Chapter 19

System Phases, Modes, and States of Operation

19.1 INTRODUCTION

Our discussion of the System Operations Model provides a workflow that illustrates HOW the User might deploy, operate, and support a system or product to perform organizational missions. In general, the workflow consists of objective-based sequential and concurrent operations, each requiring two or more tasks to be accomplished. Tasks in turn are subdivided into subtasks, and so on.

As we probe deeper into the System Operations Model, our analysis reveals that it consists of three types of SYSTEM OF INTEREST (SOI) operations. These operations are required to: 1) prepare for a mission, 2) conduct and support a mission; and 3) follow-up after the mission. These SOI operations are performed by the integrated efforts of the MISSION SYSTEM (s) and the SUPPORT SYSTEM.

When a system is fielded, Users learn the basics of system operations that include HOW to employ a system, product, or service during these phases of operation via user’s guides, reference manuals, and checklist procedures. Each phase of operation, which is assigned objectives to be accomplished, consists of embedded modes of operation. Each mode of operation represents User selectable options available to perform specific mission operations and tasks. Users also learn about EQUIPMENT capabilities, safe operating procedures, and performance limitations available to support these operations and tasks. WHAT the User sees are the results of system development; however, they do not reflect the highly iterative, time-consuming analysis and decision making that the SE design process requires to produce these results.

Our discussion in this chapter introduces the concept of system phases, modes, and states of operation. We build on the foundation of use cases and use case scenarios and System Operations Model to illustrate how SEs:

1. Establish phases of operation.
2. Derive modes of operation from use cases.
3. Derive system architectural configurations and interfaces that represent the system’s state of operation.

Given a foundation in HOW a system is organized, we explore how modal transitions occur within and between system phases of operation. Finally, we illustrate how modal capabilities are accumulated and integrated as physical configurations or states of the architecture to support User phase-based objectives.
What You Should Learn from This Chapter

• What is a phase of operation?
• What is the objective of the pre-mission phase of operation?
• What is the objective of the mission phase of operation?
• What is the objective of the postmission phase of operation?
• What is a mode of operation?
• What is a state of operation?
• What is the difference between an operational state and a physical state?
• What are the relationships among phases, modes, and states of operation?
• How do use cases and scenarios relate to modes of operations?
• What is a modal triggering event?

Definitions of Key Terms

• **Mode of Operation** An abstract label applied to a collection of system operational capabilities and activities focused on satisfying a specific phase objective.
• **Phase of Operation** Refer to definition provided in Chapter 16 System Mission Analysis.
• **State of Operation** The operational or operating condition of a SYSTEM OF INTEREST (SOI) required to safely conduct or continue its mission. For example, the operational state of an aircraft during take-off includes architectural configuration settings such as wing flap positions, landing gear down, and landing light activation.
• **State** “A condition or mode of existence that a system, component, or simulation may be in; for example, the pre-flight state of an aircraft navigation program or the input state of a given channel.” (Source: IEEE 610.12-1990)
• **State Diagram** “A diagram that depicts the states that a system or component can assume, and shows the events or circumstances that cause or result from a change from one state to another.” (Source: IEEE 610.12-1990) State diagrams are also called state transition diagrams.
• **State Machine** A device that employs a given configuration state to perform operations or tasks until conditions or an external triggering event causes it to transition to another configuration state.
• **Triggering Event** An external OPERATING ENVIRONMENT stimuli or cue that causes a system to initiate behavioral response actions that shift from a current mode to a new mode of operation.

19.2 SYSTEM PHASES, MODES, AND STATES RELATIONSHIPS

To facilitate your understanding of system phases, modes, and states of operation, let’s establish their context using the entity relationship framework shown in Figure 19.1.

Author’s Note 19.1  The following description depicts the results of a highly iterative analysis of system phases, modes, and states that may be very time-consuming, depending on system com-
plexity. In the list there are included subphases and submodes of operation, although most systems do not employ these features. They are provided here for illustration purposes for those systems that do employ those terms.

1. Each phase of operation (1):
   a. Consists of at least one or more modes of operation (2).
   b. Allows application of at least one or more use cases (3).
   c. May consist of at least two or more subphases of operation (4).

2. Each subphase of operation (4) (if applicable) is:
   a. An element of a higher level phase of operation (1).
   b. Accommodates at least one or more use cases (3).
   c. Supported by at least one or more modes of operation (2).

