HOLISTIC SYSTEMS ENGINEERING: PHYSICAL, INFORMATIONAL, AND COGNITIVE DOMAINS

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Abstract

Military commanders require accurate, time-driven information that is instantly integrated and processed. Information sources can be physical, informational, and cognitive, and include: sensors, shooters, machines, and humans.

The authors of this qualitative descriptive study reviewed a sample of open literature which discusses systems engineering and studied the inadequacies that exist in holistic, or integrated, systems engineering. This literature indicates many systems are poorly integrated, stand-alone, single-unit entities. Problems are exacerbated when an attempt is made to integrate multiple systems and/or subsystems.

Consequently, from a systems engineering design philosophy perspective, systems should be developed with respect to physical, informational, and cognitive domains. The holistic perspective should include all three domains whether technology is classified as microscopic (small scale-component-subsystems) or macroscopic (large scale-system of systems).

The authors conclude a paradigm shift might lead the way to more successful development of systems and technologies which link subsystems, functions, and attributes in one timeline.

Keywords

Systems engineering, domain, data, information, knowledge, situation awareness, architecture

Introduction

This paper addresses both traditional and nontraditional viewpoints of systems engineering (SE). It reviews professional, societal, and academic definitions for SE. Functional, physical, and implementation architectures will be discussed, and holistic thinking in the realm of SE is explored.

Systems engineering data, information, and knowledge considered in this paper are those pertinent to development of military systems. The concerns of combatant commanders are comprised of three domains: physical, informational, and cognitive. This paper examines linkages between telepresence, sensors, transducers, shooters, hiders and finders, as they relate to the physical battlespace being a system for combat and military operations. Ultimately, success in SE for military systems involves collaboration and sharing of information and knowledge, and the successful integration and interoperability of systems and subsystems.

Foundation

The traditional definition of SE is “a management technology involving the interactions of science, an organization, and its functional environment as well as information and knowledge bases that support each (Figure 1) [1-2].” And, the functional meaning of technology, “as a fundamental human activity, is the organization, application, and delivery of scientific knowledge for the presumed enhancement of society…management involves the interaction of the organization with the environment…associated with this, to make an effective management technology, is the information and knowledge that enables understanding and action to effect change.” Systems engineering is a methodology that assists organizations toward improving how they define, develop, and deploy technological products, services, or processes that support functional objectives and fulfill needs. Moreover, “the engineering of a system also involves the interaction with humans and organizations that are
There are many definitions for systems engineering; however, several of those definitions seem to be incomplete. The United States Air Force’s Aeronautical Systems Center (ASC) states; “Systems Engineering (SE) is a rigorous, interdisciplinary set of iterative activities which supports the full life cycle of any product. It is adaptable to any over-arching management process. It assesses and fully integrates cost, schedule, and performance and provides robust technical support for all required management decisions [3].” This is true. However, this definition is top-level and far removed from the holistic perspective presented here.

After making a comparison between several institutions’ definitions, International Council on Systems Engineering (INCOSE) [4] definition was used as reference for defining SE. The Air Force’s and several academic institutions’ definition directly echoes the INCOSE standard. The Massachusetts Institute of Technology grants degrees from its Engineering Systems Division (ESD) [5] using this established standard. Washington University, at St. Louis, Missouri, described its SE program as follows:

“…expected to have mathematical competence and knowledge of systems analysis, control, and design methods, numerical methods, differential equations, dynamic systems theory, automatic control theory, system stability, estimation, optimization, modeling, identification, simulation, and basic computer programming [6].”

The Washington University systems engineering program provides a better description of the discipline from a holistic technology management perspective, but neglects the business management perspective. From this program description we see the elements of diverse domains being explored as a part of the SE process and methodology. This discovery prompts us to explore the holistic viewpoint from the military perspective.

The authors used leaders in commercial enterprise and academia as sources and explored the definition of SE from their viewpoints. The views of Norman Augustine, former Chairman and CEO of Lockheed Martin; Dr. Richard H. Thayer, software systems engineering California State University, Sacramento, California; and Andrew P. Sage, Dean Emeritus, George Mason University, were explored.

