Communication And Collaboration Cognition Systems: A Sociological Process For Integrating Standalone Technologies With The Global Information Grid

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***Abstract*— This thought experiment discusses concepts that should be considered when performing systems integration and systems engineering efforts applicable to integrating standalone avionic and electronic cognition systems to attain complex adaptive communication and collaboration capabilities. The concepts are artificial sensory and cognition systems; biomimetics; engineering and systems engineering memes; and informational silos and their relationships to memes and memes integration problems. Put simply, from a problematic perspective, one problem is the following: Design and development teams oftentimes encounter technical challenges when attempting to integrate standalone, biomimetically-based, communication and collaboration cognition systems that were not designed to be integrated with other systems. A second problem is the following: Design and development teams oftentimes integrate systems based only on their machine-centered designs and functions and without consideration of human factor elements such as informational silos, memes and corporate cultures. A third problem is the following: Teams might encounter other systems integration and systems engineering problems and roadblocks too such as proprietary information; perceptual lenses; blind spots; and interdisciplinary and professional prejudgments, parochialisms and stereotypes. The latter can also interfere with efforts to integrate standalone systems (developed by different companies) and can also interfere with the systems being capable of providing individually attained information into command and control networks within required response times. Use of sociological processes related to holistic systems engineering, systems thinking and non-traditional professionals can be used to solve people-rated problems, to categorized unknowns for mitigating risks, and to then perform systems integration regarding communication and collaboration cognition systems. Applications for cognition systems are discussed. Finally, applications that are fundamental to integrated cognition systems are discussed. Nonetheless, all of the ideas, topics and theories such as HSE, silo integration, biological models, memes, and inclusion of non-traditional professionals as stovepipe integrators that were discussed in this paper are still located within the theoretical realm and have yet to be experimented upon to determine their validation. However, many of these subject matters are seldom discussed within this forum either.**

I. Introduction

The goal of communication and collaboration cognition (architectural) systems is to improve the efficiency of how integrated avionic and electronic standalone systems can be designed, developed and integrated to operate seamlessly as though they are one biological entity. In past efforts, this (non-specific consideration of biological models) approach has led to only the coarsest representations of biological communication and collaboration cognition systems. However, our desire now is to develop integrated systems that meet smaller response time requirements and that interact more accurately, regardless of machine location; it requires us to develop different ways of thinking about such technological challenges.

Consequently, to develop artificial biomimetically-based avionic and electronic types of entities that operate based on more precise representations of biological cognition systems, new paradigmatic mindsets need to be considered. Relative to changing our mindsets, the author highlights three technological challenges for our consideration.

First, design and development teams oftentimes encounter technical challenges when attempting to integrate standalone, biomimetically-based, communication and collaboration cognition systems that were not designed to be integrated with other systems.

Second, design and development teams oftentimes integrate systems based only on their understandings of the avionic and electronic technical designs and functions and also based on the physical domain and the machine-centered sub-domain, without considering other domains and sub-domains and also without considering human factor elements such as informational silos, memes, inter-organizational competitiveness, and corporate cultures.

Third, design and development teams might encounter other systems integration and systems engineering problems and roadblocks too. For instances, there are challenges relating to proprietary information; perceptual lenses; blind spots; and interdisciplinary and professional prejudgments, parochialisms and stereotypes.

To solve the abovementioned people-related problems and to integrate complex biomimetically-based avionic and electronic architectures, the author recommends using technological and sociological integrative processes offered through the use of holistic systems engineering (HSE); and for developing processes that make needed information available for implementing shared services across an entire integrated engineering enterprise.

Nonetheless, realizing the aforementioned goals involves a large amount of collaboration, coordination, and decision-making and also a large amount of senior level managerial commitment. It involves having involved with authority to get the job done. It involves customer ownership relating to the cognition architecture. It involves disciplined processes and methods. It involves configuration control over architectural objects. It involves a financial structure that provides incentives and that promotes a seamless viewpoint about the goals at hand. It involves openness to new ways of thinking about problem-solving. It involves holistic integration of risks and reasonable schedules that can be traced back to the abovementioned components and risks.

The proposed HSE solution can account for missing issues related to informational silos, multiple domains (such as physical, informational, cognitive, social, etc.) and sub-domains (such as machine-centeredness, human-centeredness, and application-centeredness).

Section II describes the problem statement. Section III describes communication and collaboration systems, avionic and collaborative systems, concept of biomimetics, biomimetics examples, sensory systems, cognition, biomimetically-based cognition systems along with cognitive hierarchy and cognitive diversity, dissonance, architecture, in addition to informational silo. Section IV describes sociological process for solving problem statement; it discusses the need to integrate informational silo; it describes memes, their pluses and minuses, and inclusion in solving the problem; it discusses systems thinking and processes and holistic systems engineering. Section V describes how process is applicable to communication, collaboration, cooperation and shared knowledge, and context applications.

