A Comprehensive Cognitive Engineering Process  
for Human-Information Systems

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Abstract

The USAF is in the midst of an information revolution that requires thoughtful consideration of (1) cooperative problem solving (2) emergent complexity and (3) changing paradigms. Not only is the information revolution evident in the technology that proceeds from it (e.g., virtual reality systems, ubiquitous computing, groupware) but it is having a deleterious affect on the human’s ability to adapt to new performance levels that require sustained attention, trust in intelligent associates, or a new reliance on teamwork. The purpose of this paper is to compare traditional human factors with cognitive engineering to assuage complex human-information system problems, look at how cognitive engineering processes have been partially applied in real world domains, and propose a broader model for USAF targets of opportunity. The affects of the information revolution on human-centered systems may be contemplated by asking DeGreene’s three basic questions [1]. What is the nature of the real world? How can the real world best be studied? How can design best be accomplished? In turn, cognitive engineering must be attuned to these questions if it is to have lasting effects, and if it is to be responsive to continuous process improvements in USAF systems.

1. Challenges and complexities in real world problem domains

When complex situations involve multiple operators, information systems, and simultaneously changing conditions, real world problem solving becomes a challenge. Collaboration, cognition, computation, context, and design must coexist in a delicate balance. For example, piloting, designing, and surgery are three real world activities that typify integration of collaboration, cognition, computation, context, and design [2]. Inherent in their assessment were several characteristics of real world problem solving that should be considered in complex human-information systems: group members spontaneously generate knowledge in the context of a situation; coordinate multiple cognitive processes, applied through multiple paths; and pickup critical perceptual cues for potential solutions. Collaboration directed towards solving real world problems is often interpersonal, ill-structured, involves interwoven problems and extended timeframes, requires discovery of problems with subproblems, and invites the social construction of knowledge.

Human-information systems will need to counteract the chaotic, uncertain, emergent situations that occur when distributed agents, intelligence, and objects are required to pursue intentional ends through opportunistic means. Failure, dilemmas, catastrophe, unknown pathways, and chaos can snag any hope of successful system performance. The cause of failure in many large scale systems [1] (e.g., Three Mile Island, Space Shuttle Challenger, etc.) precipitates when:

“...a small, usually trivial event triggered a massive change; several forces interacted, unanticipated and unplanned-for contingencies occurred; new problems emerged in trying to handle the failure; normal day-to-day activities set the stage for failure; and widespread complacency had arisen after a period of normal complacency (p. 224).”

The real world is dynamic - not static, longitudinal - not cross-sectional, continuous - not discrete, nonlinear - not linear, and synthetic/holistic-not analytical/reductionistic.

Likewise, global military situations encountered in the next millennium will be highly contingent on multi-sensor integration; real-time image interpretation; broad
bandwidth data fusion across several corridors; timely and meaningful cognitive, communication, and learning processes; information warfare and battlespace dominance; space and autonomous satellite operations, intelligent remote sensing, and virtual battlefield presence. At the microlevel, global awareness begins with individual operations. In turn, traditional and contemporary user-centered perspectives typically center on individual interface/workstation designs. However, as more complexity enters into military situations, more players are involved as individuals aggregate and share information. In additional to local tasks, constraints, and operations, user-centered approaches will increasingly be required for joint operations that are distributed across a global awareness context. This term is used in a manner similar to the analysis of dominant battlespace awareness [3]. Future battlefield situations are described as involving multidimensional knowledge about current position, classification, identity, condition, and recent history of all items of military significance on the battlefield (in the 200 nm area); to also know of the objectives, intentions, and plans for all the players inclusive of strategic conventional (e.g., factories) and unconventional targets (e.g., financial networks). The various levels of 'knowing' this information are emergent at any given time. Each player within the situation may have different necessities regarding the need to make information instantaneously available for any given event. Furthermore, problems resulting from distribution and storage of varying levels of information, caused under conditions of limited resources, creates major challenges. Such is the nature of upcoming domains within which consideration of human interaction and human intentions are formed.