Augustine discusses the economic, social, and political implications that must be considered. He defines a systems engineer as “one who seeks to influence systems [7].” This simple statement steered the authors toward a more holistic and integrated definition of systems engineering. The authors next looked at Dr. Thayer’s discussions on systems engineering from a software systems engineering (SwSE) perspective. This view looked beyond the viewpoint of hardware and investigated SE from a software point of view. He states “SwSE produces documents, not components [8].” Thayer further states, “SwSE begins after the system requirements have been partitioned into hardware and software subsystems [8].” What is referred to as hardware, software, and anything else of a technical nature, including SwSE and SE, are rolled up into architectures. Architecture can be described as the structure of components, their interrelationships, and the principles and guidelines which govern their design and evolution over time.

Figure 2 illustrates how systems engineers must combine science, technology, enterprise, management, organizational behavior, and social and political environments to develop and produce a product or service. The three architectures from which systems engineers must work—functional, physical, and implementation—are indicated in Figure 2.
Figure 2. Systems Engineer is Broker of Knowledge for Enabling Specifications of System Architecture and Engineering Solutions at Any of Six Levels [9]

The functional architecture represents the functional needs of a using organization or customer. The documented functional architecture is then translated into the physical architecture, which identifies the attributes of the system or subsystem and thereby enables the partitioning process from macroscopic to microscopic. Sage informs us that “each of these subsystems should be as independent as possible and should be such that integration of them after implementation is as straightforward and feasible as possible [8].” The physical architecture is finally translated to the implementation architecture, which provides guidance for various implementation contractors in integrating the various subsystems which comprise the system.

The functional architecture describes mission needs, concept of operations, and so forth. The physical architecture describes what must be done from a technical perspective to perform the missions or operations. The implementation architecture describes what characteristics, capabilities, or effects are necessary from a science and technology perspective for the customer to accomplish goals. The authors agree that SE is multi-dimensional. However, Sage’s description of SE does not fully qualify or link to the temporal, geospatial, political, social, economic, and psychological domains.

Because combatant commanders now require Department of Defense systems engineers to develop or modify systems according to battlespace requirements, including the domains stated above, systems engineers must look at system development from a broader perspective. Along with hardware and software machine-centric development, they must consider mission and human perspectives.

In addition to these technology development perspectives, SEs must consider the physical, informational, and cognitive domains associated with system development. Along with the aforementioned efforts, SEs must consider systems engineering and interoperability. They must develop systems and subsystems from a holistic systems engineering perspective. Nonetheless, there is not enough emphasis placed on the whole of systems engineering; the SE viewpoint of development from microscopic to macroscopic, and the interdependence of its components.

Holistic Systems Engineering

Several trends are emerging in holistic SE. The concepts related to those trends should be considered when defining systems engineering from a holistic perspective. The most common holistic viewpoint involves the concept of linking sensors, transducers, shooters, coordinates, domains, time, space, response time, autonomic responses, et cetera. The less commonly-held holistic perspective which considers physical, informational, and cognitive domains will be discussed later in this paper. Increasingly, commercial enterprises are acknowledging the need to develop tele-presencing- and biomimetics-capable systems to meet commercial and military capabilities requirements. Hence, the ultimate objective is to achieve a system of systems that expands the senses and performs similarly to biological entities.

Biomimetics is the study of the structure and function of biological systems as models for the design and engineering of materials. Thus, engineers performing the engineering process attempt to mimic the function of plants and biological entities.

Examples are cellular telephone technology and echolocation. Echolocation is the process used by bats and dolphins to orient themselves according to the reflection of the sounds they have produced. Technologies mimicking this process are radar, sonar, and so forth.
Sensors and Transducers

Sensor devices sense physical changes such as temperature, pressure, intensity of light, sound, or radio waves. The sensors can convert the measure of change into a useful input signal for an information-gathering system. The transducer, a special type of sensor, converts variations in one energy form into corresponding variations in another form, usually electrical. Measurement or input transducers use physical, chemical, or biological effects to realize transduction, and design principles related to sensitivity and minimum disturbance to the measurand; that is, the quantity to be measured.

The concepts of electronics sensors and their transducers are based on the biological concepts of receptors and mechanoreceptors. Receptors provide an organismic information about changes in the environment such as movement, tension, and pressure. In higher animals, receptors are the only means by which the animal receives information about its surroundings; the animal reacts to those environmental changes. Mechanoreceptors are excited by mechanical disturbances of a biological entity’s environment through deformation of its transducer structure, resulting from pressure or tension, or through a combination of these.

