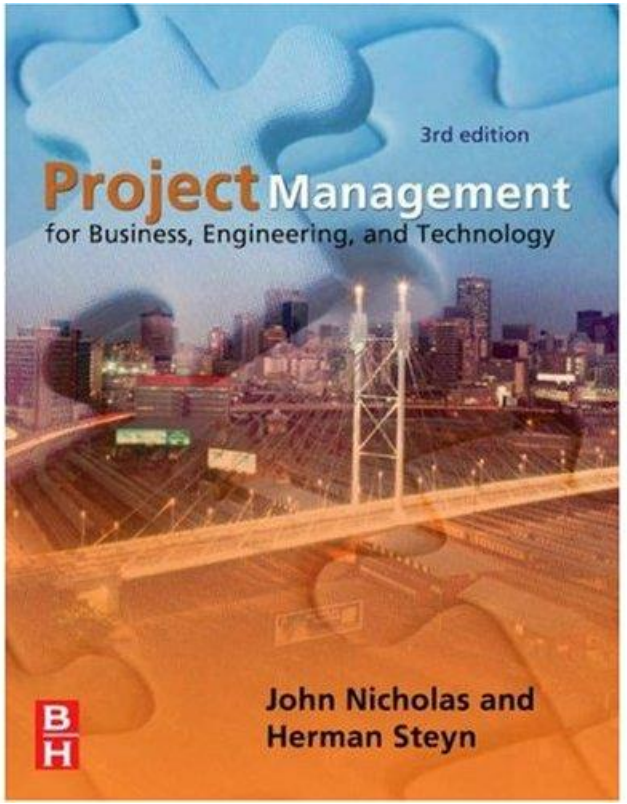
Chapter 2
Systems Approach and Systems Engineering

Project Management for Business, Engineering, and Technology



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Definition of System

A system is an organized or complex whole; *a group of parts interacting in a coordinated way*.

1. The parts of the system *affect the system* and *are affected* by it

2. The group of parts *does* something

3. The group is of particular interest

System Concepts and Principles

Natural versus Human-Made Systems

- Natural systems came into being by natural processes (e.g., animal organisms and planetary systems).
- Human-made systems are designed and operated by people (e.g., communication systems and human organizations).
- Projects exist for the purpose of creating or enhancing human-made systems (or altering natural systems).

System Concepts and Principles

Goals and Objectives

- Human-made systems are designed to *do* something; they have goals and objectives that are conceived by people.
- In designing a human-made system, the place to start is by defining the goal of the system and a hierarchy of objectives that relate to the aspects the system.