II. PROBLEM STATEMENT

Design and development teams oftentimes encounter technical challenges when attempting to integrate standalone, biomimetically-based, communication and collaboration cognition systems. Further, the teams oftentimes integrate systems based on *physical domain* and *machine-centered sub-domain* designs and functions only and without consideration of human factor elements such as informational silos, memes and corporate cultures. Furthermore, the teams sometime encounter other types of systems integration and systems engineering problems and stumbling blocks such as proprietary information; perceptual lenses; blind spots; and interdisciplinary prejudgments, parochialisms and stereotypes. The previously mentioned challenges highlight the possibility of notionally networked integrated cognitive systems having low synergistic performance. When low synergistic system performance levels occur they can sometimes be traced back to perceptual lens preferences. These problems can be overcome if biomimetically-based models are emphasized as templates for development of avionic and electronic communication and collaboration cognition systems.

III. COMMUNICATION AND COLLABORATION SYSTEMS

A human in addition to an electronic communication system makes communication possible between different groups of people and machines, through the use of biological, personal, social or technical unit carriers. A human or electronic communication system provides a channel for mutual informational exchange that is not individually given to specific categories of information.

A. Avionic and Electronic Communication and Collaboration Cognition Systems

Avionic and electronic Communication and collaboration cognition systems (C&CCS) networks are artificial, neural, biomimetically-based extensions of human sensory and cognitive systems. (*See Table 1 and Figures 1-4.*) Put simply, C&CCS are a combination of artificial sensory and cognition systems that allow us to perform supernormal or long-distance detections and measurements of heat signature, tactility, perception, force, hearing, visibility, range, and target in addition to chemical and biological particulate, aerosol and gas.

Given the abovementioned, avionic and electronic C&CCS can be classified as biomimetically-based cognitive systems. Biologically, the cognitive system is an integrative information processing hub. Individually, avionic and electronic systems have their own cognitive systems. A vertically and horizontally integrative information processing hub can be modeled, simulated, and analyzed according to a biomimetically-based perspective.

B. Biomimetics

Biomimetics is the study and understanding of complex adaptive biological systems—that is, anatomical and physiological systems and components—such as structures, processes and functions identified as parts of human, animal and plant entities. Natural, biomimetically-based, design and engineering materials and concepts are used for purposes of deriving models, simulations, and analyses to produce avionic and electronic components and devices that are more capable. There are many biomimetically-based examples that have been used for engineering purposes; to prove this point, the author offers four naturally-based examples that have been applied to avionic and electronic systems.

C. Biomimetics Examples

In this subsection, the examples that have resulted in defense- and consumer-oriented products being realized are as follows: First, bats using radar-like techniques to detect their prey (or targets which are primarily insects). Second, electric catfishes using laser-like electric discharges to knock out their prey (which are usually other fishes); and using those same discharges to dissuade predators. Third, we have cellular communication between different types of living system cells. Fourth, a subset of cellular communication is cell signaling and it is part of a complex system of communication that governs basic cellular activities and coordinates cell actions; it includes the ability of cells to perceive and correctly respond to their microenvironment and according to situational awareness.

D. Biomimetically-Based Sensory Systems

We have examples of sensory receptors for detecting sensory signals and for converting them into signals that can be interpreted by cognitive systems. Moreover, from a biological perspective, sensory systems enable perception. Sensory systems maintain homeostatis by adjusting body conditions to respond to environmental changes. To do so, requires integration of the peripheral and central nervous system. The sensory part of the peripheral nervous system gathers information regarding sensory stimuli in and around the body. The sensory information moves through the spinal cord to the brain. The brain then processes this information and, if required, generates a motor response to the stimuli. Sensory receptors (or neurons) detect sensory stimuli and then converts the stimuli into electrical signals, in the form of nerve impulses; that can be interpreted by the brain. Sensory receptors are located throughout the body, but are mostly concentrated in the sense organs. (See types of sensory receptors in Table 1.)

TABLE I.

Table Types of Sensory Receptors		
Receptor type	***Stimulus***	***Location***
Thermoreceptors	**Temperature change**	**Skin, hypothalam us**
Pain Receptors	**Tissue damage**	**All tissues and organs except brain**
Mechanoreceptors	**Movement, pressure, tension**	**Skin, ears**
Photoreceptors	**Light**	**Eyes**
Chemoreceptors	**Chemical**	**Tongue, nose**

a. Biology: Principles & Explorations *(Johnson & Raven, HR&W, 2001, p. 964)*

E. Biomimetically-Based Cognition System

Cognition means having the capability to understand how something could be, at a future point in time, and taking it into consideration. It means recalling what happened at a point in the past and anticipating future happenings. Thereby linking cognition and memory by using the past to predict the future and then incorporating what does actually happen to adapt and improve the cognition system's anticipatory ability in terms of processes relating to action and perception. (*See Figure 2.*) Cognition breaks through the present obstruction and takes us into the future with the aid of the past, in a manner that helps the system to adapt and improve.

F. Biomimetically-Based Cognitive Hierarchy

The cognitive hierarchy identifies four different stages of value. (*See Figure 5: Cognitive hierarchy.*) Data is the simplest stage of information on the cognitive hierarchy. Obviously, processed data are thought to be more valuable than are raw data—and some might be of immediate value—but that is determined by evaluation. Put simply, data consist of unprocessed signals communicated between information systems (such as people, radios, computers, etc.), after signals are sensed from the environment and detected by collectors (such as human, mechanical, or electronic systems).

Information is processed data which provides higher value. (*See Figure 5: Cognitive hierarchy.*) Processing involves the filtering, fusing, formatting, organizing, correlating, translating, categorizing, and arranging of information. Information can be used for urgent application. Information can be employed for threat avoidance, acquisition, or for determination of what urgent actions to take. Information forms the foundation deriving a common operational picture (COP).