Sensors and Shooters

In a machine, onboard sensors and transducers are designed to transmit and receive energy that create environmental changes or disturbances. Using a reference, they measure changes by collecting, detecting, processing, and identifying the information received. The changes can be made by either onboard or other offboard sensors or transducers. Sensors and transducers can also provide targeting information to shooters, telling them where to shoot.

A shooter is a system or combination of subsystems. The subsystems that comprise a shooting system are military air, ground, or sea vehicles; the combatants onboard or offboard the vehicles; the weapons; and the triggers or buttons installed on vehicles to activate or launch projectiles according to measured or communicated coordinates, and the attached or installed projectiles fired or launched by the combatants to destroy targets. Sensors and transducers provide coordinate information for the shooters.

Coordinates

Coordinate information is communicated according “to richness, reach, and quality of interaction required,” according to Dr. David Alberts. “Targeting precision guided munitions, for example, requires location accuracy down to a few meters. The information must be current if the target is mobile or if its use can change from military to civilian [10].” Alberts goes on to state:

“…Hence, there are minimum needs for richness. Reach is required to deliver the information to the target planners and the shooters. Interaction is needed to keep the information up to date, particularly when the target has dynamic features. Late updates on target location or character (e.g., from police station to location where hostages are held) can be crucial to mission success [10-11].”

Domain

A domain is a sphere of activity, concern, or function. In his Access Science encyclopedic article, “Design Engineering: Science of Design,” Nam P. Suh [12] describes the concept of design domains as follows:

“Design is made up of four domains: customer, functional, physical, and process. The customer
domain is characterized by customer needs or the attributes that the customer is looking for in a product, process or system. In the functional domain, the customer needs are specified in terms of functional requirements and constraints. In order to satisfy the specified functional requirements, design parameters are conceived in the physical domain. Finally, to produce the product specified in terms of design parameters, the process domain is developed and characterized by process variables. All designs fit into these four domains and can be generalized in terms of the same principles. Because of this logical structure, generalized design principles can be systematically and concurrently applied to all design applications.”

The authors concur with Suh’s [6] explanation; however, for this paper we have translated the domain concept into three domains which relate to military use: physical—which includes spatial, temporal, location, materials, environment, traversing or modulated data, physical connections, components and devices, aggregate of components and devices, targets, people, etc.; informational—which is detected, collected, received and transmitted data; and combined visual and aural data; and cognitive—comprised of perception, awareness, cultural filters or lenses, stimulation of receptor organs of body, transformed or encoded stimulation into neural activity, specialized receptor mechanisms, etc.

**Physical Domain**

The physical domain addresses concepts of space, time, location, and connectivity. It is the domain where battles are fought and combatants live and die, win or lose. It takes into account the environment for people and technology and combat. The physical domain utilizes communication and data links for air, ground, and sea vehicles. Alberts, et al, state, “In our analyses and models, the physical domain is characterized as reality, or ground truth. Important metrics for measuring combat power in this domain include lethality and survivability [10].”

**Informational Domain**

Information is data recorded, classified, organized, related, or interpreted within a comprehensible framework. That is, data is arranged in meaningful patterns that are potentially useful for decision makers. Information is often confused with knowledge.

Knowledge, alternatively, is something that is believed and is true, effective, and reliable. Knowledge is necessarily associated with an experiential context, and so is generally more valuable than information. However, knowledge is much harder to assimilate, understand, transfer, and share than information.

It is important to understand the differences between threat data, information, knowledge, and wisdom. Threat data correspond to points in space and time that relate to specific features. Information is data important to decision making; it relates to description, definition, or outlook. Information is responsive to questions of "what," "when," "where," or "who.” Knowledge is information embedded in context and might contain approach, method, practice, or strategy. Knowledge answers questions about "how" to do something. Wisdom is sometimes considered as a higher-level construct that represents insights, prototypes/models, or principles that can be responsive to questions concerning "why.” If the distinction is not made, knowledge is expected to answer "why" questions as well as "how.”

