

# THE ARMY'S NEED FOR COGNITIVE ENGINEERING

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## ABSTRACT

*Imagine Soldiers reacting to an unpredictable, dynamic, stressful situation on the battlefield. How those Soldiers think about the information presented to them by the system or other Soldiers during this situation – and how well they translate that into thinking into effective behaviors – is critical to how well they perform. Importantly, those thought processes (i.e., cognition) interact with both external (e.g., the size of the enemy force, weather) and internal (e.g., ability to communicate, personality, fatigue level) factors. The complicated nature of these interactions can have dramatic and unexpected consequences, as is seen in the analysis of military and industrial disasters, such as the shooting down of Iran Air flight 655, or the partial core meltdown on Three Mile Island. In both cases, decision makers needed to interact with equipment and personnel in a stressful, dynamic, and uncertain environment. Similarly, the complex and dynamic nature of the contemporary operating environment faced by the United States Army makes it clear that mission performance depends on systems that are engineered to ensure that the complex systems of people and technology (i.e., sociotechnical systems) can sustain high levels of cognitive performance needed for success. This session overview highlights cognitive engineering and illustrates how modeling and simulation can address different aspects of this important field.*

## INTRODUCTION

Imagine Soldiers operating a complex, multi-function crew station while encapsulated in the back of military vehicle reacting to an unpredictable, dynamic, stressful situation on the battlefield. Importantly, how those Soldiers think about the information presented to them by the system or other Soldiers during this situation — and how they translate that thinking into effective behaviors — is critical to how well they perform. With advancing technologies, however, it has become clear that performance will not reflect the Soldier's thought processes alone, but rather that systems will at a minimum impact Soldiers thinking (e.g., through the selective presentation of information) and in many cases will make decisions directly (e.g., see autonomous navigation technologies). Here, we define *cognition* broadly as the mental processing that, in humans, occurs within the brain. In early conceptions, the term *cognition* denoted “higher-level” abstractions (e.g. decision making), as distinguished from processes closer to either perception or movement control, nor did it emphasize emotional, historical, cultural, and other contextual (e.g., environmental) factors [2]. In contrast, many contemporary researchers regard the distinctions between these factors as largely artificial, and view cognition as encompassing

physical, mental, and social aspects of human behavior [3]. In our definition, the actions of the Soldier-system, such as making decisions and generating physical movement, results from many Soldier and system processes, working together, along with other processes that integrate or modulate them (e.g., attention, arousal, and mood).

Cognitive engineering is concerned with the importance of the interactions between the humans and systems (i.e., sociotechnical interactions), how these interactions effectively create cognition to enhance performance, and the potentially disastrous consequences of failing to address these interactions. Generally stated for the Army, cognitive engineers attempt to design Soldier-systems that facilitate performance by focusing on the “thinking” aspects within sociotechnical systems [1].

## SOCIOTECHNICAL INTERACTIONS

Ensuring that the Soldier-system “thinks well” is not a trivial matter. Returning to the Soldiers operating the multi-function crew station, the overall “thinking” or cognition will be impacted by both external (out of the Soldier-systems control: e.g., the size of the enemy force, the time of day, temperature) and internal (e.g., ability to communicate, Soldier's personalities/system intelligence, Soldier

fatigue/system degradation) factors. These factors will interact and the complicated nature of these interactions can be disastrous. For example, in both the shooting down of Iran Air flight 655 by the U.S.S. Vincennes in 1988, or the partial core meltdown of the nuclear reactor on Three Mile Island in 1979, decision makers needed to interact with equipment and personnel in a stressful, dynamic, and uncertain environment. Analyses of these disasters revealed that cognitive aspects of complex human–system interactions were linked to the dramatic and unexpected consequences (see [4]).

As is pointed out in the presentation by Oie and Paul, a major contributor to the complicated nature of sociotechnical interactions in the contemporary operating environment is the explosive growth in the volume of available data and the speed with which it can be transferred, accessed, and presented that has occurred over the past several decades. While providing an incredible opportunity for increased capability, this growth also threatens to overwhelm an individual’s ability to adapt to new technologies effectively. This point was illustrated in the shooting down of Iran Air flight 655, where displayed information was believed to be improperly interpreted [4].

A second major contributor to the complex sociotechnical interactions is the increasingly dynamic and nonlinear nature of the battlefield. New challenges and dangers emerge as enemy forces adopt advanced information technologies and non-traditional approaches to warfare, and as our forces have high levels of interaction with the local populations and political leaders. Additionally, we must adapt to the demands of future warfare, which will require reduced

manpower, greater availability of information, greater reliance on technology, and full functionality even while moving [5]. These changes fundamentally alter the balance and nature of the sociotechnical interactions, which fundamentally changes conceptions of cognition from models that primarily rely on Soldiers to those that involve a balance between Soldiers and systems.

