Session Name: Cyberinfrastructure-mediated interaction.

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1. Why is this area important to address the problems of cyberinfrastructure for the social, behavioral, and economic sciences?

The Internet has led to a true revolution in communication. It supports rapid and inexpensive text-based communication in the form of electronic mail and instant messaging. In addition, it provides for the sharing of visual and auditory information and, to a degree, even kinesthetic information, allowing for more meaningful and realistic communicative interactions. Other advances that rely on information technology are having profound effects on the communicative experience. These include mobile phones, PDAs, distributed and embedded sensors, ubiquitous and affective computing, digital imaging and music, wearable computers, GPS devices, innovative display technologies, etc. These changes have affected not only how we conduct science, but they also have had a profound effect on many aspects of our lives, including commerce, education, health care, and other behavioral, social and cultural activities. The impact of these advances can also be very broad, for example, helping to alter national boundaries and, hence, contributing to globalization.

The essence of cyberinfrastructure (CI) mediation is *interaction*, which cuts across many different activities and scales. Research at the frontiers of science now often requires global collaborations, terabyte data infrastructures, grid computing and software tools for automating research and enabling collaboration. CI enables a multidisciplinary group of researchers to address problems that far exceed the measurement capabilities, computing power and data storage capabilities of individual labs. Understanding how technologies of information and communication affect relationships and social networks is in many ways a lynchpin of future social science. A wide range of concerns turn on this issue, from cultural change to civic engagement and international security. Use of technology can (but does not necessarily) build both weak ties and strong ties, expanding loose networks of affiliation as well as building social capital. We know also that technology can foster a range of organizational forms that affect relationships and networks. It builds possibilities for centralized, top-down communication and the social structures associated with it, and also possibilities for emergent, fluid, networking, communication and social structures.

2. What are the opportunities and challenges in this area with respect to cyberinfrastructure for the social, behavioral, and economic sciences?

Opportunities:

One opportunity relates to the emerging ubiquity of inexpensive, intelligent, networked devices and the development of the cyberinfrastructure that supports them. Cellphones, a well established form of technology, provide one of the very best models for how and why new technological innovations can become widespread. From this perspective, cell phones are important because their cost and ease of use

represent a model for how to ensure that the technology is used. In certain countries, such as Finland, Hungary and Japan, the vast majority of the population have access to such devices. In underdeveloped countries cellphones can be the saving device for connecting between big centers and for communication to the outside world. Why has that happened? A number of reasons, including mobility, affordability, and ease of use. In most cases, cellphones don't require any special training -- you talk. Illiterate people can use them. In poor villages, people share and rent them. In addition, the whole concept of interactional co-presence has been changed by cellphones, instant messaging, GPS, SMS, group communication and interaction. As advances in cyberinfrastructure drive additional convergence between cellphones and video-based media, and barriers to access remain low, social interaction will continue to evolve as it affected by these technologies. These developments provide enormous opportunities for behavioral and social scientists to study our technologically guided activities and gauge their impacts, both positive and negative, on our society and culture.

Scientists have much to learn from emerging practices in cyberculture, which provide models for a wide variety of new research and dissemination strategies and methods. There is a tremendous benefit to be had from taking a closer look at day-to-day practices of distributed communication. The blend of social interaction and entertainment inspires a tremendous amount of both learning and creative motivation in both children and adults. Computer games, such as the extremely popular *The Sims*, provide many opportunities for situated learning and embodied interaction with simulations of complex systems. New models for distributed collaboration can also be found in the modern domain of massively multi-player online role-playing games. Every day, vast numbers of players who have never met each other face-to-face deploy and manage complex missions using skills that will become increasingly critical in the future not only to business and science, but also to national and international security. We cannot fully leverage these trends in network culture until we understand them better. A core to understanding how to build better cyberinfrastructures for science is developing a deeper understanding of the ways that cyberinfrastructures are used in the "real world." This underscores the importance of social science and the human sciences.

Opportunities abound in the areas of teaching and training, casual and emergency communication, overcoming disability, and as a means of democratization because of the equalization of access.

One near-term direction is for greater integration of the scientific literature with shared (or at least published) data and generally-available tools. Thus a published paper could include (links to) code that would generate its statistical analyses, tables and graphs from the original data, or run the models that it proposes.

Simple (i.e. relatively unstructured) web-based collaborative tools can make a big difference in certain fields. In particular, some kinds of research can benefit a great deal from the ability to make simple annotations on regions of (shared) audio or video streams, pictures, etc., to share these annotations through various modes of networked aggregation, and to search, browse, summarize or otherwise interact with the results.

Challenges:

Many social and behavioral scientists and other domain experts don't see the value of CI. Yet it is already here. There is a need for integration of CI into the research methodology and additional study of its impacts.