Complex global systems come into play at the macrolevel when teams must interact, monitor, comprehend, and exchange information with other teams, and determine allocation of joint activities. Real world collaboration [4] is defined as "a process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their own limited view of what is possible (p. 5)." By inference, military global awareness can be thought of as a learning process that emerges over time and requires information sharing to establish mutual understanding. Mutual understanding means that information brokers jointly identify and define a problem, search together to explore options, establish cooperative goal interdependence, and commit to action making within flexibly shared interaction and information spaces. Action making refers to activities that team members do to impart change in conditions, based on their joint experience and knowledge, and their ability to use/adapt this knowledge in the course of a changing mission. Enhancing global awareness will increasingly become more contingent on large group displays, information agents, electronic communications media (e.g., desktop teleconferencing), distributed data conferencing/groupware facilities, and cooperative learning systems.

As one can see many of the complexities resident in next millennium military domains emanate from the constant information flux, the information sharing-distribution necessitated by the domain, and the individual/team/team-to-team interactions that occur through the use of advanced information systems. Together these complexities exert new requirements for contemporary human-centered approaches to adequately address human-information system interaction. Instead of reengineering simple controls/displays, there will be a need to design innovative human-information systems (e.g., virtual reality domes, ubiquitous computing embedded in C4I command posts and mobile workstations, dynamic sensors/controllers, adaptive cerebral-based interfaces) that are highly compatible with human cognition and collaboration; and consequently afford easy information assimilation, assessment, and action in emergent situations.

Such is the nature of the real world as relevant to USAF targets of opportunity (e.g., information warfare, medical evacuation, uninhabited combat air vehicles). As designers generate adaptable interfaces, attuned and balanced to the nature of these settings, it is evident that many approaches, methods, and studies taken to address these complexities are not consistent with real world constraints. In many cases, the Weltanschauung that proliferates may correspond with past conceptualizations of a field. Perhaps this is true in the area of human factors engineering.

2. Potential approaches to complex human-information systems

Real world problem solving, involving clusters of humans and information system components operating in various contexts, presents many challenges to implement a user-centered approach. Many traditional roles of analysis and study may be outdated or even insufficient to attend to the increased level of emphasis on multi-place interactions, and on the increased importance of the context itself. Three different approaches (human factors engineering, knowledge engineering, and cognitive engineering) to assure human-information systems concerns are suggested and briefly compared.

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[1] Webster's New World Dictionary defines Weltanschauung as a worldview - one's philosophy or conception of the universe and of life.
2.1. Human factors engineering

Early accounts of human engineering [5] by McCormick suggest it is the adaptation of human tasks and working environments to the sensory, mental, physical, and other attributes of people which applies to the design of equipment, man-machine systems, consumer products, and work. In many cases, this defining statement is inclusive of knowledge engineering and cognitive engineering specialties. Yet, the practice of human factors has drifted somewhat from these early views. The field often lives and dies by the approaches used to invoke adaptations between human and system constraints. Traditional human factors engineering has typically had a preeminent goal of serving the user but generally treats the (1) context of work and (2) socio-organizational / collaborative factors with much disdain [6]. Recent exceptions to this have played out in the areas of macroergonomics [7] and ecological interface design [8]. Human factors may also connote ‘human’ as one who may be perceived to be passive, fragmented, depersonalized, unmotivated [6]. The human is treated as just another component with limited characteristics to be factored into the overall system. By comparison, real situated environments find the human not as a factor but as an actor who acts according to individual differences, membership and roles with a community of workers, and constraints imparted by the setting itself. Typically human factors focuses on human performance and emphasizes issues such as workload, anthropometry, control-display integration, lighting, and other factors that highlight human-design compatibility issues. Experiments usually vary a number of human-machine interface elements then measure system states and human capabilities-limitations. Although this tradition is vastly important, and has its place in improving user’s needs, it may not tell the whole story. Frequently, human factors aims directly at asking “How can design be accomplished?” without first attending to “What is the nature of the real world?” and “How can the real world be studied?”

Within human factors practice, conflicts arise in assessing what a person knows, what a person experiences, what a person does, or what a person needs. For example, the design of human-computer interfaces for Internet browsers may only examine keystrokes (what a person does) without addressing some of the cognitive constraints of usability (what a person knows, experiences, or needs). These gaps are evidenced by failures in designs, clumsy automation impacts [9], or brittle knowledge bases [10]. As complex systems emerge (e.g., the glass cockpit, nuclear power plants, intelligent highway systems), and are subject to more of these conflicts, there is a necessity to examine some of the traditional limitations within human factors that might be addressed by knowledge and / or cognitive engineering processes.