**Systems engineering** is concerned with developing appropriate relationships between the major groups associated with engineering large systems. These groups are represented by the rows in Figure 3, which shows a two-dimensional framework for information and knowledge derived from an adaptation of architectural framework. The framework can be associated with any of the phases associated with the engineering of a system. The rows of Figure 3 represent the perspectives or views of the many stakeholders to a large issue such as sustainable development: policymakers, planners, enterprise owners, life-support systems engineers and architects, life-support system builders, and the public impacted by the resulting systems. Information and knowledge relevant to each cell in this framework must be present in any constructive effort to engineer solutions to large issues.
Figure 3. Knowledge Management Perspectives of Systems Engineering Stakeholders [10]

Figure 3 shows two umbrellas of importance related to information and knowledge. The informational domain addresses the concept of what constitutes information and where it can be found. The knowledge area relates to specific awareness about something such as a threat or target. Whereas knowledge is information collectively placed into a pattern of sorts, the informational domain is the place where information is produced, adapted, and shared. The informational domain provides communication information (location, target, etc.) among warfighters, where the command and control of military forces are communicated and where commanders’ intent are expressed [11].

However, information that exists in the informational domain may or may not truly reflect ground truth. For example, a sensor observes the real world and produces an output (data) that resides in the informational domain. With the exception of direct sensory examination, most information related to our environment comes through, and is affected by, our relations with the informational domain. For example, with the exception of telepathy, humans communicate with other humans through the informational domain. [10].

Alberts informs us: “The key attributes of the information domain can be subdivided into three major dimensions or vectors: the richness or quality of the information domain, the reach or distribution of the information domain, and the quality of interaction within the information domain. Each of these is, of course, multidimensional in its own right.”

Cognitive Domain

The cognitive process is that which pertains to the mental processes of perception, memory, judgment, and reasoning, as contrasted with emotional and volitional processes. Perception is the recognition process in response to sensory stimuli; the act or process by which the memory of certain qualities of an object is associated with other qualities impressing the senses, thereby making recognition of the object possible.

The cognitive domain relates to that which goes on in the minds of the participants regarding an activity. This is the place where perceptions, awareness, understanding, beliefs, and values reside and where, as a result of sense making, decisions are made. This is the area where battles and wars may be won or lost. It is the domain related to such intangibles as leadership, morale, unit cohesion, level of training and experience, situational awareness, and public opinion. The informational domain is the place where an understanding of commanders’ intent, doctrine, tactics, techniques, and procedures resides. The features of the informational domain are hard to measure, because like each individual mind, each sub-domain is distinctive [10].

It is understood that differences in bias and perception will happen. It is understood that people have their unique cultural lens or filtration system(s) that various contents must pass through. Human perception is a part of the cognitive domain through which the information must pass and be interpreted. This filter consists of the person’s worldview, the body of personal knowledge the person brings to the situation, his or her experience, training, values, and individual capabilities (intelligence, personal style, perceptual capabilities, etc) (See Figure 4). Since these human perceptual lenses are unique to each individual, we know that individual cognition (understanding) is also unique. There is one reality, or physical domain. This is converted into selected data, information, and knowledge by the systems in the information domain. By training and shared experience, we try to make the cognitive activities of military decision makers similar, but they nevertheless remain unique to each individual, with differences being more significant among individuals from different services, generations, and countries than they are among individuals from the same unit or service [10].
Commanders and their forces desire to have an awareness of the situation as it exists in the physical domain, the informational domain, and the cognitive domain. This need is reputedly shared by combatants and focuses on reality. The differing informational domains of the different sides and their different cognitive orientations (worldviews, doctrine, etc.) guarantee that cognitive awareness will differ. All contribute to the situation that is part reality, part information, and part cognition.

The goal is to develop a technologically-produced (radar, sonar, infrared detection, audio and the like) telepresence and teleprocessing of sorts, where the phenomenon of perception or awareness relates to far-away adversaries and targets at distances beyond human ability to sense physically. Those adversaries and targets represent a prospective external opposing force that a combatant commander wants to be aware of in the absence of any “true physical” sensory stimulation which arises from adversaries and friendly hiding-finding systems. Moreover, for combatant commanders, the telepresencing and teleprocessing capabilities that result from the hiding-finding systems’ data situation awareness collections provide Situational and Battlespace Awareness.

When the term “situational awareness” is used, it describes the awareness of a situation that exists in part or all of the battlespace at a particular point in time. The components in Figure 5 include missions and restrictions related to missions, capabilities and intentions of applicable forces, and key attributes associated with an environment. Elements associated with the environment are terrain, weather, social, political, and economic elements. Alberts, et al., state: “For most military situations, time and space relationships (e.g., weapon ranges, rates of advance across different terrain) and the opportunities and risks relevant to the forces are also crucial elements [10].”

