**Table 4.1** Descriptions of system attributes, properties, and characteristics

| ID | Attribute | Description |
|---|---|---|
| 1 | System benefactors | Every system has at least one or more benefactors such as owners, administrators, operators, and maintainers, who benefit from its behavior, products, by-products, or services. |
| 2 | System life cycle | Every system, product, and service has a life cycle that depicts its level of maturity. |
| 3 | System operating domain | Every system has an operating domain or “sphere of influence” that bounds its area of coverage, operations, and effectiveness. Humans have learned to extend the area of coverage by employing other assets that enable a specific system to “amplify” its range.<br><br>**EXAMPLE 4.1** An aircraft has a specific range under specific operating conditions such as fuel, payload, and weather. Deploying refueling sources—airborne tankers—and maintenance facilities along its mission flight path can extend the range. |
| 4 | System frame of reference | Every system at any point in time has a *frame of reference* that serves as the permanent or temporary:<br>**1.** Base of operations for its operating domain.<br>**2.** Basis for navigation.<br><br>**EXAMPLE 4.2** An aircraft may be assigned to a permanent home base that serves as the center of its operations. The aircraft may be ordered to perform special (temporary) assignments from a base in Europe. The Apollo Space Program used the Kennedy Space Center (KSC) and the Earth as its frame of reference. |
| 5 | Higher order systems | Every system:<br>**1.** Operates as part of a higher order system that may govern, direct, constrain, or control its operation and performance.<br>**2.** Provides resources for missions. |
| 6 | Purpose-based role | Viewing the universe as a “system of systems (SOS),” every natural and man-made system has a beneficial role based on a reason for its existence as envisioned by its original Acquirer or System Owner. |
| 7 | System missions | Every system performs missions in fulfillment of its purpose to achieve outcome-based performance objectives established by its owner and Users. |
| 8 | Mission goals and performance objectives | Each system and mission must be characterized by a set of goals and objectives, preferably documented. *Goals* and *objectives* provide the fundamental basis for resource expenditures by the system owner and shareholders based on a planned set of multifaceted accomplishments and an expected return on investment(ROI). Each goal must be supported by one or more specific objectives that are *quantifiable*, *measurable*, *testable*, and *verifiable*. |
| 9 | System operating constraints and conditions | Every system, in execution of its mission, is subjected to a set of operating constraints and conditions controlled by higher order systems. |
| 10 | System utility | Every system must provide a physical, psychological, sociological, financial, and economic *value-added utility* to its User. System utility includes ease of use, usefulness, etc. |

*(continued)*

**Table 4.1** *continued*

| ID | Attribute | Description |
|---|---|---|
| 11 | System suitability | Every system has a level of *operational suitability* to the User in terms of suiting its planned application and integration into the users organizational system.<br><br>**EXAMPLE 4.3** A gas-powered lawn edger is suitable for cutting grass around trees and flower gardens; they are not, however, suitable for mowing lawns unless you do not own a lawn mower. |
| 12 | System success criteria | Each system and mission requires a set of success criteria that the system owner and shareholders agree represent WHAT objective criteria constitute successful accomplishment of a mission via goals and results-oriented objectives. Ultimate success resides in User *acceptance* and level of *satisfaction*. |
| 13 | Mission reliability | Every system is characterized by a *probability of success* in accomplishing mission objectives for a specified mission duration and set of operating environment conditions and scenarios. |
| 14 | System effectiveness | Every system has some level of *cost* and *technical effectiveness* related to accomplishing the system's mission with an anticipated probability of success per unit of cost.<br><br>**EXAMPLE 4.4** Consider the *system effectiveness* of an educational system or a health care system. The challenge is: Effectiveness from WHAT stakeholder's perspective? |
| 15 | System efficiency | Every system has a *degree of efficiency* in processing raw materials, information, stimuli, cues, etc. As engineers, we assign an *efficiency* metric that provides a ratio of the quantity of output produced for a known quantity on input. |
| 16 | System integrity | Every system has a *level of integrity* in its ability to deliver systems, products, and services as required despite operating constraints and conditions. |
| 17 | System sustainment | To ensure success in accomplishing its mission, every system, product, or service requires resources such as personnel, funding, consumables, expendables; corrective and preventive maintenance; and support such as spares, supplies, and training. |
| 18 | System promotion | Some systems, namely businesses, promote their systems in anticipation of sales via demonstrations, advertising, etc. The promotion activities may require protection and security.<br><br>**EXAMPLE 4.5** A publisher plans to release a new book in a series on a specific day and time, promote the book via advertising, and impose sale constraints and conditions on bookstore owners. The bookstore owners must keep the book under lock and key (protection) with 24 hour surveillance (security) until the official release. |
| 19 | System threats | Every system and its missions may be threatened by competitors or adversaries in its operating environment that may exhibit friendly, benign, or hostile intentions or actions. |
| 20 | System concealment | Because of *vulnerabilities* or the need for the element of surprise, some systems require *camouflage* or *concealment* to shield or alter their identity. |
| 21 | System protection | Every system must have some *level of protection* to *minimize* its vulnerability to external threats. |