3. Each use case (3) is:
   a. Applicable to at least one or more phases of operation (1).
   b. Analytically abstracted into at least one or more higher level modes of operation (2) or into submodes of operation (5).
   c. May require one or more physical configurations (7).

4. Each mode of operation (2):
   a. Is unique to one and only one phase of operation (1).
   b. Accommodates at least one or more use cases (3).
   c. Supported by at least one or more physical configurations (7).

5. Each submode of operation (if applicable) is:
   a. Unique to one and only one mode of operation (2).
   b. Accommodates at least one or more use cases (3).
   c. Supported by at least one or more states of operation (6).
6. Each state of operation (6):
   a. Supports at least one or more modes of operation (2) or submodes of operation (5).
   b. Consists of at least one or more physical configurations (7).

7. Each physical configuration (7) is:
   a. Characterized by the system/item architecture, interfaces, and settings.
   b. Unique to a state of operation (6).
   c. Employed by at least one or more use cases (3).

Author’s Note 19.2 Since our focus here is on general relationships of system phases, modes, and states of operation, Figure 19.1 is presented with those key elements. As we will see in Chapter 21 System Operational Capability Derivation and Allocation, the linkages between use cases, modes and states of operation, and physical configuration states (i.e., the physical design solution) are accomplished via required operational capabilities that lead to performance requirements. The subject of phases, modes, and states is often confusing; this is because it is complicated by people who often misapply the terms. Therefore, we defer the required operational capabilities dimension until later.

Given this framework of entity relationships, let’s begin our discussion with system phases of operation.

19.3 UNDERSTANDING SYSTEM PHASES OF OPERATION

Our discussion of the System Operations Model introduced a key concept in understanding how human-made systems typically operate. The operations presented in Figures 18.1 and 18.2 provide an initial framework for organizing and collecting system capability requirements as well as developing the initial system engineering design. Let’s explore the relationship of phases and operations.

Operational Phase Objectives

If we analyze and assimilate the set of system operations and their objectives, we can partition the operations into three distinct classes of abstraction: pre-mission, mission, and postmission operations. Analytically we refer to these abstractions as phases of operation.

Author’s Note 19.3 All human-made systems have at least three phases of operation. Although some systems may be placed in storage, keep in mind that the operative term is “operation.” Since the system does not perform an action, storage represents an action performed on a system and is therefore not considered an operation.

Pre-mission Phase Objective. The objective of the pre-mission phase of operations, at a minimum, is to ensure that the SYSTEM OF INTEREST (SOI) (i.e., MISSION SYSTEM and SUPPORT SYSTEM) is fully prepared, configured, operationally available and ready to conduct its organizational mission when directed.

Mission Phase Objective. The objective of the mission phase of operations, at a minimum, is to conduct the mission SYSTEM OF INTEREST (SOI). Besides achieving the SOI’s mission objectives, one must mitigate mission risks and ensure the system’s safe operation and return.

Post-mission Phase Objective. The objectives of the postmission phase of operations, at a minimum, are to:
1. Analyze mission outcome(s) and performance objective results.
2. Replenish system consumables and expendables, as applicable.
3. Refurbish the system.
5. Analyze and debrief mission results.

To see how phases of operation may apply to a system, consider the example of an automobile trip.

**EXAMPLE 19.1**

During the pre-mission phase prior to driving an automobile on a trip, the driver:

1. Services the vehicle (oil and filter change, new tires, repairs, etc.).
2. Fills the tank with gasoline.
3. Checks the tire pressure.
4. Inspects the vehicle.
5. Loads the vehicle with personal effects (suitcases, coats, etc.).

During the mission phase following a successful pre-mission checkout, the driver:

1. Departs on the trip from the point of origination.
2. Drives defensively in accordance with vehicle safe operating procedures.
3. Obey vehicular laws.
4. Navigates to the destination.
5. Periodically checks and replenishes the fuel and coolant supply enroute.
6. Arrives at the destination.

During the post-mission phase on arrival at the point of destination, the driver:

1. Parks the vehicle in a permissible space.
2. Unloads the vehicle.
3. Safely secures the vehicle until it is needed again.

**Subphases of Operation**

Some complex systems may employ subphases of operation. Airborne systems such as aircraft and missiles have phases of flight within the mission phase. Phases of flight for an aircraft system might include: 1) push back, 2) taxi, 3) take-off, 4) climb, 5) cruise, 6) descend, 7) land, 8) taxi, and 9) park. Using the phases of operation as the frame of reference, the phases of flight would be equated to subphases of the mission phase of operation. Each of the subphases focuses on specific aspects and objectives that contribute to the overall aircraft system objective: transport passengers safely and securely from a Point of Origination or Departure to a Point of Termination or Destination.