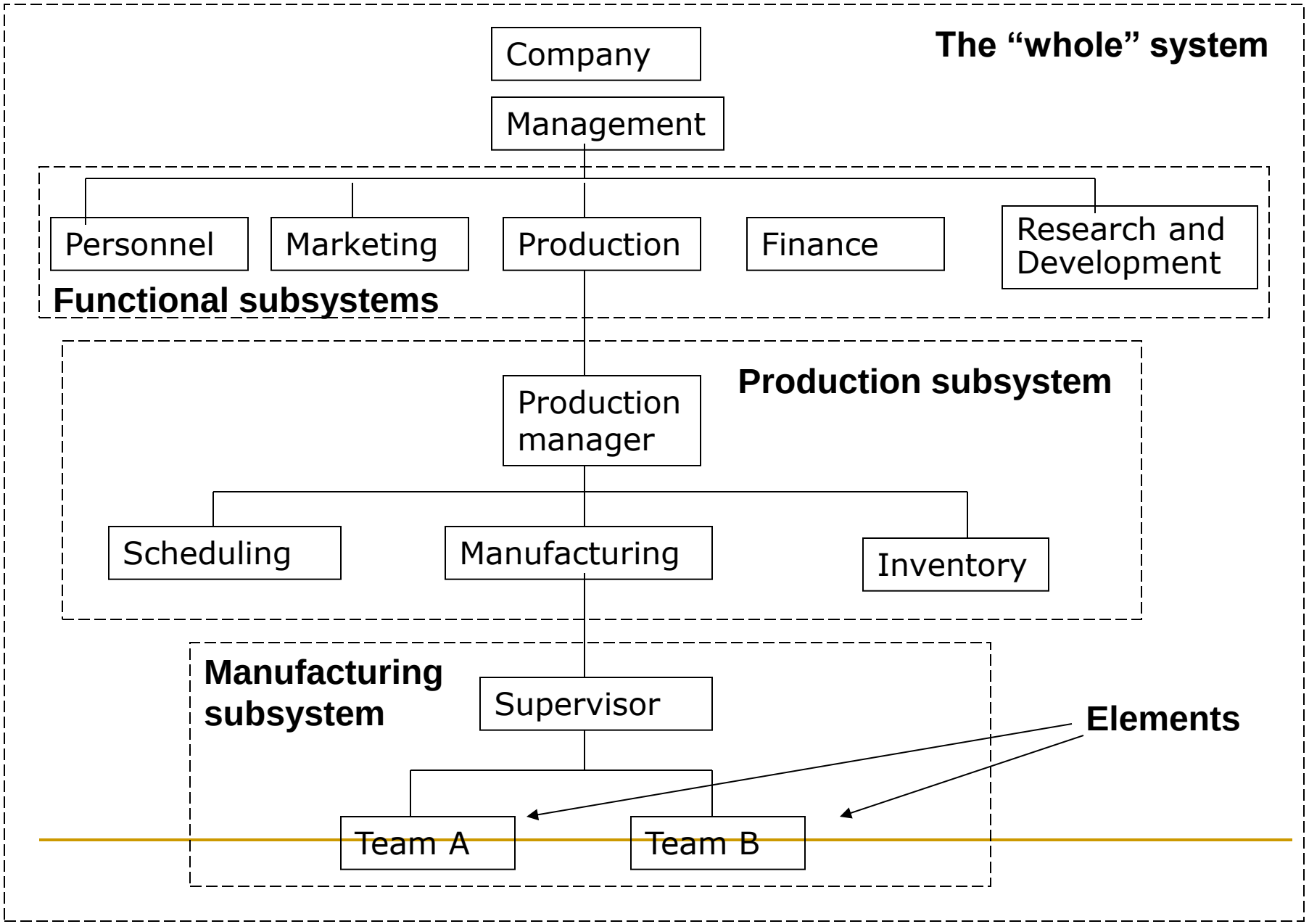
System Concepts and Principles

Elements and Subsystems

- Systems can be broken down into smaller parts.
- These parts in combination form “the assemblage of parts” that constitutes the system.
- The smallest part of a system is an *element*.
- The parts of the system might themselves also be systems; these are called *subsystems*.

  A subsystem is a system that functions as a component or part of a larger system.

A Company as a System



System Concepts and Principles

Attributes

- Systems, subsystems, and elements each have distinguishing characteristics called *attributes*
- These describe or express the condition of system, subsystem, or element in qualitative or quantitative terms.