*(continued)*

**Table 4.1** *continued*

| ID | Attribute | Description |
|---|---|---|
| 22 | System security | Man-made systems may maintain a *level of security* such as physical security (PHYSEC), communications security (COMSEC), operational security (OPSEC), and information security (INFOSEC). |
| 23 | System architecture | Every system consists of a multi-level, logical (functional) and physical structure or architecture that provides the framework for its *form*, *fit*, and *function*. |
| 24 | System capabilities | Every system, by definition, has inherent capabilities such as processing, strengths, transfer functions that enable it to process inputs such as raw materials, information, and stimuli and to provide a response in the form of behavior patterns, products, and by-products.<br>System capabilities, like operating domains, can be extended using tools or other systems. |
| 25 | System concept of operations (Con Ops) | Every system has a *Concept of Operations* (*ConOps*) as envisioned by its system owner, system developer, and/or system maintainer. The ConOps provides the basis for bounding the operating space, system capabilities, interfaces, and operating environment. |
| 26 | System phases, modes, and states of operation | For each system/product life cycle phase, every system, product, or service evolves through a series of phases, modes, and state of operation that may be cyclical or nonrecurring (single use). |
| 27 | Operating norms, standards, and conventions | Every system employs a set of *operating norms*, *standards*, and *conventions* that governs its operations, morals, ethics, and tolerances. |
| 28 | System description | Every system should have a system description that characterizes the system architecture, its elements, interfaces, etc. Each of these characteristics is represented by system capabilities and engineering performance parameters that must be captured and articulated as requirements in the *System Performance Specification (SPS).* |
| 29 | System operating constraints and conditions | Every system has *operating constraints* and *conditions* that may be physical (capabilities), imposed by higher order authority—international, governmental, environmental, social, economic, financial, psychological, etc. |
| 30 | System sensors | Every natural and human-made system possesses some form of *sensor* that enables it to detect external stimuli and cues. |
| 31 | System behavior patterns | Every system is characterized by *patterns of behavior*. |
| 32 | System responsiveness and sensitivity | Every system possesses performance-based behavioral characteristics, such as throughput, that characterize its ability to process raw materials or stimuli and provide a response. We refer to the quickness as its *responsivity*.<br>**EXAMPLE 4.8** Accelerator boards enable computer processors to improve responsiveness. |
| 33 | System interfaces | Every system has internal and external interfaces that enable it to interact within itself and its operating environment. |
| 34 | System pedigree | Every system has a pedigree derived from predecessor system designs, technologies, and improvements to those designs to correct for flaws, defects, deficiencies, errors, etc. |

*(continued)*

**Table 4.1** *continued*

| ID | Attribute | Description |
|---|---|---|
| 35 | Mission resources *(system inputs)* | Every system requires inputs such as tasking, expendables, consumables, and operator actions that can be transformed into specific actions required to stimulate motivate, maneuver, process, and output behavioral and physical responses. |
| 36 | System products, services, and by-products | Every system produces:<br>**1.** Value-added products and/or performs services that benefit its stakeholders<br>**2.** By-products that may impact system performance and/or its operating environment.<br><br>**EXAMPLE 4.9** By-products include heat, waste products—trash, exhaust, thermal signatures, and colorations. |
| 37 | Procedural data | Every human-made system requires *procedural data* that describe safe operating procedures related to equipment, services, and operator interfaces and interfaces with external systems. |
| 38 | System lethality | Some defensive and offensive systems are characterized by their *lethality*—their potential to destroy or inflict damage, disable, neutralize, or otherwise cause harm to a threat or target. |
| 39 | System vulnerability | Every system has some form *vulnerability* that exposes *uncertainties* or *shortcomings* in its behavioral and physical characteristics. Vulnerability includes physical, psychological, social, economic, security, privacy, and other factors.<br><br>**EXAMPLE 4.10** Military tanks have additional layers of protection to minimize the impacts of direct hits. Internet sites have vulnerabilities to computer "hackers." |
| 40 | System survivability | Every system has degrees of *fault tolerance* that enable it to perform missions and achieve mission objectives while operating at a *degraded* level of performance for a given set of internal or external induced or malfunctions. |
| 41 | System availability | The state of a system's operational readiness to perform a mission on-demand. Availability is a function of the system's reliability and maintainability. |
| 42 | System aesthetics | Every system possesses psychological or appearance characteristics that appeal to the senses or are aesthetically pleasing to its stakeholders. |
| 43 | System blemishes | Every system is unique in its development. This includes *design flaws* and *errors*, *work quality* and *material defects*, *imperfections*, etc., that may impact system performance or cosmetically diminish its value based on appearance. |
| 44 | Risk | Every system, product, or service has an element of risk related to mission operations and its operating environment that include:<br>**1.** *Probability of occurrence.*<br>**2.** *Consequence(s) of failure.* |
| 45 | System environmental, safety, and health (ES&H) | Every human-made system, at various stages of the system/product life cycle, may pose environmental, safety, or health risks to system personnel—operators and maintainers, private and public property, the environment, etc. |
| 46 | System health status | Every system has an operational health status that represents its current state of readiness to perform or support User missions. |
| 47 | System total cost of ownership | Every human-made system has a *total ownership cost* (TOC) over its life cycle that includes *nonrecurring* and *recurring* development operational costs. |