**Guidepost 19.1** Once the systems phases of operation are established, we can proceed with aligning the use cases with the respective phases.

**Aligning Use Cases with System Phases of Operation**

Once the system’s use cases have been identified, SEs align each use case with a specific phase of operation as shown in Table 19.1. Each use case in the table is associated with a phase of operation.
19.4 UNDERSTANDING SYSTEM MODES OF OPERATION

Operationally, modes of operation represent options available for selection at the User’s discretion, assuming certain conditions and criteria are met. Consider the following example:

EXAMPLE 19.2

An automobile driver, assuming certain conditions and criteria are met, has the following modes of operation available for discretionary selection: PARK, REVERSE, NEUTRAL, DRIVE, and LOW. While the vehicle is in the DRIVE mode, the driver is permitted by the vehicle’s design to shift to the REVERSE mode subject to satisfying the following conditions and criteria:

1. The vehicle is at a safe location conducive to the action permissible under law and safe driving rules.
2. The vehicle is safely stopped and the brake pedal is depressed.
3. The driver can view on-coming traffic from all directions.
4. The action can be safely completed before other traffic arrives.

Deriving Modes of Operation

When we analyze use cases aligned with specific phases of operation, we soon discover that some use cases share an objective or an outcome. Where there is sufficient commonality in these sets or clusters of use cases that share an objective, we abstract them into higher level modes of operation. Figure 19.2 illustrates how use cases (UCs) are abstracted into modes of operation.

Author’s Note 19.4 You may discover that some modes can be further abstracted into higher level modes. Where this is the case, we establish a modal hierarchy and designate submodes within a mode of operation. For simplicity, we assume that all use cases reside at the same level in the Figure 19.2 illustration.
In some cases there are no specific guidelines for identifying modes of operation. Independent teams of equally capable SE analysts and developers can then hypothetically design and produce a system or product that complies with a set of User capability and performance requirements. Each team may nevertheless have variations of system modes of operation. The point is to learn to recognize, understand, and establish a team-based consensus concerning system phases and modes of operation. Then, together, the team can apply common sense in abstracting operations into modes of operation.

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Understanding the Modes of Operation Construct

Modes of operation can be depicted graphically or in tabular form. Since SEs communicate with graphics, we will employ the basic construct shown in Figure 19.3.

The construct is divided into pre-mission, mission, and postmission phases of operation to facilitate a left to right control flow. Although each of these phases of operation may consist of one or more modes of operation, only one mode is shown in each phase for simplicity.

Other than a general left-to-right cyclical workflow (pre-mission to mission to postmission), modes of operation are both time dependent and time independent. Many systems establish Mission Event Timelines (METs) that constrain: 1) the pre-mission-to-mission transition, 2) mission-to-post-mission transition, and 3) post-mission-back to pre-mission transition during the system turnaround. Within each mode of operation the MET event constraints may be further subdivided.

Understanding System Modal Transitions

The preceding discussion highlights the identification of system modes of operation by phase and the transition diagram used to modal interactions. Based on this understanding, we are now ready to investigate the stimulus or triggering events and conditions that initiate transition from one mode to another.
Note that each mode in Figure 19.3 is interconnected via curved lines with arrows that represent transitions from one mode to another. These transitions are initiated by pre-defined triggering events or conditions.

Our discussion here focuses on the entity relationships of phases, modes, use cases, use case scenarios, and required operational capabilities. The question is: What causes a system, product, or service to transition from one phase, mode, and use case to another during a mission? This brings us to a discussion of triggering events.

**Triggering Event-Based Transitions.** Most systems, as state machines, are designed to cycle within a given mode of operation until some external stimulus such as an operator initiates a transition to a new mode of operation. The occurrence of the external stimulus is marked as a triggering event. As discussed earlier, the triggering event may be data or interrupt driven whereby:

1. The system receives data from an external system.
2. A system User enters/inputs data into the system in accordance with prescribed Standard Operating Practices and Procedures (SOPPs) or rules of engagement to transition to the next phase or mode of operation.

Data-driven triggering events may be synchronous (i.e., periodic) or asynchronous (i.e., random) occurrences. When making the transition from one mode to another, the User may impose specific time requirements and constraints.