- In human-made systems, many of the attributes are *designed into* the system so that the system performs as required.

System Concepts and Principles

Environment and Boundary

- The *environment* refers to anything that influences the behavior or outcome of the system yet lies beyond the decision maker's or stakeholder's ability to control
- The system is separated from its environment by a *boundary*. The boundary might be somewhat obscure, and it might be difficult to distinguish the system from its environment.

System Concepts and Principles

In order to distinguish the system from its environment ask two questions:

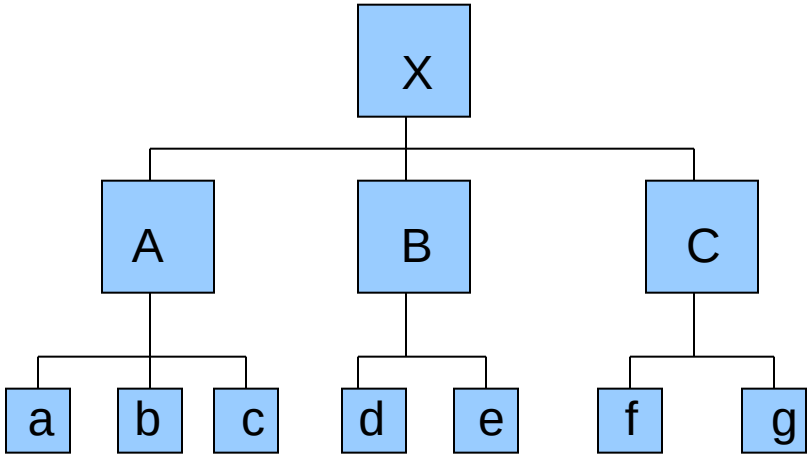
Can the decision maker control it?	Is it relevant to the system? Yes	No
Yes	System	The Irrelevant Environment
No	Environment	