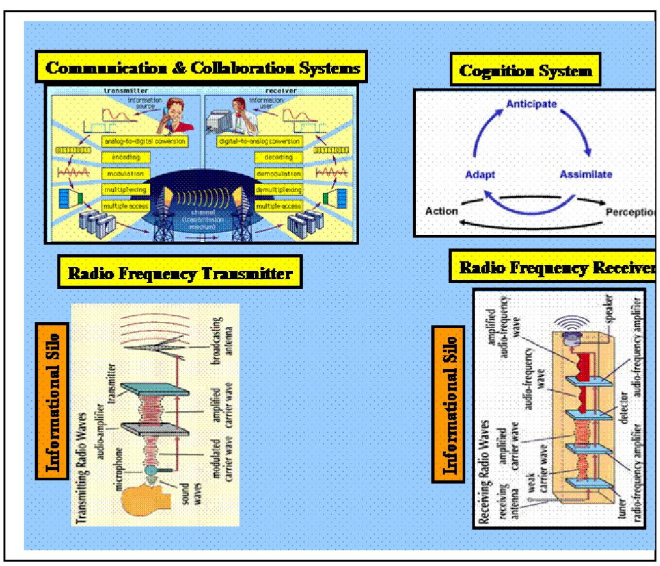
In the perspective of the cognitive hierarchy, knowledge is information analyzed to provide meaning and value, or evaluated as to implications for the operation. (*See Figure 5: Cognitive hierarchy.*) Knowledge is data that has been evaluated (by human, mechanical, or electronic systems) as it relates to reliability, relevance, and importance. Knowledge is processed data that has been integrated and interpreted for constructing a picture of the situation or even a COP for multiple or fast changing situational environments.

In the perspective of the cognitive hierarchy, understanding is knowledge that has been synthesized and had judgment applied to it in a specific situation or applied to it according to multiple or fast changing situational environments for understanding the internal and external human- or machine-centered relationships as they relate situations. (*See Figure 5: Cognitive hierarchy*.) The highest level of information is that of understanding—that is, knowledge that has been synthesized and applied to different situations for increasing greater levels of awareness of those situations. Understanding means we have an increased level of situational awareness. Understanding makes known the significant factors in any circumstances.

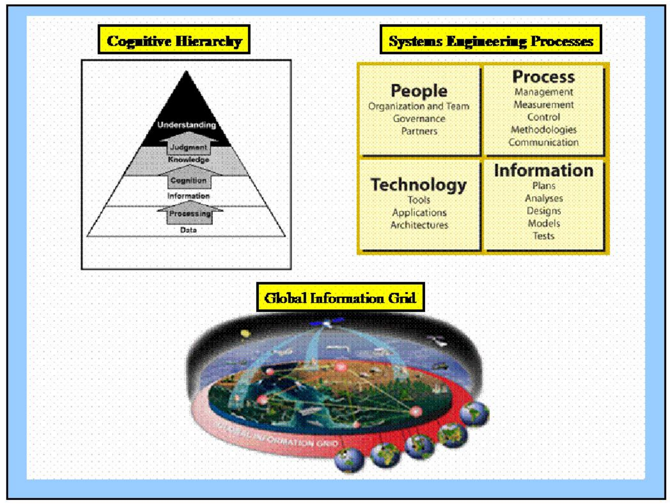
G. Biomimetically-Based Cognitive Diversity And Dissonance

To develop robust models for complex adaptive communication and collaboration systems we should consider integrating biomimetic and artificial cognition processes (such as transceivers, communications, collaborations and knowledge sharing) into models, simulations, and analyses (MS&A).

To develop MS&A for biomimetically-based cognition systems there are at least four matters we need to consider. First, we need to think critically about *cognitive diversity* [**1-2**] and *cognitive dissonance* and the importance of each. Second, we need to think about networks leading to information processing hubs and cognition processes.



Figures 1-4. C&C Cognition Systems



Figures 5-7. Cognitive Hierarchy, SE Processes, GIG

H. Biomimetically-Based Cognitive Architecture

A *cognitive architecture* and its functionality are described by Singh and Minsky according to the following:

> To build systems as resourceful and adaptive as people, we must develop cognitive architectures that support great procedural and representational diversity. No single technique is by itself powerful enough to deal with the broad range of domains every ordinary person can understand—even as children, we can effortlessly think about complex problems involving temporal, spatial, physical, bodily, psychological, and social dimensions…How can we build a machine with the intelligence of a person? There is no shortage of ideas for how to implement in machine aspects of human intelligence, for example, methods for recognizing faces, parsing the syntactic structure of sentences, or planning paths through cluttered spaces. [**3**].

Almost any system design such as a complex adaptive cognitive architecture is a reflection of its designers and developers, their values, beliefs, silos, communications, and memes. Cognitive hierarchy, diversity, dissonance, and architecture can be described as complex adaptive systems.

I. Biomimetically-Based Complex Adaptive System

A Complex system is a system comprised of interconnected simple parts; that together demonstrate a high degree of complexity from which emerges a higher order behavior. Examples of complex systems include ant-hills, ants themselves, human economies, climate, nervous systems, cells and living things, including human beings, as well as modern energy or telecommunication infrastructures.

