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**Position Paper for the NIH/NSF Visualization Research Challenges Fall Workshop**

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Visualization to support science is (and future visualization to support society should be) fundamentally about enabling human thinking – *about leveraging the power of human vision and cognition to generate insight, solve problems, and make decisions*. Substantial advances in computer power as well as in technologies and methods for human-computer interaction have enabled similarly substantial advances in our ability to render large volumes of data quickly, to generate real-time animation of large data streams, and to interact with visual representations in flexible ways.

In spite of the progress, visualization methods and tools (as envisioned in the 1987 ViSC report and in subsequent reports by a range of organizations) are not well integrated into the process of science and are largely absent from other activities that require analytical reasoning and decision-making. One reason is a lack of multi-disciplinary research and, in particular, a lack of attention to how visualization enables thinking and decision making with heterogeneous information, both for individuals and for groups. Challenges include:

- To advance the science of visualization, it is essential to develop a comprehensive understanding of the role of visual displays of complex data in the process of analytical reasoning, hypothesis generation, and decision-making. Key barriers to solution here are a lack of basic knowledge in vision and cognition relevant to use of dynamic (particularly user controlled) displays (particularly representing spatial and temporal information) and a similar lack of understanding of the role (or potential role) of dynamic visual displays in both scientific reasoning and real-world activities (that range from business planning, through crisis management to policy formulation).
- Most visualization research has focused on single user environments; most important work in science and society requires coordinated effort by groups (and organizations). Fundamental objectives for next generation visualization environments are to develop a comprehensive understanding of the mechanisms through which dynamic visual displays can and do mediate group work and to develop dynamic visual methods and tools that enhance the work of groups and groups of groups. Some specific question here are: understanding the ways in which dynamic, user-controlled visual displays support external/ distributed cognition of individuals and groups; developing mechanisms that support dialogue and argumentation as a group works toward mutual understanding, consensus, and decisions; and addressing display and rendering challenges of physical and virtual group work spaces that support multiuser simultaneous control.
- Many hard, real-world problems require integration and understanding of time-varying, heterogeneous, geospatially varying information (that includes numerical data, text, images, models, maps). Example problems include understanding the local and regional human and environmental implications of global environmental change; predicting, recognizing, and responding to biological terrorism; and hurricane and wildfire response and recovery. Today's visualization methods and tools cannot support the integrated analysis and decision-making required, because visualization solutions have emphasized single information types as well as single kinds of application. The fundamental challenge here is to develop visually-enabled human-information interaction methods that support the integrated understanding of heterogeneous, dynamic, geographically varying information ingested, as needed, from multiple distributed sources.