System Concepts and Principles

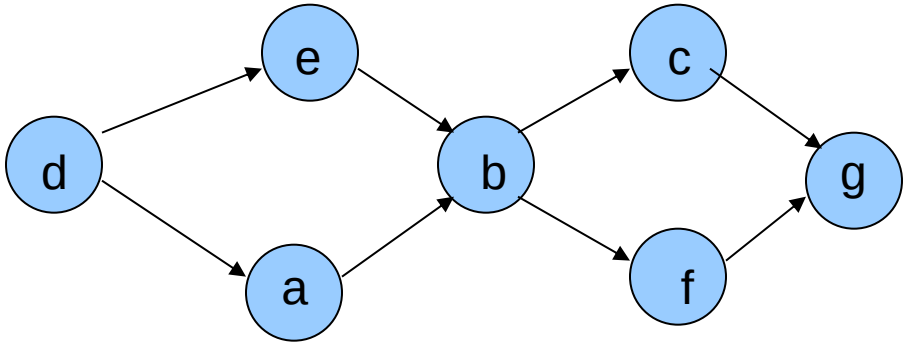
System Structure

- Elements and subsystems are linked together by relationships. The form of the relationships is referred to as the *structure* of the system.
- Most systems, including projects, can be conceptualized as hierarchical and network systems.

Hierarchical structure



Network structure



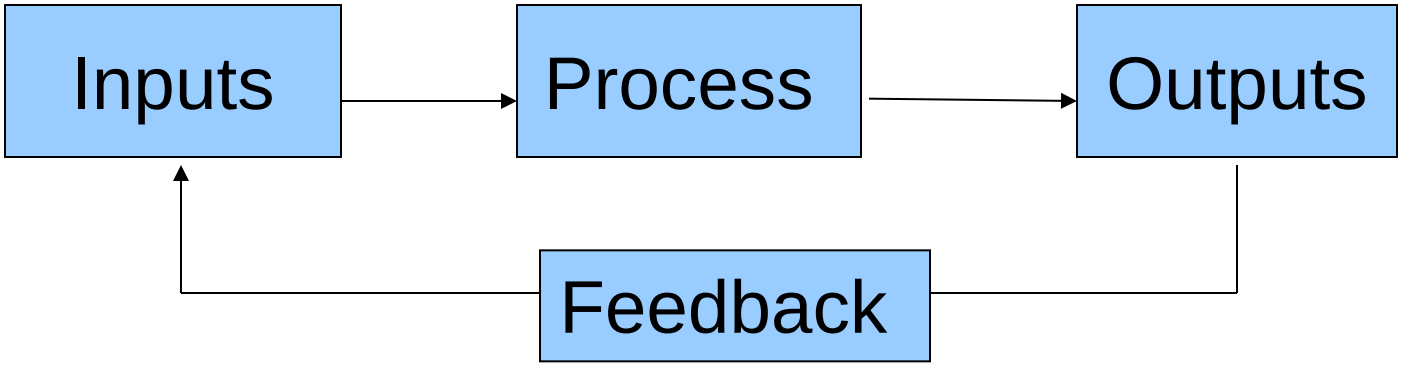
Two ways of conceptualizing a project

System Concepts and Principles

Inputs, Process, Outputs

- Human-made systems achieve objectives by converting *inputs* into *outputs* through a defined *process*.
- *Outputs:* end-result of a system and the purpose for which the system exists.
- *Inputs:* the raw materials, resources, or prior steps necessary for the system to operate, produce outputs, and meet objectives.
  - *Feedback:* Input that originates from the system itself.
- *Process:* means by which the system transforms inputs into outputs.
  - One goal of *system design* is to create a process that produces the desired outputs and meets system objectives effectively, and minimizes consumption of inputs and production of wasteful outputs.

