PANEL SUMMARY:

Behind the curtain: The cognitive tasks behind the visualizations.

Decision-makers face a complex, dynamic and multidimensional world and which frequently overloads them with information. As cognitive engineers it is our job to represent this complex data as visualizations. However, visualizations can do much more than simply replace tables of numbers with pictures. When properly designed, visualizations are cognitive tools that that support their users and enabling them to explore, reason on, and summarize large quantities of information effortlessly.

Many evaluations of visualizations focus on outcome measures of their 'success'. These measures include workload and performance metrics. Typically, system evaluators vary a number of human-system interface elements and then measure the impact of such variations on the operator's performance. Based on the implications of their findings, the system changes are implemented. While these types of measures are important for overall evaluation of the degree of support provided by the visualization, they ignore the 'process' metrics. That is, an evaluation of the degree of support for the underlying cognitive demands that the visualizations are intended to support. This would include assessments of error potential, error detection and recovery, user adaptation and tailoring, and automation surprises (Woods and Sarter, 1993).

Visualizations must be viewed as more than simple inputs to the decision-maker; they guide and constrain user behavior. Because visualizations serve as cognitive tools, it is important to recognize and specify the cognitive processes that the visualizations are intended to support. Without this specification it is impossible to determine if the cognitive tools that designers provide are supporting users needs as they intended or making the “supported” task more difficult. Compared to the research that has been done on internal human cognition, very little work has been done describing the nature of visualizations in complex information processing task (Zhang). One of the goals of this panel is to identify relationships between types of cognitive demands (e.g., monitoring decisions) being supported and the form (e.g., visualization technique) for presenting the information to support those demands.

To accomplish this goal, the key is to develop a mapping between information on the state and behavior of the domain and the syntax and dynamics of the visualization or training aid being developed. From an interface design perspective, the goal is to reveal the critical information requirements and constraints of the decision task through the user interface in such a way as to capitalize on the characteristics of human perception and cognition.

Woods (1992) has called this the 'Mapping Principle' – that computer-based displays of data function of a representation of some *thing* for some *one* in some goal/task *context*. The mapping principle means that one cannon understand computer-based information displays in terms of purely visual characteristics. The critical property is how the underlying cognitive demands map into the structure and behavior of the visual elements. This has several critical implications, including:

- The need for an approach to uncover the essential cognitive demands to be supported by the visualization;
- The dynamic nature of the mapping – one must consider how the display behaves or changes as the state of the problem domain changes;
- The constraints of the 'virtual perceptual field' offered by the computer-based display system that exacerbates the mapping challenge.

However, this is a non-trivial task. With a vast array of graphical techniques available to represent the desired information, it is reasonable to generate multiple alternative designs to satisfy the specified information requirements. In addition, with the ever-increasing capabilities in computer-based display systems, the design step is often considered to consist of a substantial amount of subjective interpretation and artistic abilities. However, if we are ever to hope for rigor and 'engineering quality' in the design of advanced visualizations, we must require designers to be explicit about the specific cognitive activities that a given presentation element is to support.

Recently, there has been a tremendous effort to apply a variety of Cognitive Engineering principles that have variously been called representational aiding (Bennett and Flach, 1992; Woods, 1995; Roth, Malin and Schreckenghost, 1997) and Ecological Interface Design (Vicente, and Rasmussen, 1990; Vicente and Rasmussen, 1992; Reising and Sanderson, 1998). The objective of these approaches is to design visualizations and other aiding concepts to reflect the underlying information requirements and to organize the virtual 'information space' explicitly around these information requirements thus reinforcing a mental model of the domain in any user of the interface.

This panel will focus on "looking behind the curtain" and explaining innovative visualizations and the cognitive demands they are meant to support. This mapping between display techniques and supported decisions is crucial for identifying general principles and advancing the state of the practice. This panel will also explore the linkage between cognitive analyses techniques and the resultant decision aiding artifacts as well as other means for deriving inspiration for what Tufte describes as "cognitive art". By depicting the process used to innovate the actual system design (visualization and underlying support processing of the decision aid) a greater understanding of how to incorporate cognitive analyses into the systems engineering of real world systems will be provided.

Both the nature of the visualization itself, and the linkage to the processes 'behind the curtain' will be presented. Panel members will offer an example of an innovative decision support visualization and reveal the underlying cognitive demands it is meant to support as well as any artifacts they used in its development. Panelists will discuss the various techniques used and the pro's and con's of each. The discussion of the visualization will focus on issues related to information presentation formats, display space allocation and organization, and user interaction and navigation.