As an example of the type of process that typically incurs when traditional human factors approaches are applied to a design, refer to Figure 1 (derived in part from [11, 12]). Although this process has been used to various degrees of success, it still has inherent problems that can lead to the problems just discussed.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Issues</th>
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<tbody>
<tr>
<td>Program Planning</td>
<td>Situation Awareness</td>
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<td>identify overall needs, operational requirements, schedule, cost, technology</td>
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<td>Up-Front Analysis</td>
<td>Automation</td>
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<td>define mission and crew requirements</td>
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<td>initiate crew system specifications</td>
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<td>Crew Systems Analysis</td>
<td>Workload</td>
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<td>literature search</td>
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<td>function definition and flow</td>
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<td>function allocation and tradeoffs</td>
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<td>begin human performance / workload study plans</td>
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<tr>
<td>Crew System Design</td>
<td>C/E Integration</td>
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<td>static workplace / cockpit layout</td>
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<tr>
<td>prototype dynamic control / displays; crew systems layout</td>
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<td>integrate crew systems analyses as they affect design</td>
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<tr>
<td>produce baseline cockpit simulator based on design tradeoffs</td>
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<tr>
<td>Crew System Evaluation</td>
<td>Phys. Workplace</td>
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<td>perform human performance studies</td>
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<td>pilot-in-the-loop, part task simulation</td>
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<td>pilot-in-the-loop, full task simulation</td>
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<td>in-flight observation</td>
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<td>reintegrate results / findings into final crew system specification</td>
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<td>Lighting</td>
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<td>Noise</td>
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<td>Viability</td>
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Figure 1. A typical human factors approach to an aviation domain

2.2. Knowledge engineering

Knowledge engineering generally derives from computer science concerns and is not subject to principles such as “know thy user”. Early techniques applied to limited, toy domains wherein ‘accessed knowledge’ was relatively easy to come by. The process became much more difficult for real world systems (e.g., medical diagnosis [13]; pilot aiding [14]). Knowledge engineering usually progressed like most other engineering disciplines in the sense that processes were engaged for the sole intent of building an end product with little regard as to how the end product is compatible with human interaction. Most expert systems were designed to be used by operators engaging the system - therein the end products were human-computer interfaces. But relatively little credence was given to this perspective in the early design of these systems. Exceptions were in the human engineering of medical expert systems [13]. Today, this
has changed as the evolution of human-computer interaction and computer-supported cooperative work has essentially redefined our vision of information systems in contrast to the notion of ‘artificial intelligence’ systems from the early-to-mid 1980s. Still, the engineering of knowledge within human-computer interfaces may proceed from traditional knowledge engineering standards resulting in impoverished or problematic interfaces. Therein, knowledge engineering also focuses on accomplishing design without consideration of the real world, or how to study the real world.

Knowledge engineering [13] is “the process of mapping an expert’s knowledge into a program’s knowledge base (p. 5)”. Research traces knowledge engineering as one coined by Edward Feigenbaum after Donald Michie’s phrase epistemological engineering. Engineers elicit knowledge from experts in an attempt to ‘represent’ knowledge in a workable structure (e.g. frames), thereby allowing a computer system to approximate human reasoning. Knowledge building tools, or even automated knowledge acquisition systems, have been developed to streamline this process. Unfortunately, this process presents bottlenecks as an expert must “access” native knowledge in a form directly exportable to the knowledge structure. This has resulted in rejection of the process by experts, faulty representations which fail to consider socio-organizational and contextual factors, and brittle computer systems. How to elicit user-centered knowledge from operators, and how to transform that knowledge to fit information system requirements remain as core issues for the discipline today. Refer to Figure 2 (adapted after [15]) which shows a traditional knowledge engineering process which may be contrasted with the human factors process.