Input-process-output relationship



System Concepts and Principles

Constraints and Conflicts

- Systems *constraints* are limitations that inhibit the ability of a system to reach goals and objectives. Time and money are two universal constraints.
- In human-made systems, the objectives of the subsystems sometimes *conflict* with each other, which reduces the ability for them or the overall system to realize their objectives.
- Removing conflict between the objectives of subsystems to enable the overall system to meet its objectives is called *integration*.

System Concepts and Principles

Integration

- For a system to perform effectively and achieve its goal, all of its elements must work in unison.
- Designing, implementing, and operating a system to achieve pre-specified objectives and requirements through the coordinated functioning of its elements and subsystems is called *system integration*.

System Concepts and Principles

Open Systems and Closed Systems

- A *closed system* is one that is viewed as self-contained; “closed-systems thinking” means to focus on the operation, structure, and processes of a system without regard to the environment.
- An *open system* interacts with and adapts to its environment.
- Any system that must be adaptable to its environment must be treated as an open system.
- Human organizations and social systems are open systems.

Systems Approach

The systems approach

- Acknowledges that the behavior of any one element affects the behavior of others and that no single element can perform effectively without help from the others.
- Recognizes *interdependencies* and *cause-effect* relationships among elements.

Systems Approach (cont'd)

- Retains attention on the overall system and the ultimate goal
  - Allows focus on the parts, but only in regard to their contribution to the whole system
- Avoids actions that focus *exclusively* on parts of the system, since such actions are suboptimal for the total system.

Systems Approach Methodology

The *systems approach* is a *methodology* for solving problems and managing systems that accounts for

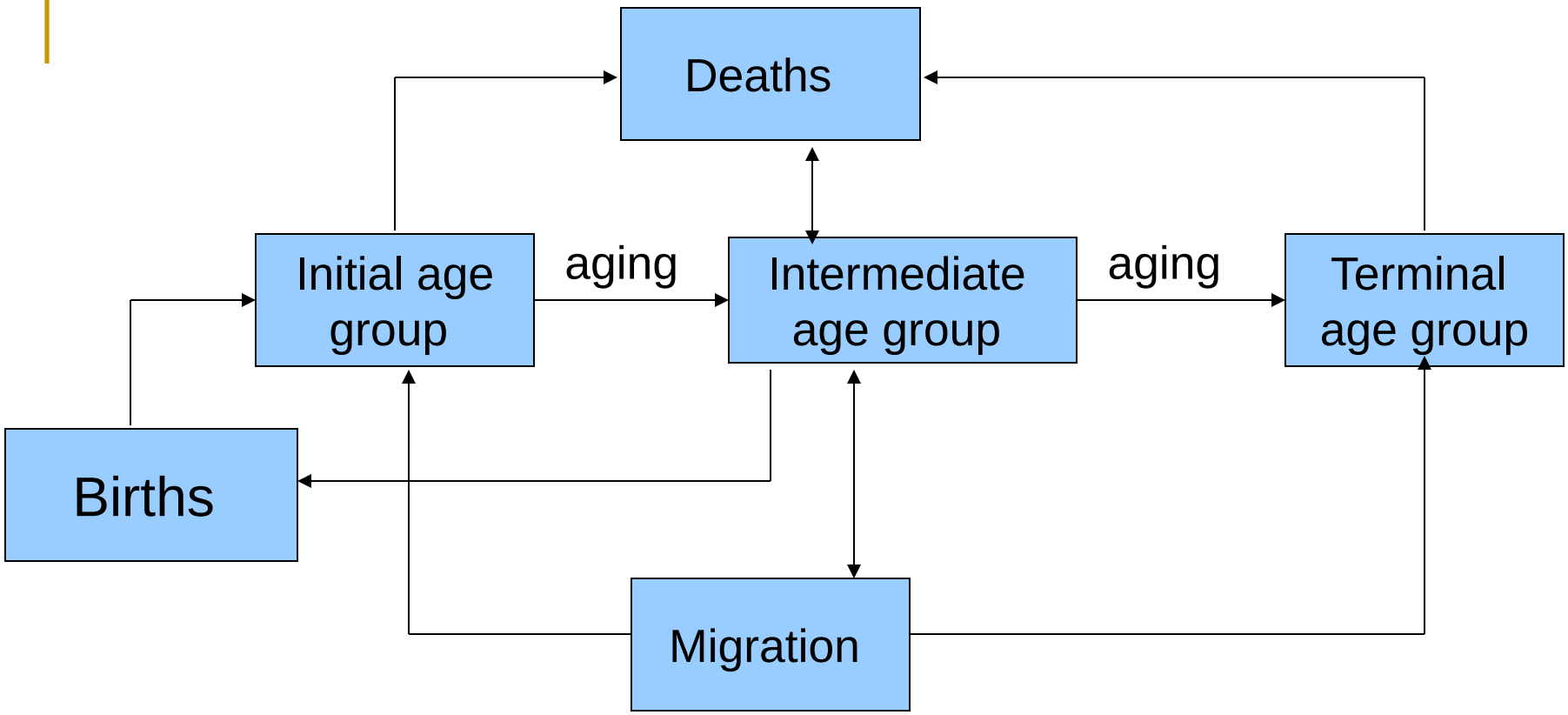
1. The *objectives* and the *performance criteria* of the system.
2. The *environment* and *constraints* of the system.
3. The *resources* of the system.
4. The *elements* of the system, their functions, attributes, and performance measures.
5. The *interaction* among the elements.
6. The *management* of the system.