Complex adaptive systems are unique cases of complex systems. They are *complex* in that they are different and made up of multiple interconnected elements and *adaptive* in that they have the capability to change and learn from experience.

J Biomimetically-Based Informational Silo

Informational silos function much in the same way as the telephone game. From a metaphorical perspective, the game works like so. A group of people stand in line, with each person communicating or whispering a sentence to the person next to himself or herself and that person communicates that same sentence to the person next to himself or herself and from that point onward the message is communicated or whispered down to the end of the line. (*See Figures 3-4: RF transmitter and receiver with informational silo.*) When the last person speaks the message aloud for all to hear, it turns out to be different from what the first person said. The telephone game shows how information gets changed according to an individual perceptual lenswhen it is transferred or communicated from one person to the next. If something like this were the case for design teams or groups working on the same project within the same company, one can only imagine cases where there are multiple stovepipes and corporations and agencies that must communicate across different corporate cultures, disciplines, philosophies, informational silos, memes, etc.

IV. SOCIOLOGICAL PROCESS SOLUTIONS

The social behavior of scientists, engineers and PMs might require a paradigmatic shift when integrating informational silos for development of complex adaptive systems. Subsections A-H describes systems engineering processes, silo integration, systems thinking and paradigmatic shifting in thinking, and the professionals capable of integrating multiple organizations and complex adaptive systems and performing knowledge management where required.

A. Systems Engineering Process

The systems engineering process is a series of actions, changes, and functions required to bring about the desired result. The systems engineering process is the technique that is used for integrating different technologies into newer and more complex, man-made, systems in which a change in one part of the system affects the functionality of components in other parts of the system. Moreover, the process is one, according to Figure 6, that integrates people, processes, technologies, and information. The processes in the Figure 6 could be of assistance for integrating multiple informational silos.

B. Need For Informational Silo Integration

To integrate informational silos or standalone systems many other domains such as information, cognition, social, and knowledge and human- and application-centered sub-domains need to be considered along with the physical domain and machine-centered sub-domain.

According to Figure 8, human limitations because of perceptual lenses can contribute to reductions in capabilities for sensory systems. Hence, without defying the laws of physics, the illustration depicts an engineering design team designing a cognition system to only detect data according to their own prejudgment limitations. Hence, they can mistakenly under-design an integrated cognitive system that does less than what it might have otherwise been capable of doing.

The complexity of bimimetically designing complex cognition systems that autonomously and instantaneously perform information processing regardless of time and location requires information silo integration. Six problems regarding this problematic matter are described below as the following:

> **Problem 1**: Fourteen communications models are highlighted and if the models are not considered they can also be factors that interfere with how efficiently integrated cognition systems performing as one *supernormal* sensory system will work. The models are 1) human; 2) electronics; 3) collaboration; 4) cognition; 5) perception; 6) applications; 7) usability; 8) learning; 9) perceptual lenses; 10) cultures; 11) memes; 12) research and development; 13) physical, informational, cognitive, social, knowledgeable, economic, etc., attributable domains; and 14) human-, machine-, and application-centered attributable sub-domains.
> **Problem 2**: Lack of content integration and the opening up of information silos.
> **Problem 3**: Information is collected with mismatched software and hardware and used by different people in organizations without knowledge of one another.
> **Problem 4**: Sensory integration disorder which concerns an inability of the cognitive neurological (global information grid) systems to manage inputs from the different sensors.
> **Problem 5**: Inability to attain documented knowledge that can be shared.
> **Problem 6**: Inability to transfer tacit, implicit, and explicit information.

The challenges stated above for developing and innovating cognition systems and their networked connections affect social, political, economic, educational, psychological and cultural domain values and, likewise, those values affect how cognition systems are designed and perform functional tasks. For instance, without acknowledging or recognizing other domains, engineering educational institutions oftentimes place greater emphases on educating learners about their disciplines according to the physical domain and the machine-centered sub-domain. The author argues that this bias contributes to narrowing as opposed to broadening the perceptual lenses of those learners whom will eventually become cognition system engineering practitioners, managers and leaders themselves.

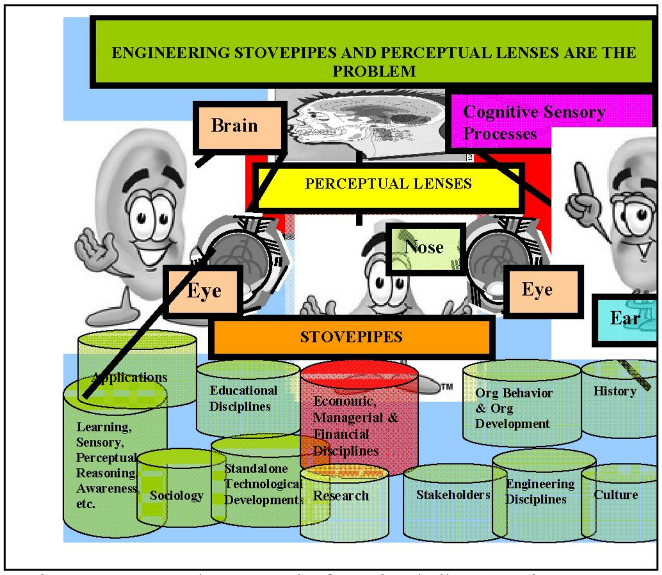


Figure 8.. Perceptual Lenses and Informational Silo Integration

C. Memes

A meme is a cognitive or behavioral pattern that can be transmitted from one individual to another. It is also described as a contagious information pattern that can be

