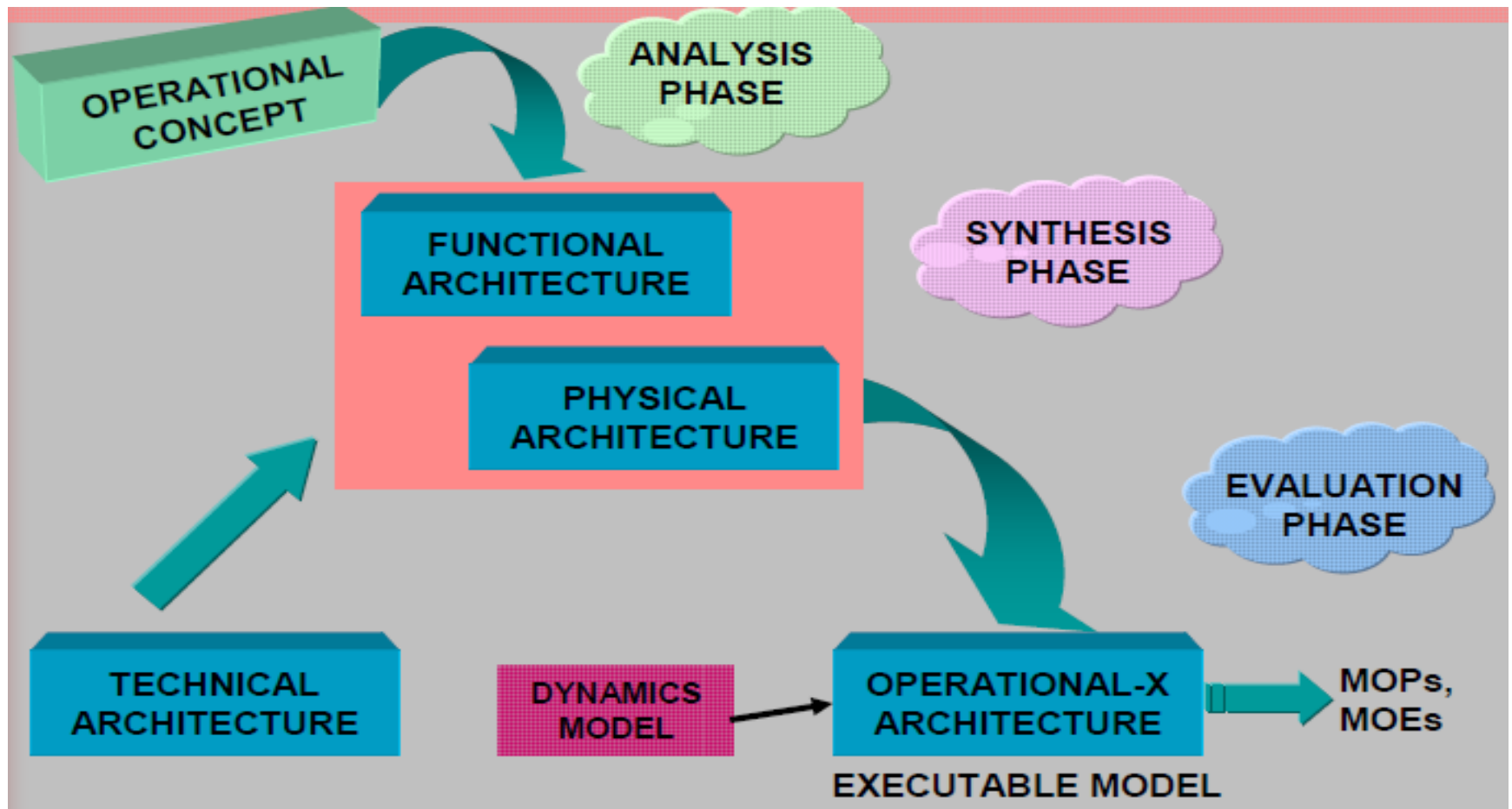
Executable Model

- 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

The Three-Phase Process of Architecture Development



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

Summary - 2

⌘ 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

⌘ 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

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