The methodology commonly employs ***models***

System Models

- A *model* is a simplified representation of the world; it abstracts the essential features of the system under study.
- A *physical model* is a scaled-down abstraction of the real system. It includes some aspects of the system and excludes others.
  - Example: model airplane.
- A *conceptual model* depicts the elements, structure, and flows in a system in terms of a schematic diagram or mathematical formulation.
  - Example: population dynamics schematic (next)

Conceptual model of population dynamics



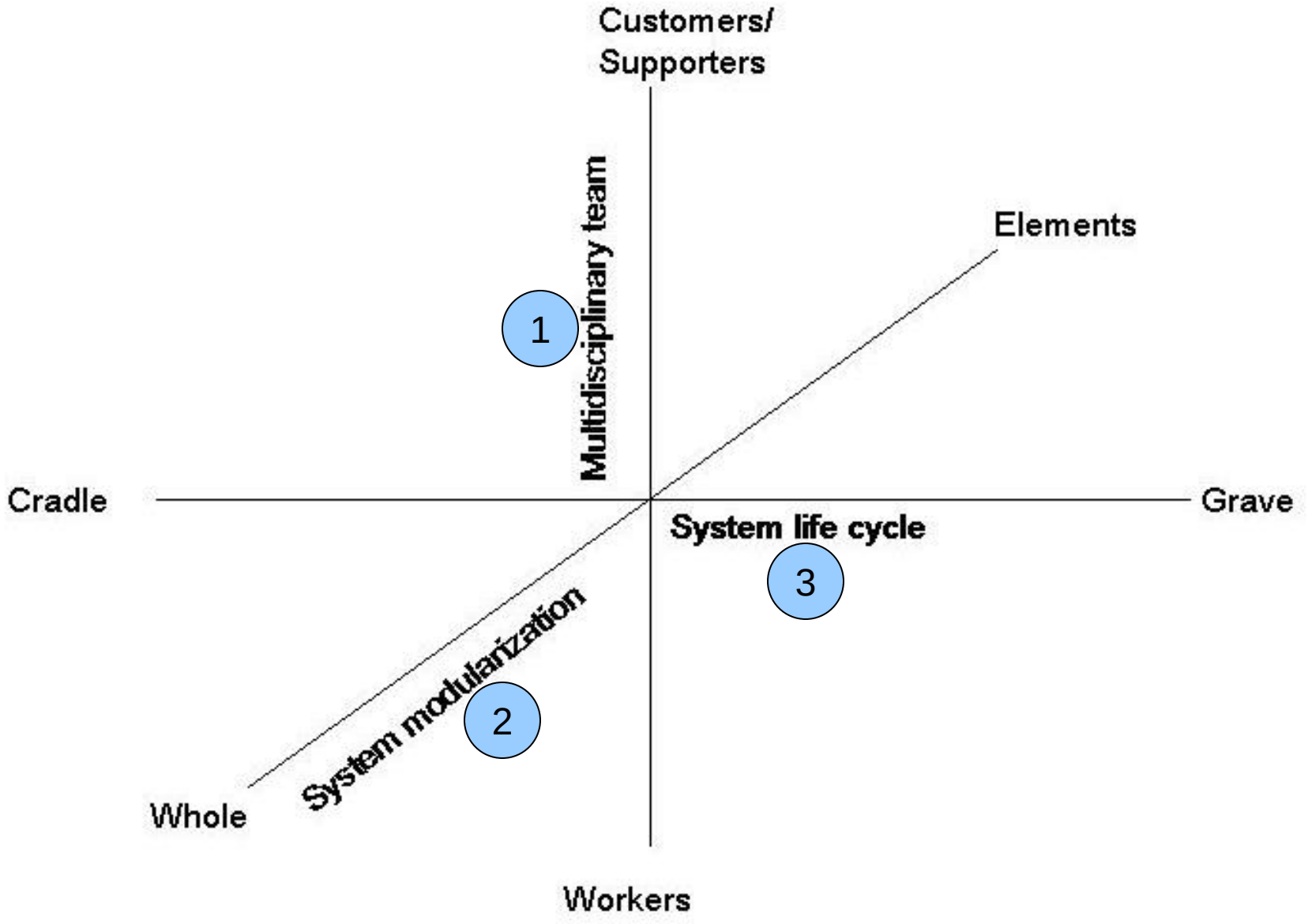
System Life Cycle

- System life cycle is the pattern of change or evolution that similar kinds of systems follow.
- The basic life cycle of all *organisms* is the pattern of conception, birth, growth, maturity, senescence, and death.
- The basic life cycle of human-designed systems is the series of logical, structured steps called the *systems development cycle*.
  - The cycle has the phases of conception, definition, design, development, fabrication, testing, installation or launch, production, operation and maintenance, and enhancement, replacement, or termination.
  - The prescribed stages or phases for large-scale development projects is called *systems engineering.*

Systems Engineering

- The science of designing complex systems in their totality to insure that the components and subsystems making up the system are designed, fitted together, checked, and operated in the most efficient way.
- The conception, design, and development of complex systems where the *components themselves* must be designed, developed, and integrated together.
- A way to bring *a whole system into being* and to *account for its whole life cycle*—including operation and phase-out—during its early conception and design.

Dimensions of Systems Engineering



Dimensions of Systems Engineering (Cont'd)

1. SE is a multifunctional, interdisciplinary, concurrent effort.
   - Systems engineers work with the system's stakeholders to determine their needs and what the system must do to fulfill them.
   - The needs become the basis for defining the system requirements, which specify *what* the system will do.