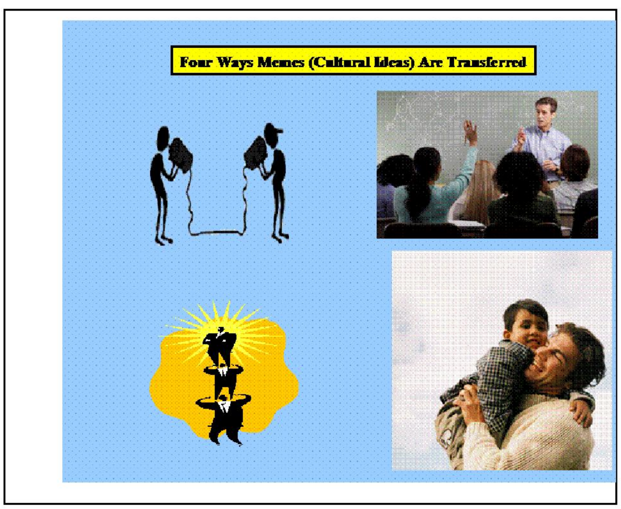


Figure 9. Meme Transfer and Cognitive Apprenticeship

repeated through the passing of the same information from one person to another or through the parasitic infection of human minds by said information and the sequential altering of human behavior that thereby causes them to propagate the pattern.

In a 2005 paper, "The Evolution of Meme Machines," presented at London, England, for the 30th Annual Conference for Development in Cybernetics, Dr. Susan Blackmore wrote the following:

> We humans are meme machines. So are the printing presses and telephones, and the computers and web servers that we have built. Memes are habits, skills, ideas, technologies and stories that are copied from person to person, or from a person to paper or silicon and back again. In other words, memes are the information that makes up human culture. Like genes, memes are selfish replicators. That is, they are information that is copied with variation and selection, and this means that they must inevitably give rise to a new evolutionary process. As with other evolutionary processes, memetic or cultural evolution happens for the benefit of the replicators themselves, not for the benefit of individual humans who copy them, nor for the benefit of the species, nor for the benefit of the planet [http://www.cybsoc.org/cybcon2005prog.htm].

Consequently, positive and negative engineering and systems engineering memes are also deeply embedded within work cultures, corporate cultures, and informational silos. (Memes are forms of transmissions similar to radio frequency transmissions.) To properly integrate individually developed communication and collaboration cognition systems or to integrate informational silos we need to think differently about how to solve the new biomimetically-based technical problems.

The memetic life-cycle is made up of four phases that collectively determine the meme's suitability based on assimilation, retention, expression and transmission. (*For basic understandings of memetic transmissions, see the illustrations in Figure 9.*) For a meme to be duplicated, it has to transition through four phases: 1) assimilation by a person, who thus turns into a host of the meme; 2) retention of the meme in that person's memory; 3) linguistic and behavioral expression of the meme by the individual that can be perceived by others; 4) transmission of the hence produced message or meme medium to one or more other individuals. This last phase is trailed once more by phase 1, consequently closing the duplication loop. At each phase there is selection or sense-making for determination of which memes are retained and removed from memory. To retain and eliminate positive and negative memes, respectively, regarding engineering projects systems thinking and holistic systems engineering needs to be included.

D. Systems Thinking

Systems thinking, shown in Figure 10, relates directly to having an ability to appreciate complexity. This type of thinking involves having an ability to see the system as a whole and its components and understanding the ways in which the parts interact and influence results.

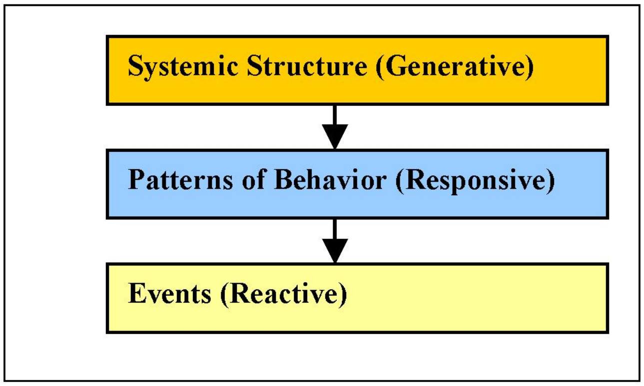


Figure 10. Systems Thinking

Systems thinking is an approach for problem solving where opportunity costs and seldom discussed and considered issues are integrated into system design and development philosophy and included as a part of a system's identification of risk and overall functional requirements. (*See Figure 10.*) Consequently, not focusing on potentially bad outcomes and opportunity costs and associating them with functionality only further exacerbates undesired problems and thereby negate other issues such as middleware compensatory effects for informational silo integration.

In addition to little-known costs, issues, risks and functions, systems thinking is a framework that is based on the belief or understanding that individually researched and developed component parts of different systems will behave differently when those systems are integrated together.