With the rapid advancements in our understanding of human cognition and brain function and the novel approaches to computing that have occurred over the past several decades, cognitive engineering is now a multidisciplinary field, drawing largely from human, computer, and engineering fields. Today’s cognitive engineering is unique in its combination of two concepts: first, a focus on the cognitive demands of the workplace; and second, a focus on interactions in which behaviors of both humans and technology must be conditioned on the expected behavior of other agents in the environment [6]. Critical concepts in this field include to the requirement that engineers view the sociotechnical-environmental system as the fundamental unit of analysis [7] and the need to assess cognition in relevant settings (see “Assessing Cognition in Operational Environments” test box). Engineers across this field use a variety of tools and techniques to take a broad systems approach to the problem, considering factors such as personnel selection, training, logistics, and maintenance in addition to operational functionality. Critical to these tools are modeling and simulation, and this session illustrates several approaches to modeling and simulation can address different aspects of this important field.

### **Assessing Cognition in Operational Environments**

Understanding cognition in operationally-relevant environments is of central importance to cognitive engineering for the military. Not only can real-world cognitive processes of Soldiers vary dramatically from what is observed in simplified settings, but also as the overall cognition of Soldier-systems becomes more intertwined, the interplay among people, technology, and the environment becomes the critical factor that must be addressed in systems development. Traditional approaches to understanding cognition in these environments include self-reports of Soldiers performing tasks (or the Soldier’s interpretations of their own cognitive processes), and making inferences from observations, measurements of behavior, interviews, and questionnaires. While these approaches have led to successes in many cases (Cooke and Durso give several very good examples), researchers have made great strides in understanding cognition as a result of advances in technologies that provide insight into the brain over the past two decades. These primarily laboratory-based techniques have begun to indicate how the physical structure and function of the brain impacts “thinking” and while recent efforts do not attempt to fully explain activity in the brain’s estimated one quadrillion connections, they do provide insights on general principles that can be useful for cognitive engineers. Furthermore, technological advances are just now enabling some of these same approaches to be applied in operationally-relevant settings, which should produce further insights. For example, one approach to assessing cognition in relevant environments that is gaining ground in the community is to combine the simultaneous collection of multiple measures (e.g. behavioral, physiological, or contextual) with techniques such as data mining to find “hidden” relationships (see presentation by Oie and Paul). This approach provides a potentially powerful tool for the cognitive engineer of today and tomorrow and provides a potential methodology to develop systems that assess the cognitive performance of the operator in near-real time; a breakthrough that would open the door to a wide range of adaptive and battlefield optimization technologies.

## SESSION PRESENTATIONS

This session highlights four examples that serve to illustrate models and simulations that can assist cognitive engineers in developing military applications. First, Teena Garrison and colleagues (“Understanding Soldier tasks for effective simulation”) will discuss the modeling of operational tasking which directly impacts the cognitive demands of both the Soldier and the system. One of the critical aspects of their presentation is the focus on model fidelity for the interaction between the Soldiers and the automated agents, an issue which we believe will impact how system developers conceive of battlefield cognition.

Second, two talks will focus on external factors and discuss thermal modeling of the crew compartment. Mr. Pryor and colleagues will discuss, “Development of a validated thermal model of AC performance in a mine resistant ambush protected ground vehicle,” and Dr. Pang and colleagues will discuss, “Introduction of a ground vehicle ITM (Integrated Thermal Model).” It is clear that external factors such as heat and related factors including dehydration and fatigue can have dramatic impacts on Soldiers moment-to-moment cognitive capabilities. Importantly, while these talks are focused on the modeling in relation solely to system performance, we see a clear application of such thermal models to understanding and potentially predicting cognitive behavior.

The third example illustrates a technique that can be extended to understanding the relation between physical movement and cognitive performance. Dr. Reed (“Simulating crew ingress and egress for ground vehicles”) discusses a modeling approach that is applied to understand the ramifications of the physical design of the vehicle on the movements of the Soldiers. This approach can be used to understand important issues that will directly impact cognitive performance such as the amount of “thinking” that a Soldier has to dedicate to movement control and stability and the potential impact of vehicle movement and vibration

on the Soldier’s ability to read and ultimately comprehend displayed information.

Finally, Dr. Oie and Mr. Paul (“The utility of ride motion simulation in a neuroergonomic approach to systems design”) will discuss an approach to designing systems to be consistent with human cognitive function. They specifically discuss the potential benefits of integrating state-of-the-art neuroscience approaches and highlight how large-scale ride motion simulations are a critical tool in this approach.

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