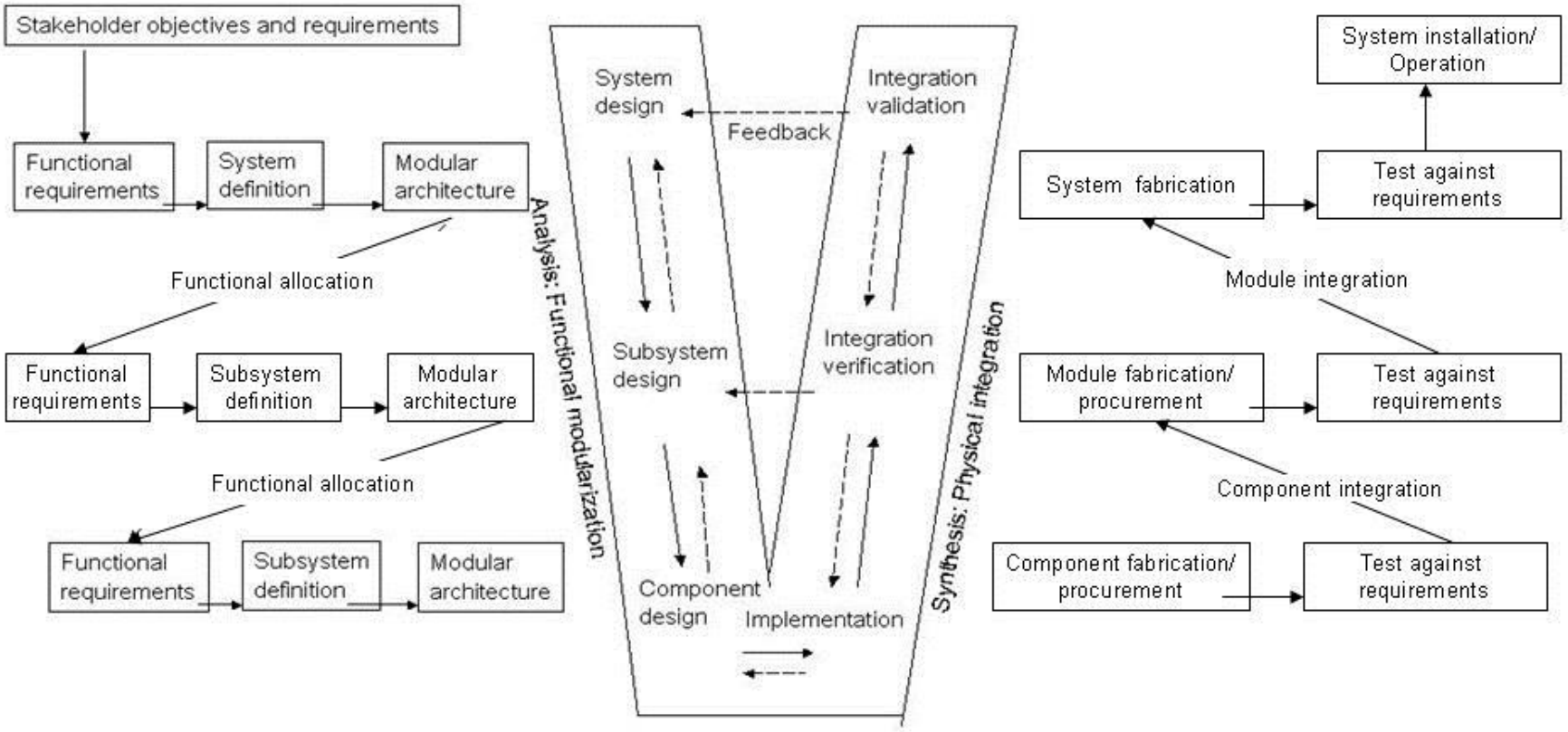
Dimensions of Systems Engineering (Cont'd)

2. It addresses the system's structure and elements—its functional and physical design.
   - System elements and subsystems are designed to perform the functions necessary to satisfy stakeholder objectives and requirements.
   - The design effort focuses on *how* the system will meet the requirements.

Dimensions of Systems Engineering (Cont'd)

3. It takes into account the way the system will be produced, operated, maintained, and finally disposed of—the entire system life cycle.
   - This helps insure that the system will be economical to develop, build, operate, and maintain, and friendly to users and the environment.

Systems Engineering Process



Forsberg and Mooz's V-model (adopted from K. Forsberg and H. Mooz in *Software Requirements Engineering*, 2nd ed., ed. R. Taylor, M. Dorfman, and A. Davis (Los Alamitos, Calif.: IEEE Computer Society Press, 1997): 44-77).

Systems Engineering Process (cont'd)

Creating a system concept that will satisfy requirements involves a series of steps to define the subsystems and elements of the system. The process is an iterative cycle of

1) *top-down analysis* of details (decomposing the system into smaller parts)
2) *bottom-up synthesis* (building up and integrating the parts into successively larger parts)
3) *evaluation* (checking to see that results meet requirements)

Systems Engineering Process (cont'd)

- The downstroke of the V represents subdividing functions of the system into subfunctions and requirements.
  - At each level the process of working with customers to define requirements repeats, except the "customer" becomes the function at the next higher level and the question becomes, What must the functions at this level do to meet the requirements of the next higher level function?

Systems Engineering Process (cont'd)

- The upstroke of the V represents
  - assessing "design alternatives" to satisfy requirements
  - implementing design decisions—converting designs into physical parts
  - integrating the parts
  - verifying that the integrated parts meet the requirements.
- The alternatives involve procuring available parts or designing and building new ones.
- Parts are checked individually and then assembled into modules and again tested.
  - If tests reveal that parts or modules do not meet requirements, the process returns to the downstroke of the V to determine why.
  - the analysis-synthesis-evaluation cycle repeats.