Figure 19.4 illustrates a simple, two-mode system that transitions from Mode 1 to Mode 2 when triggering Event 1 occurs and from Mode 2 back to Mode 1 on triggering Event 2. Triggering event transitions from Mode 1 to Mode 2 and back to Mode 1 require different sets of assumptions and conditions.

The graphic depicts the bidirectional transition as two separate transitions, T1 and T2. For T1, some external triggering Event t1 initiates the transition from Mode 1 to Mode 2; transition to Mode 2 is completed at Event t2. Some time later, another stimulus triggers Event t3, which initiates a transition from Mode 2 to back to Mode 1; transition to Mode 1 is completed by Event t4.
The system development team must establish the convention for transitioning from one mode of operation to another. For example, do you establish an entry criterion for the next mode or an exit criterion for the current mode? Typically a mode does not have both entry and exit criteria. Why? The transition from the current mode, \( n \), to the next mode, \( n + 1 \), is a single transition. You do not specify the exit criterion for the current mode and then specify that same condition as the entry criterion for the other side of the modal interface. In most applications, the best approach is to define only the exit criterion for the current mode of operation.

**Describing Modal Transitions.** Once you establish a conceptual view of the system phases and modes, the next step is to characterize the **triggering events** and **conditions** for initiating the modal transitions. One mechanism for accomplishing this is the mode transition table shown in Table 19.2.

In general, Table 19.2 depicts how a system transitions from its current mode: leftmost column to the next mode, which is the rightmost column. Interior columns define information relating to the transition conditions. Each row in the table represents a single mode of operation and includes a numerical transition ID. Transition information includes: identification of the triggering source or event, the type of event—asynchronous or synchronous—and any transition resource or time constraints for completion of the transition. Consider the following example from Table 19.2.

### EXAMPLE 19.3

If the system is in the OFF Mode, placement of the Power Switch in the ON position (e.g. ASYNChronous triggering event) initiates Transition ID T1. Transition from the OFF MODE to the POWER-UP INITIALIZATION Mode is constrained to 30 seconds maximum. This leads to various power system stabilization capability and performance requirements.
Author’s Note 19.7  Note that the process of identifying system modes of operation and modal transitions is highly iterative and evolves to maturity. Since subsequent technical decisions are dependent on the system modes decisions, your role as an SE is to facilitate and expedite team convergence.

Analyzing Mode Transitions. Modal transitions represent interfaces whereby control flow is passed from one mode to another. While the modes characterize SYSTEM level operations, there may be instances whereby different PRODUCTS or SUBSYSTEMs provide the mode’s primary capabilities. If separate system development teams are addressing the same modes, make sure that both teams operate with the same set of assumptions and decisions. Otherwise, incompatibilities will be created that will not surface until system integration and test. If left undiscovered and untested, a potential hazard will exist until field system failures occur, sometimes catastrophically.

The challenge for SEs is to ensure compatibility between any two modes such that initializations and conditions established for one mode are in place for the successor mode processing. The intent is to ensure that modal transitions are seamless. How do you ensure consistency? Document the modes of operation, Mission Event Timeline (MET), and modal transitions in the system’s ConOps or operational concept description (OCD) document.

Final Thoughts about Modal Transitions. In our discussion of system operations and applications, we highlighted various types of system applications—single use, reusable, recyclable, and so forth. Most reusable systems are characterized by cyclical operations. Cyclical systems have a feedback loop that typically returns workflow or control flow back to the pre-mission phase of operation, either powered down or prepared for the next mission.

Now consider a system such as the Space Shuttle’s External Tank (ET). From a mission perspective, the ET’s fuel resource is a consumable item and the ET’s entity is an expendable item. At a specific phase of flight and MET event, the ET is jettisoned from the Orbiter Vehicle, tumbles back toward Earth, and burns up on reentry into the atmosphere.

In the case of an expendable system such as the ET, one might expect the modes of operation to be sequential without any loop backs to previous modes. However, from an SE design perspective, ET operations involve systems that may require cycling back to an initial mode due to “scrubbed” launches. Therefore, expendable systems require modes of operation that ultimately transition to a point of termination mode—such as REENTRY.
Generalized Modes of Operation for Large, Complex Systems

The preceding discussions addressed a simple product example as a means of introducing and illustrating system modes of operation. When you investigate the modes of operation for large, complex, multipurpose, reusable systems, additional factors must be considered.

EXAMPLE 19.3

Example considerations include reconfiguration, calibration, alignment, replenishment of expendables, and consumables.

As in the case of the System Operations Model, we can define a template that can be used as an initial starting point for identifying classes of modes.