- Awareness is a Perception of the Situation

Battlespace Awareness capability is the result of the data collections undertaken to increase information or knowledge about an adversary as well as secreting known facts from the enemy. Alberts, et al., assert: “Awareness always exists in the cognitive domain. It covers not what the information systems know, but what the people (commanders, key staff, etc.) know and are aware they know [10].”

By the late 20th to early 21st-Century, response time necessary to achieve battlespace awareness capability had become even more problematic. Battlespace response time appeared to have increased because of the performance improvements of information technology (IT). Fast and accurate IT was allowing financial institutions to provide worldwide services to their customers such that they were able to perform fast and reliable financial transactions regardless of geo-location or country where the transaction was initiated. This new time-driven IT capability appeared to remove barriers such as mountains, valleys, oceans, seas, rivers, and any other geographical distances.
between major population centers. Time-driven IT capability has narrowed geographical distances. Information technology is continually flattening our world.

**Time-Driven Information**

In his book, *The World is Flat: A Brief History of the Twenty-First Century*, Friedman discusses how fiber optical connectivity now makes the Earth’s terrain appear to be flat. That financial and business transactions and the like are done instantaneously. He infers that if this is true for business, it is most definitely true for defense. In his book, he also gives us insight on how a "mutant supply chain" can assist a small asymmetric force like Al-Qaeda toward committing an act of terrorism that is amplified, large, and destructive. Alberts, Garstka, et al, have written two textbooks which describe the reason the United States military should change the way it views time. From a network-centric warfare perspective, Alberts, Garstka, et al, state the following about how thought processes about time must change:

“Across a broad range of activities and operations, the times required by individuals to access or collect the information relevant to a decision or action has been reduced by orders of magnitude while the volume of information that can be accessed has increased exponentially. In some competitive domains, the timelines for creating value have been reduced from hours to seconds (e.g., on-line trading). Consequently, across a broad range of value-creating activities, the fundamental limits to the velocity of operations are no longer governed by space or time. Instead, the fundamental limits are governed by the act of deciding, by the firings of neurons, by the speed of thought.

Clearly, these revolutionary changes in the information domain have the potential to have the same level of impact on the fabric of society that previous revolutionary technologies have wrought (e.g., the steam engine, the internal combustion engine, the airplane). These changes created new opportunities for creating and distributing wealth and power. At this phase of the Information Age, it is clear that we are poised to continue compressing time and space beyond the physical limits of the Industrial Age [11].”

**Hiders and Finders**

Hiders are onboard sensor systems and subsystems that use various techniques such as echolocation, radio wave, infrared, and infrasound energy vibrations to detect and locate targets. Finders are air, ground, and sea vehicles equipped with onboard sensor systems and subsystems that use several techniques or methods to detect and locate hostile targets. The methods used by finders are echolocation, radio wave, infrared, and infrasound energy vibrations. Vehicle finders attempt to interpret the vibrations emitted by hiders to obtain tactical information by identifying the hiders’ unique signatures or attributes.

The hiders and finders challenge has persisted since radar technology was developed. The technology competition between aircraft and radar is an old one. Hiders are determined to reduce their cross-section signatures; while finders advance radar (radio detection and ranging) technology further to improve the means of gaining tactical information, including ever-more advanced and capable sensors. Stealth, of course, is a hiding capability that makes potential target detection more difficult for finders. Nonetheless, the finders remain tenacious in their quest.

Watts informs us of the hider-finder competition:

“The hider-finder competition encompasses more than stealthy air vehicles versus radar-based air defenses. US stealthy strike platforms also seek to find enemy forces and targets to attack them; any competent adversary will strive to hide forces and targets from American air attack using concealment, dispersion, camouflage, placing high-value facilities deep underground, active countermeasures against American sensors, and any other means that might prove effective. Historically weather and darkness greatly aided hiders, but technological advances have severely undercut their effectiveness in recent decades” [13].

**Collaborative Information Retrieval**

Economics drive the use of legacy and/or extant military vehicles to perform combat missions, which elevates the importance of collaborative information retrieval and sharing capability.
Collaborative information retrieval enables joint and allied air, ground, and sea finder and hider vehicle systems or nodes to “identify and resolve a shared information need” [13, 14]. Collaborative information retrieval provides combatant commanders information about targets by way of installed vehicle sensor systems and subsystems which find, analyze, and identify information needs.