Figure 2. A typical knowledge engineering framework

2.3. Cognitive engineering

Cognitive engineering’s value is that, unlike human factors and knowledge engineering, there is the opportunity to design complex human-information systems through a balanced viewpoint - one that tries to make sense of the affordances, effectivities, and mutual transactions that may occur between an agent and his/her environment, under a variety of changing conditions. Affordances [16] represent the ways the environment permits one to act, whereas effectivities specify an agent’s capabilities to act relative to affordance availability. For example, ladders afford climbing but can alternatively afford sitting, according to one’s capabilities. A person can climb a ladder if they have specific capabilities associated with leg length and strength. On the other hand, the body size may be too large to permit sitting on a rung. Likewise, global awareness is enhanced when we have specific effectivities to actively sense and collaboratively fuse information across distributed point nodes. But these effectivities are relative to what the specific situation affords. For example, near real time conflicts may only afford sense-taking at one point of the battlespace while at another battle sector there is an affordance for damage assessment. Together these affordances must be understood and communicated across sectors. Agent-environment interaction is denoted [16] as an adherence to an ecological perspective to cognitive engineering. The Merriam-Webster dictionary defines ecological as the interrelationship of organisms and their environments; in turn it defines perspective as the capacity to view things with the proper relationships as to value, importance, and basic qualities. Taken together they emphasize the multidisciplinary nature of living systems, their environments, and the reciprocity that has developed between them. Sometimes change is required in perspective to address new complexities in problems or to overcome stagnation or shortsightedness of the status quo. Agent-environment transactions are viewed as goal-directed, self-organizing, and intentional processes which often take the form of perceptual-action cycles (OODA loops). Adaptive transactions are at the heart of many non-linear, multi-operator problems. Therein, cognitive engineering can be thought of as a middle ground existing between traditional human factors and knowledge engineering.

The goal of cognitive engineering is to provide meaningful information to operators (as compiled from various raw data sources) as a function of (1) understanding situated cognitive principles (2) engineering intuitively designed interfaces (3) engaging user-centered participation. These goals are often realized by approaches such as individual knowledge elicitation, cognitive modeling, and design [17]. While the cognitive side of cognitive engineering is contingent on new advances in language considerations (semiotics), cognition (planning, problem solving), anthropology (ethnographic study), neuroscience (cerebral scanning-mapping),
philosophy (epistemology) and computer science (machine learning), the engineering side requires investments in requirements (systems analysis), representation (functional decomposition), integrated design tradeoffs (cognitive walkthroughs and storyboarding), modeling (human performance), and simulation (distributed). By melding cognitive science with engineering practice within specified situated contexts, cognitive engineering begins to derive meaning as a kind of next-order human engineering as defined in the McCormick tradition [5]. Principled considerations of cognitive engineering are necessarily bound to formal cognitive science fundamentals. But one must not consider such fundamentals without consideration of the situated contexts where real world problems occur. The combination of emergent-distributed contexts, collaborative activities, and innovative computing technologies form problem spaces that traditional approaches are not prepared to consider.

Cognitive science concerns for USAF new millennium initiatives revolve around potentially devastating requirements for attention, memory, group problem solving, perception, learning, knowledge acquisition-access, and motor control. These concerns may be jointly referred to as distributed cognition [18]. That is, cognition is situated and shared across multiple agents, objects, and environments. This is an example of what some have referred to as 'cognition in the wild' [19]. Distributed cognition as applicable to future USAF capabilities (e.g., in uninhabited combat air vehicles) will involve an intricate fusion of pilots, remote pilots, airborne and ground station reconnaissance and surveillance operators, and other associated crew members; fulfilling various human supervisory control functions; and alternating in-and-out of multifarious OODA (Observe-Orient-Decide-Act) loops coexisting in non-linear timeframes. Without proper attention, any single operator in a given OODA loop can experience combinatorial explosion resulting in major cognitive deficits. This is not an isolated problem as global awareness factors require information sharing, transmission, storage, and reception across highly stratified, yet interdependent functions. When a given point node of cognitive activity goes down, extant errors proliferate across different OODA loop phases in accordance with the temporal and geographical spread of information. This ‘spreading activation’ affect needs to be offset by application of cognitive engineering principles that design intelligent interfaces to reduce overload and channelized attention bottlenecks. Concomitant with combinatorial explosion affects, research related to large-scale function adaptation as distributed across several battlespace corridors, will be absolutely critical for determining increases in precision strike capabilities. Many of the salient cognitive engineering research issues cannot be addressed by merely rehashing traditional turn-the-crank human factors (e.g., behavioral task analysis), paradigms of the past (single-operator research studies), or models of cognition that fail to incorporate real world context (e.g., human information processing approaches).