Generalized Modes of Operation Template

Theoretically we can spend a lot of time analyzing and abstracting use cases into a set of modes by phase of operation. Once you develop a number of systems, you soon discover that system modes are similar across numerous systems and you begin to see common patterns emerge. This leads to the question: Rather than reinvent via modal use case analysis the modes for every system, WHY NOT explore the possibility of starting with a standard set of modes and tailoring them to the specific system application? If this is true what are the common set of modes?

Table 19.3 provides a listing of common phase-based modes of operation. Further analysis reveals that these modes have interdependent relationships. We illustrate these relationships in Figure 19.5. Is this template applicable to every system as a starting point? Generally, so. Recognize this is simply a starting point, not an end result.

19.5 UNDERSTANDING SYSTEM STATES OF OPERATION

Scientifically, the term state refers to the form of physical matter, such as solid, liquid, or gas. In this context a state relates to the structure—meaning a configuration—and the level of activity present within the structure. Therefore, a state:

<table>
<thead>
<tr>
<th>Phase of Operation</th>
<th>Potential Mode of Operation</th>
</tr>
</thead>
</table>
| Pre-mission Phase* | • OFF mode (coincides with state)  
• POWER-UP/INITIALIZATION mode  
• CONFIGURE mode  
• CALIBRATE/ALIGNMENT mode  
• TRAINING mode  
• DEACTIVATE mode |
| Mission Phase*     | • NORMAL operations mode  
• ABNORMAL operations mode |
| Postmission Phase* | • SAFING mode  
• ANALYSIS mode  
• MAINTENANCE mode |

* Some systems may permit MAINTENANCE mode(s) in all three phases.
1. Should be observable, testable, measurable, predictable, and verifiable.

2. May be STATIC or DYNAMIC—having an infinite number of time-variant states.

**Author’s Note 19.8** The term “infinite states” refers to situations, such consumables, whereby the amount of the resource remaining represents a physical state. Examples include fluid levels, brake pad wear, and tire wear. SE, as a discipline, builds on the physical configuration theme to define the STATE of a system, product, or service. Therefore, STATE encompasses the system’s physical architecture, such as interfaces and configuration settings, and a range of acceptable tolerances of physical components at a given instance in time or time period.

**Operational versus Physical States**

The concept of states of operation is often confusing because of two contexts: operational versus physical. Let’s describe each of these.

**Operational States.** We describe the state of a system or product in simple terms such as ON (operating) and OFF (nonoperating). Organizations often use the term state to represent the state of readiness or operational readiness of the integrated set of system elements—such as PERSONNEL or EQUIPMENT. By inference, this means that the integrated system and each system element is:

- Physically Configured Architectures and interfaces with a capability necessary and sufficient to conduct specific types of mission(s).

- In acceptable operating condition or health at a given point in time sufficient to safely and reliably accomplish the mission and its objectives.

Operating states are generally identified by terms with “-ed” or “-ing” suffixes. Consider the following examples:
EXAMPLE 19.4

The operational states of an aircraft (EQUIPMENT, crew, etc.) include parked, taxiing, taking off, ascending, cruising, descending, and landing.

EXAMPLE 19.5

A lawnmower having an adequate supply of fuel and oil and tuned for efficient operation can be described in the following operational states:

1. STOPPED/READY In a state of readiness for the homeowner (the User) to mow the lawn or store the mower.
2. IDLING Engine operating with blade disengaged; mower standing still.
3. MOWING Engine operating with blade engaged; mower moving across lawn mowing grass.
4. STORAGE Stored with the fuel drained from the tank, etc.

EXAMPLE 19.6

Consider an automobile operating on a flat road surface. When the driver configures the vehicle in the DRIVE (mode), the vehicle’s physical design responds to the driver’s inputs. In response, the vehicle configures its subsystems to respond to the stimulus accordingly. The drive train—meaning the engine and transmission—are designed to allow the driver to control the following vehicle operational states: PARKED, STOPPED, ACCELERATING, CRUISING, DECELERATING, and BRAKING.

Physical Configuration States. The operational state of a system or product may consist a number of allowable physical configuration states. Building on our previous discussion, consider the following example:

EXAMPLE 19.7

An automobile’s physical system design consists of several subsystems such as drive train, electrical, environmental, fuel, and entertainment. Subject to some prerequisite conditions, the automobile’s design allows each of these subsystems to operate simultaneously and independently. Thus, when the vehicle is in an operational state—such as STOPPED or CRUISING—the driver can choose to:

1. Turn the sound system ON or OFF.
2. Turn the windshield wipers ON, OFF, or change their wiping interval.
3. Adjust the heating/cooling temperature level.
4. Adjust seat positions.
5. Apply force to or release the accelerator.
6. Apply braking.