In a 2004 speech given by Chris Caine, Vice President of Government Programs, IBM, about integrating information silos, the following comments were made:

> IBM is a leading player in this public-private partnership. The objective is to create a national health information infrastructure that will drive real-time information sharing and collaboration across the entire healthcare industry.
>
> The simple fact is that while the U.S. enjoys 21st-century healthcare diagnostics and treatment systems, the information infrastructure linking these disparate systems and data belongs to the 1950s. Working across these information silos is costly, time-consuming and leads to preventable errors.
>
> It's estimated that the inability to share healthcare information in the U.S. contributes to 44,000 to 98,000 preventable deaths each year. Now, that's higher than the fatality rate on U.S. highways, and three times the number of deaths from AIDS [**4**].

The example above highlights the problem of integrating information systems across parallel humanistic universes, corporate cultures and—that is, dissimilar work cultures, information system designs, network infrastructures, individual costs and risks, and privacy and proprietary issues—also across parallel technological networks relating back to those universal philosophies.

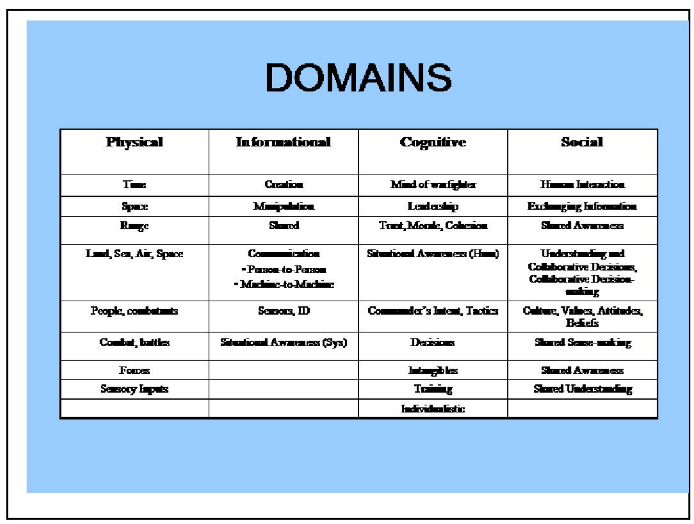
E. Holistic Systems Engineering

The perceptual lens problem illustrated in Figure 8 can be overcome. For example, let us suppose each column in Figure 4 represents a different perceptual lens. Let us further suppose, perceptual lenses can be broadened by inculcating the aggregation of the domains, illustrated in Figure 11, into cognitive system design processes.

Furthermore, let us suppose even more that lenses can be broadened by inculcating other domains, like artificial barriers and political, economic, educational, psychological, cultural domains, and so forth; and they can be broadened by also using a similar process for integrating information silos.

Similarly, if one were to inculcate the information in Figures 11-12 into cognition system design and integration processes, one might be able to further reduce cost and schedule slippages and also mitigate risk and meet requirements.

Using holistic systems engineering (HSE) techniques as referenced above [**8**], one can vertically and horizontally


DOMAINS

Physical	Informational	Cognitive	Social
Time	Creation	Mind of warfighter	Human Interaction
Space	Manipulation	Leadership	Exchanging Information
Range	Shared	Trust, Morale, Cohesion	Shared Awareness
Land, Sea, Air, Space	Communication • Person-to-Person • Machine-to-Machine	Situational Awareness (Hum)	Understanding and Collaborative Decisions, Collaborative Decision-making
People, combatants	Sensors, ID	Commander's Intent, Tactics	Culture, Values, Attitudes, Beliefs
Combat, battles	Situational Awareness (Sys)	Decisions	Shared Sense-making
Forces		Intangibles	Shared Awareness
Sensory Inputs		Training	Shared Understanding
		Individualistic	

Figure 11. Holistic Systems Engineering Domains

integrate within each information silo and across different silos. Nonetheless, HSE is incomplete because it focuses on integration of technology, without necessarily addressing the anatomical, physiological, and people-related issues also related to technology development for cognition systems.

To address the latter issues, anatomical and physiological specialists are important to enable integrators to understand cognitive and artificial neural network activity. The aggregated machine learning process requires transformation of collected data from various cognition systems from knowledge to comprehension, from comprehension to application, from application to analysis, from analysis to synthesis, and from synthesis to evaluation.

Additionally, it is important to include the learning and cognitive domain, history of science and technology and sociology of science and technology systems engineers for collecting, understanding, and documenting people-related issues for the technical activities according to cognitive diversity, cognitive dissonance, psychological, parochial, (tacit, implicit, explicit) knowledgeable, sociological and historical perspectives [8-9].

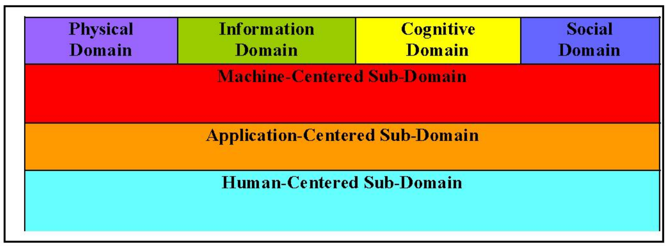


Figure 12. Holistic Systems Engineering Sub-Domains

F *Other Professionals: Anatomists And Physiologists*

Anatomical, physiological and biophysical specialists are important for addressing issues relating to electronic biomimetics and the mimicking processes for connecting anatomy, physiology and biophysics functions to integrated electronic cognition systems. By understanding such information, integration teams will know more about actual animalistic organ, cognition, and nervous (and other body) functions. They will have insight for what is required for integrated electronic sensory, cognitive and artificial neural network systems and for spatial and temporal message activity for machine-learning.