In lieu of existing human factors and knowledge engineering limitations, there exists a need for a different approach to the design of human-information systems, one that could engineer intelligent systems to be adaptive with human cognition. As a philosophy, cognitive engineering brings expert-centered knowledge to bear on complex designs. It is a technical specialty that encompasses different methods for capturing multiple perspectives on user knowledge, experience, and context; and actively seeks user participation in transforming these elements into real world design solutions [20]. In this sense, cognitive engineering imparts ‘knowledge-as-design’ for the user, by the user, and with the user. As an approach, cognitive engineering is primarily concerned with acquiring, exploring, and transforming knowledge throughout different stages of a design process (see Figure 3, adapted after [21]). Unfortunately, cognitive engineering tools and techniques in practice are typically applied to single operator settings, often only use a unidimensional representation of knowledge for a single operator, are under-developed in manipulating and transforming knowledge into design parameters once it has been elicited, and are applied in piecemeal ways. For example, an approach may only yield a task-analytical modeling perspective, or may be limited to a microscopic element of an overall mission. Often, cognitive engineering is a paper-and-pencil exercise, is conducted by a single engineer with a single domain expert, and does not take advantage of advances in computer assistance. In order to address some of these concerns, a more comprehensive view of cognitive engineering is necessary.

![Figure 3. A typical cognitive engineering approach](image-url)
3. A comprehensive cognitive engineering approach

For the last five years the Armstrong Laboratory Human Engineering Division has developed a vision of cognitive engineering theory and practice. There have been mistakes and advances but a goal of continuous process improvement has been intentional and proactive. On the basis of experiments, ethnographic studies, and through the collaboration of many experts working in the ‘Living Lab’ a comprehensive cognitive engineering framework is proposed (Figure 4). Various facets (or processes) have been used, either individually or in combination, to explore and verify different avenues of use through multiple case studies. Initial efforts focused on preconcept / concept stages of product life cycle development, trying to directly understand user’s needs and constraints in their operating environments. This led to derivation and emphasis on a ‘knowledge as design’ philosophy eventually leading to a variety of studies using user-centered knowledge elicitation techniques. Techniques focused on the use of concept mapping, IDEF functional decomposition, and design storyboarding for real world missions. These methods were in the tradition of participatory ergonomics and were convened by individual or group interviews with experts familiar with their work and contexts.

Focus groups
Surveys
Technology Assessment

Ethnographic Tools
Mentor Protocols

HCl simulations and evaluation methods

Figure 4. A comprehensive cognitive engineering process

2 This framework was co-developed with assistance from Lt. Col. Bernard Asiu, Armstrong Laboratory, Brooks AFB, Texas.

3.1. Initial application: The Pilot’s Associate

Part of a cognitive engineering effort should include multidimensional description, analysis, and synthesis of a) the context the activity occurs in and b) the cognitive basis (e.g., plans, strategies, knowledge, decisions) for action in that context. A very complex environment in piloting is that of designing an electronic crew member to assist the pilot. Our initial work in cognitive engineering focused on developing requirements for the knowledge base, then used this knowledge to define the interface between the pilot and the pilot’s associate. To limit the problem’s scope, the target acquisition elements of a tactical mission were selected for study.

First, we concept mapped pilots to create mental models of how they viewed their mission, the contexts they typically experienced during a mission, and the knowledge and concepts that precede actions taken. Initial maps were summarized and used to inform subsequent design solutions. After pilots completed maps that defined their knowledge, they were given a missile profile which contained specific targets, weapon selections, attack geometry, etc. Using this information, they initially plotted out a rough timeline map of target acquisition. Within this timeline, critical decision points were defined by the pilots. Surrounding each decision point the pilot provided a variety of information related to plans, strategies, perceptual recognition, action points, etc. in proper sequence and in the context of the real mission demands. This method allowed us to make a series of cognitive walkthroughs. Pilots acted in the role of mentors while using case-based reasoning to derive new strategies, procedures, and requirements. The combination of the mental models directly acquired from the pilots, along with the sequential progression through a mission, allowed a great deal of understanding of the cognitive complexity resident in this problem.

Prior to taking these cognitive mappings, we decomposed the mission into hierarchical levels revealing functional inter-dependencies and associated actions. It was useful to compare / contrast these multidimensional views of the cognitive requirements necessary to perform the mission, and begin to think of ways an electronic associate might aid a pilot.

Next, we were ready to use our base of knowledge to leverage the design solution part of cognitive engineering. For each of the decision points that were defined and developed, a storyboard was created to explicitly transform ‘knowledge as design’. Design storyboarding, used in the film industry to depict information requirements through use of a sequence of images, allows illustration of a scene’s staging and outlines a story. Information is portrayed as what should be heard or seen, how it should
be experienced, and when it should appear. Storyboards look like a comic strip as they develop a storyline through graphic portrayal. The pilot's individual storyboards were merged to form a final summary storyboard which contained specific knowledge about preflight planning, key decision nodes, communications, visual acquisition, aircraft systems, problems and solutions, and information requirements [20]. This example shows some of the 'basic how-to' for one cognitive engineering approach.