Each of these physical adjustments ranges from finite to an infinite number of physical configuration states.

The preceding example illustrates WHY a system’s operational state includes one or more physical configuration states. This leads to the question: What is the relationship between system phases, modes, operational states, and physical configuration states of operation? As illustrated in Figure 19.6, we can define the entity relationships via a set of design rules listed in Table 19.4.

To see how these entity relationships are applied, consider the following example:
EXAMPLE 19.8

The driver of an automobile places the vehicle in DRIVE (mode) and starts moving forward (operational state), both allowable actions. As the vehicle moves forward (operational state) at a threshold speed, the vehicle’s computer system automatically locks (allowable action) the doors to prevent passengers from inadvertently opening the doors and falling from the vehicle (prohibited action).
19.6 Equating System Capabilities to Modes

The preceding discussions enable us to link system operations, phases, modes, and states. Ultimately these linkages manifest themselves in the deliverable system that has allowable and prohibited actions as documented in the User’s manual for safe and proper operating practices. Allowable actions represent physical capabilities that the system provides subject to contract cost, schedule, technology, and risk constraints.

In our discussion of the system modes of operation, we considered the need to organize and capture capabilities for a given system element, OPERATING ENVIRONMENT, and design construction and constraints. For each type of capability, we described how operational capabilities are:

1. Represented by aggregations of integrated sets of requirements.
2. Documented in the SPS.
3. Allocated and flowed down to multiple system levels of abstraction.

If we analyze the System Capabilities Matrix from a mode of operation perspective, the matrix reveals combinations of system elements that must be integrated to provide the required operational capabilities for each mode of operation. Each of these combinations of elements and interactions are referred to as the system’s physical configuration state or architecture. Thus each mode of operation is accomplished by architectural configurations of system elements. Let’s explore this point further by using Figure 19.7.

The icon in the upper left side of the chart symbolically represents the System Capabilities Matrix. Note that an arrow links each of the horizontal rows of capabilities for each mode of operation to a specific Physical (Architecture) State. Thus, for the POWER OFF mode, there is a unique
physical architecture required to support the mode. Similarly, for the NORMAL OPERATIONS mode, each system entity within each level of abstraction has a unique architectural configuration that is integrated to form the Normal Operations mode configuration.

**Concept Synthesis**

In summary, Figure 19.7 illustrates how required operational capabilities flow from the System Capabilities Matrix into the SPS and subsequently are allocated to and provided by the system architecture physical states of operation for each mode of operation.

**19.7 GUIDING PRINCIPLES**

In summary, the preceding discussions provide the basis with which to establish guiding principles that apply to development of system phases, modes, and states of operation.

**Principle 19.1** Every system phase of operation consists of at least two or more User-selectable modes of operation.

**Principle 19.2** Every system mode of operation represents a capability to accommodate one or more use cases, each with one or more probable scenarios.

**Principle 19.3** Each system mode of operation requires a pre-defined set of condition-based triggering event criteria for transitioning to another mode of operation.

**Principle 19.4** Every system mode of operation requires at least one or more capability-based operational states to accomplish its performance-based objective.

**Principle 19.5** Each operational state is supported by at least one or more physical configuration states of operation.

**Principle 19.6** Each physical state of operation is characterized by at least one or more allowable actions and at least one or more prohibited actions.

**19.8 SUMMARY**

We have seen how system modes of operation are supported by the system element capabilities. Capabilities, in turn, are documented as a set of capabilities with bounded levels of performance in the System Performance Specification (SPS), flowed down and allocated to system elements levels of abstraction within the various levels of its abstraction.

**GENERAL EXERCISES**

1. Answer each of the What You Should Learn from This Chapter questions identified in the Introduction.
2. Refer to the list of systems identified in Chapter 2. Based on a selection from the preceding chapter’s General Exercises or a new system selection, apply your knowledge derived from this chapter’s topical discussions.
3. For each of the following types of systems, identify the various states of operation.
   (a) Data communications
(b) Aircraft operations
(c) Computer system states
(d) Package delivery service
(e) Organization operations
(f) Building environmental control
(g) Food service operations
(h) Natural environment
(i) Vehicle operations

REFERENCE