G *Other Professionals: Cognitive Scientists And Educational Psychologists*

The aggregated machine-learning process requires transformation of individually collected data from various cognition systems that are transformed from knowledge to comprehension, from comprehension to application, from application to analysis, from analysis to synthesis, and from synthesis to evaluation. Cognitive scientists and educational psychologists might be needed for understanding technology-related integration of learning processes and for understanding where and if, within these domains, horizontal and vertical integration efforts for information silos fall short. However, understanding of people-related integration is important too.

H *Other Professionals: Historians And Sociologists*

The aggregated human-learning processes for the integration team require transformation of individually collected data from various human cognitive systems. Likewise, that data are transformed from aggregated knowledge to comprehension, from comprehension to application, from application to analysis, from analysis to synthesis, and from synthesis to evaluation. Moreover, the team learns how to integrate electronic cognition systems as a unit. Nevertheless, at anytime people from the team can be promoted and transferred, can leave the company or agency, can retire, and can also die without any of their know-how being documented or cognitively transferred or stored for memorization purpose.

Given this, how might one capture individual and collective expertise? How might the human information silos be integrated and the knowledge documented and stored for futuristic needs?

In this case, history of science and technology and sociology of science and technology systems engineers are needed to collect, understand, document and store people-related issues connected to technical activities. Further, they will need to do so according to humanistic cognitive diversity; cognitive bandwidth; cognitive dissonance; psychological, parochial, artificial barrier, and behavioral matters; (tacit, implicit, explicit) knowledgeable issues; and sociological and historical perspectives [8-9].

V APPLICATIONS

For a cognition system to perform as such, through its sensory systems enabling its perception the system must at minimum have an ability to anticipate, adapt, assimilate, take new actions based on new learnings and, finally, it must have perceptive, targeting, re-configuration, cognition, software-defined functions and other types of capabilities based upon dynamic environmental changes.

A. *Situational Awareness*

Situational awareness concerns knowledge and understanding of complex environments for decision-making purposes. Examples are air-to-ground airport communications, radar warning receivers integrated onto fighter jets, electronic combat, command and control, and external targeting.

B. *Targeting*

In a cognition system, an internal target is any object that is aimed at or (after detection and identification) prioritized as an important item on which to perform a myriad tasks or functions such as displaying external targets of interest through machine-to-human display.

C. *Re-configurability*

Configuration is the arrangement of a system's parts or elements. Re-configurability is the cognitive ability to use software-defined capability to dynamically rearrange the elements or settings of the cognition system based on situation [7]. This happens of course through cognition and its ability to perceive and adapt.

D. *Cognition*

Cognition refers to a cognitive system's capability to use a transceiver to sense an environment and extract data that can be classified as new or old; that is, to determine if it will continue to operate according to its present design or autonomously adapt to an alternate configuration [7]. Put simply, to avoid bottle necks, cognitive capability allows a transceiver to intelligently detect where open channels are available. This capability permits it to optimize the use of an available range of network channel opportunities and to minimize interferences toward other users' transceivers.

In this case, a cognitive system is a software-defined function. This type of function includes an ability to determine locality, identify and authorize a client, encrypt or decrypt signals, sense adjacent devices and make adjustments for characteristics of interest [7].

E. *Software-Defined Function*

A software-defined function (SDF) infers a transceiver's capability to use its integrated circuits to generate or define transmitter modulation and to receive and recover transmitted information. For SDF to perform spread spectrum—an electronic combat technique—for transceivers on both ends of networks they must have *self-management* capability and be able to perform a myriad of other *functional tasks*.

F. *Self-Management*

Using cognition and SDF, the self-management sub-function provides a cognitive system with an ability to self-adapt according to its environment and to do so without the need to be either physically re-designed by an engineer or to be instructively re-structured by a central management computing entity that has a higher level of rationality [7].

G. *Functional Tasks*

1) Sensing

Using cognition and SDF, the sensing sub-function uses a search procedure to detect and measure messages at perceived levels of energy and to do so according to temporal and spatial requirements [7].

2) Representation

Using cognition and SDF, the representative sub-function performs detection, comparison and identification of comparative waveforms and informational attributes, ideas, images or knowledge for attaining information about external targets of interests [7].

3) Search

Using SDF, the search sub-function provides the cognitive system with the capability for carefully and thoroughly looking throughout the network to find external targets of interests [7].