3.2. Critical needs and improvement

One major need identified through various iterations of this example highlighted the lack of ethnographic /observational data to understand how users actually work in their environment with a prototype or an end product, both individually or with other team members. Therein, a proposed solution involved supporting development of an observational / protocol analysis tool, MacSHAPA [23], to leverage (1) the expert's knowledge and design ideas with (2) actual work and interaction in a setting. This integration continues and is exemplified by a new synthesis [21].

Upon further reflection, the initial process methods needed to be extended beyond knowledge and design elicitation at the front end stages to complement other human-centered methods that address a broader spectrum of the overall system design process. Therein, Figure 4 provides a complement of other processes to insure a comprehensive approach. Yet, there is also a need to understand different - yet interrelated - levels of abstraction within each given design stage. Work ongoing in abstraction hierarchies [24] is appropriate to integrate here as it elaborates these types of inter-connections across differing languages or representations. This is explained [25] as "...in a means-end representation, a system is described simultaneously at several levels of abstraction. Each level relates to its neighbors in conceptual means-ends relationships; the higher level answers the question of "why" while the lower level the question of "how." The top level represents the system in terms of ultimate goals; the bottom level represents the system in terms of physical appearance and resources. (p. 45)."

Finally, although design storyboards provide a good translation of knowledge into design, this process did not continue to the next stage. That is, storyboards need to be prototyped as reconfigurable-interactive simulations that afford additional robustness for cognitive talk-and-walkthroughs for evaluation by selected focus / usability groups. Furthermore, when a design reaches the simulation form, the beginning product can also be cross-validated by use of HCI evaluation standards and guidelines. Although there are certainly more improvements looming in this process, these needs were identified as the most salient at this time. The following improvements would be expected if the above solutions were implemented.

The operative context may additionally be understood by the use of means-ends hierarchies and the MacSHAPA tool acting together to meld disparate elements of multidimensional representations. At the context-preconcept stages of the process, a framework that is based on differing levels of abstraction allows an engineer to provide a bottom-up basis for function adaptation- allocation. Cyclic iteration of complementary methods may proceed thereby instantiating various nodes of the abstraction hierarchy. If one has generated a design storyboard it may be breadboarded to the point where it might be immersed in a context for initial feedback of the preconcept and concept ideas. Outcomes of this in situ evaluation may then be embedded as specific attributes of an human-information system product. As this product becomes more refined, additional user-centered feedback may be elicited through surveys, technology assessments, and new focus group activity. At this point of the cycle, much emphasis needs to be placed on continuous process improvement via multi-user participation. It is also at this point that new gaps between human(s) and their proposed information system product are identified. They may be simultaneously indexed to theory and models as evident through literature search, and / or traced back to operative context itself, to guide and define alternatives for the next cyclic improvement. Multiple layers of abstraction can be indexed to each other even though different languages or formalisms represent each layer. The context at this point is also likely to be studied through various ethnographic procedures [25], e.g., event-process-response cycles in direct observation of behavior, protocol analysis, or decision ladders [24] that are selectively applied to a given target domain.

4.0 Concluding Remarks

As one can see the comprehensive methodology presented here has various elements associated with human and knowledge engineering. It has been designed to encourage a balanced view of systems from beginning to end to yet new beginnings through the philosophy of continuous process improvement. Unlike human factors and knowledge engineering, the comprehensive approach just described begins to address all three of DeGreene’s questions [1]: What is the nature of the real world? How can the real world best be studied? How can design best be accomplished? The user is a valued entity within the overall process and must be actively engaged throughout
the system design cycle while working co-jointly with the cognitive engineer and other design team members. The cognitive engineering processes presented here represent a 'basic-level model' predicated from improvements emanating from actual case studies using the initial AKADAM paradigm [14]. Next level implementations are still required to test the wisdom of projected benefits. In hindsight, many of the advancements within cognitive engineering may still be considered to be in line with McCormick’s orientation to human engineering [5]. In that sense, the processes are more likely evolutionary, not revolutionary, and therein point human engineering in a different - yet necessary - change of direction to respond to the changing terrain of the 21st century.

References