**Collaborative Information Sharing**

Collaborative information sharing techniques are important for near-real-time sharing of information within the enterprise. They provide decision makers with a common operational picture that helps facilitate self-synchronization as well as increasing the tempo and responsiveness of operations [11].

Collaborative information sharing increases the ability of combatants to tap into accumulated military knowledge for simulated and near-real-time actual combat or warfighting conditions. This amassing of knowledge depends upon having the ability to collect and analyze and share needed information.

Information sharing happens according to a timeline and prioritized response times; it involves joint and allied friendly land, sea, and air vehicles and combatants whose transmitted and linked data are sent to a regional combatant commander. The combatants and their vehicles provide the information to the commander by transmitting visual and aural display knowledge about target(s), their location(s), operational mode(s), and potential threat to friendly forces. Commanders use this shared information and then decide whether to strike one or multiple targets.

**Collaborative Decision Making**

Decision makers are inundated with huge amounts of data; they are burdened with the complexities of combat operations; and they are overwhelmed with the accumulation of information (or processed data). The goal is to reduce their decision making response time concerned with multi-criteria, multi-objectives, and conflicting requirements. Moreover, decision makers overloaded with information must rapidly and properly identify important knowledge and employ superior understanding to make appropriate decisions. Therefore, decisionmakers require the correct information, at the correct time, in the right format, and at the right cost (financially or according to casualty). Joint and allied systems and subsystems must be integrative and interoperable to satisfy these requirements.

**Systems Integration**

Systems integration uses processes and procedures from systems engineering, systems management, and product development to develop complex systems. Complex systems include hardware and software based on existing or legacy systems tied to new requirements and additional functionality through integration of new systems or subsystems. Systems integration includes multiple companies to produce a working system. Systems integration applications can be, for example, a time-sensitive tracking system that includes an aggregate of other systems or subsystems.

**Systems Interoperability**

Architectures address the issue of interoperability among systems and subsystems. In large organizations, heterogeneity is an issue because of the expectancy of and need for acquired systems to interoperate with other acquired systems (designed by other companies) within the same organization or with other systems at other organizations or both. Major issues can be associated with interoperability among heterogeneous systems, and with application software portability.

**Informational Changes**

Although not explicitly expressed, the authors interpret Alberts, et al, as advocates for an increase in combat power, decision making, distributed awareness and knowledge among heterogeneous forces within a given battlespace [11], and that it should happen in a manner similar to that of a biological entity with autonomic response capability. In this way, decision timelines can be compressed.

The effort towards achievement of compressed timelines correlates to the increased rate of continuous warfare events, to time-sensitive or mobile targets, and to combatant commanders having telepresence ability within battlespaces. It endeavors toward the reduction of fratricide.
Conclusions

It is important that systems engineers begin thinking about systems ranging from the microscopic to macroscopic, in addition to the technology-centric perspective. Too often, systems engineers are pressed to develop systems from a management science or program management viewpoint. Those are valid management approaches, once how a system is expected to function operationally, and how it is supposed to integrate and interoperate with other systems is established. However, too often systems engineers are tasked to manage the development of a system without sufficient address of technical details to decide if the proposed design is appropriate or not, without knowing if the system will meet the customer’s requirements.

In addition to ascertaining whether the design is appropriate and meets the customer’s requirements, it is equally important that systems engineers begin to develop systems from a more holistic perspective. This is especially important with regard to “hiders” and “finders.” Developing systems from a holistic perspective saves lives, money, reduces risk, and ensures that multiple systems operate from a more integrative viewpoint. From a military integrative viewpoint, it has become increasingly important that collaboration occurs and such data, information, and knowledge be shared regardless of military branch of service or even allied nation.

Finally, because of the flattening world, not only must collaboration and sharing occur, but the informational transactions concerned with time-sensitive targeting must be executed within a matter of minutes. Therefore, the time constraints are an integral requirement in designing systems; systems engineers must keep in mind the physical, informational, and cognitive domains as well as system technology integration.

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Nonetheless, the limited sample of literature reviewed did not permit the authors to prove or disprove that the present systems engineering philosophy requires changes, since failures can occur purely due to system complexity. Furthermore, the authors cannot prove or disprove a need to change the way systems engineering philosophy is taught and advocated in technical and engineering schools and workplaces. However, literature indicates the latter viewpoint as being superior to the former.

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