4) Reasoning

Using cognition and SDF, the reasoning sub-function performs the process of drawing conclusions from detecting, measuring and identifying external targets of interests [7]. This includes the attributes of machine-learning, learning domain, and decision-making.

a) Machine-Learning

Using cognition and SDF, the machine-learning sub-function provides the cognition system with an ability to improve its performance by changing or adapting its behavior based upon previous results. (*See Figure 2: Cognition system; and Table 1: Types of sensory receptors.*) Sensory and neural networks feed information into networked cognitive systems for machine-learning. Put simply, machine-learning uses the machine's artificial intelligence capability to self-adapt or learn based on adaptation, perception, anticipation, and assimilation and also the history or knowledge the cognitive systems know about themselves and their ability to compare such to new learning. For instance, learning takes the form of updating knowledge, adjustments of searches, reconfigurations based on representations, and augmentations based on reasoning. This sub-function aids the system in information processing of data and transforming that information within the learning (cognitive, affective, and psychomotor) domain [7].

b) Learning Domain

Using cognition and SDF, as explained above the transformation that occurs within the cognitive domain transforms data from raw knowledge, to knowledge that can be comprehended, analyzed, synthesized, and evaluated. For the affective domain, the transformations range from receiving to responding to phenomena and from those to valuing, organizing, and internalizing values of phenomena. For the psychomotor domain, the transformations include reflex movements, fundamental movements, perceptions, physical activities, skilled movements, and communication;

further, mechanisms for responses, complex overt responses, adaptation to responses, and origination of responses.

c) Decision-Making

Using cognition and SDF, the decision-making sub-function can be regarded as an outcome of the machine's cognitive processes leading to a selection of a course of action given several alternatives.

CONCLUSIONS

From a thought experiment perspective, the paper discusses the fact that information silos exist. It discusses the structure and function of biological systems as models for the design and development of a prospective world-wide electronic cognition systems and its sensory and neural network. It discusses the difficulties of integrating standalone electronic communication and collaboration cognition systems.

The technical level of difficulty for designing and developing a complex adaptive cognition system is expected. What is under-recognized is the people-related difficulty. For instance, perceptual lenses, privacy and proprietary rights, interdisciplinary discrimination, lack of knowledge sharing, etc. As stated above, in the same way that technology can be a complex adaptive system, the same can be said for people, culture, and memes and these too should be included as part of the integration of information silo process.

Use of HSE methodology that includes people and their peculiarities is recommended as an approach that could lead toward possible solutions and mitigation of risks when attempting to develop cognition systems with complex adaptive capabilities. The HSE methodology includes multiple domains and sub-domains. The domains relate to attributes required for overall desired system functionality within various environments. Another outcome could be its potential for broadening perceptual lenses while simultaneously creating a means for integrating information silos. Other professionals such as cognitive scientists, educational psychologists, anatomists, physiologists, biophysicists, historians of science and technology and sociologists of science and technology are recommended as intermittent team members or contributors for helping to integrate information silos and perform knowledge management; to create a desired integrated cognition system; to ensure sharing of (tacit, implicit, and explicit) knowledge; and for documentation and organizational memorization of knowledge and integration of informational silos.

Finally, applications that are fundamental to integrated cognition systems are discussed. Nonetheless, all of the ideas, topics and theories such as HSE, silo integration, biological models, memes, and inclusion of non-traditional professionals as stovepipe integrators that were discussed in this paper are still located within the theoretical realm and have yet to be experimented upon to determine their validation. However, many of these subject matters are seldom discussed within this forum either.

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REFERENCES

[1] C.C. Miller, L.M. Burke and W.H. Glick, "Cognitive diversity among upper-echelon executives: Implications for strategic decision processes," Strategic Management Journal, 1998, Vol.19, No.1, pp. 39.

[2] R. Mitchell and S. Nicholas, "Knowledge Creation in Groups: The Value of Cognitive Diversity, Transactive Memory, and Open-mindedness Norms," The Electronic Journal of Knowledge Management, 2006, Vol. 4, No. 1, pp 67-74, http://www.ejkm.com/volume-4/v4-i1/Mitchell-Nicholas.pdf.

[3] P. Singh and M. Minsky, "An Architecture for Cognitive Diversity," Massachusetts Institute of Technology, Media Lab, April 23, 2004, http://web.media.mit.edu/~push/CognitiveDiversity.pdf.

[4] C. Caine, "Government in an Era of Rapid Innovation: Embracing The Future," Vital Speeches of the Day, February 1, 2004, Vol. 70, No. 8, pp. 237.

[5] Encyclopedia Britannica, "Cartoon Illustrations Of Radio Waves: Transmitters, Receivers And Radars," www.eb.com.

[6] Microsoft, "Collaboration Is Fundamentally About People Working Together, Both In Real-Time And Asynchronously," Sorting Out Microsoft's Collaboration Technologies, http://msdn2.microsoft.com/en-us/library/ms788699(office.11).aspx.

[7] E. Adamopoulou, K. Demestichas, and M. Theologou, "Enhanced Estimation of Configuration Capabilities in Cognitive Radio," IEEE Communications, April 2008, Vol. 46, No. 4, pp. 56-63.

[8] K.W. Jones, L.C. Jenkins, and J. Ramsey, 2005, "Holistic Systems Engineering: Physical, Informational, and Cognitive Domains," presented at 24th Digital Avionics Systems Conference (DASC), Systems Engineering Track, Hyatt Regency Crystal City, Washington, D.C., USA, 2005. Published in IEEE, pp. 9.B.6-1- 9.B.6-11.

[9] W.K. McQuay, W. Smari and K.W. Jones, "Workshop on Sociology of Science and Knowledge: Collaboration, Decision Support Systems, Decision-Making, and Systems Engineering (SoSaK 2008)," The 2008 International Symposium on Collaborative Technologies and Systems (CTS 2008), May 19-23, 2008, http://cisedu.us/cis/cts/08/.