The convergence of CI with nanotechnology suggests a massively networked world where even the most mundane devices will be "smart." There is also much excitement about the scientific benefits of integration of information from disparate but related sources. However, there is considerable potential for intrusion and surveillance in such a data-rich, networked world and there is legitimate, growing fear about the creation of a surveillance society. A key question is whether political and social systems will evolve

at a pace to stay ahead of what technology might soon allow. SBE-funded researchers are in the best position to address questions about technology-driven social and cultural change and the evolution of institutions to cope with these changes.

How does the information overload of emerging technologies relate to limitations of attention? How does this impact education, particularly in those areas that require real concentration? Are new social divides being manifested—whether economic or generational—between those who have considerable facility and feel at ease with the new technologies and those for whom cyberinfrastructure remains largely mysterious and alien?

Synergy is needed between SBE and CISE researchers. In order to achieve this, both intellectual and material interfaces must be shared. For example, it is not sufficient for SBE researchers to be provided with CI if they do not possess the technical expertise to use this technology effectively. Many SBE researchers lack the technical know-how to participate without significant support from CI experts. Similarly, CISE researchers often lack sufficient domain-specific knowledge to appreciate the complexity of the technical problems that truly need to be solved by SBE researchers. There is an important distinction between multidisciplinary research and collaborative research, because assembling researchers from different disciplines to work on the same project does not ensure that they will collaborate. It will be important for the two research communities to develop strategies to truly collaborate if a joint research initiative will be successful. Two specific suggestions regarding collaboration include: (1) new interdisciplinary programs for graduate students to insure that they become knowledgeable about the intellectual problems as well as knowledgeable about the technologies necessary for achieving these goals, and (2) providing mid-level support (IT workers with M.S. degrees) to SBE researchers to ensure that they possess sufficient technical expertise over the short term to enable them to participate as full partners in these initiatives.

3. What are the potential roles for the SBE and CISE communities in this area?

No single academic discipline or point of view is sufficient to comprehend all the implications of cyberinfrastructure. On the technology side, new challenges arise as engineers deal with the unpredictable uses to which tools end up being put by actual communities of users. Thus the success of cyberinfrastructure will depend to a significant degree upon information technology's ability to grapple with the fundamental complexity and ambiguity of culture, communication, and social interaction. The problems and issues that challenge and excite social and human scientists are often complex and difficult ones. They are of considerable international concern and importance to our national interest,. Examples, which are numerous, include societal and cultural inequities such as hunger, poverty and literacy (including cultural literacy), large-scale movement of populations, conflict resolution, crime and malevolent activities, and understanding human and group behavior across a variety of scales, including areas such as development, decision making, risk assessment, literacy and cultural translation, social interaction, organizational structure and process, and response and resiliency in the face of extreme events. How can technology, in particular cyberinfrastructure, contribute to solutions to these problems?

Cyberinfrastructure amplifies and supports communication. Not only wireless telephone and computer access, but tele-immersive environments, network connectivity, location-based and affective computing, ubiquitous computing, etc. These advances raise issues for both the SBE and CISE communities, and partnerships across these communities are required.

Issues for the SBE community include:
• Understanding what multi-tasking, split attention, and the consequent multiplication of personal and transactional identities imply for communication, collaboration and education.
• Further development and application of innovative approaches such as social network analysis, agent based modeling, nonlinear dynamics, geographical information science, immersive environments, and the social analysis of cyber-cultures and the free and open source movement.

• Partnerships with computer scientists and the business community in the development of organizational and societal modeling and simulation environments.
• Partnerships with the humanities and design communities on large-scale projects that require cyberinfrastructure, such as endangered languages, regional language corpora, engineered environments for the elderly and those with disabilities, or creation of 3D visual archives and search engines.
• Outreach regarding the importance and role of cyberinfrastructure in social and behavioral science research and overcoming the resistance of some in the community to large-scale projects. Greater education is needed about how such approaches are becoming a reality, the requirement for resources at larger scale than previously seen, and the balance between core disciplines and large-scale social science.

Issues for the CISE community include the following open problems.
• The development of multimedia protocols and meta-descriptions.
• The creation and use of large-scale networks of cameras, microphones, sensors and mobile devices.
• The extraction of the right information at the right time and in the right place.
• The design of operating systems and cyberinfrastructure for real-time interaction of distributed, mobile devices, with the appropriate privacy and security.
• Modeling the interactive process as a dynamical system, especially geographically distributed information with temporal considerations.
• Protocols and common standards for collection and display of cultural objects.

4. What are the recommendations from your session?
a. *Building or strengthening communities* in several emerging areas including: (i) multimodal communication, (ii) social network analysis; (iii) emerging cyber-cultures; (iv) spatial social science; and (v) digital government.
b. Providing *shared data resources* and innovative measurement, annotation, analysis, visualization and descriptive tools.
c. Support CI-based *science portals* in selected areas, including, but not restricted to: cognitive neuroscience, cyber-culture (including on-line communities, games and digital environments), digital government, multimodality, social network analysis, and spatial social science.
d. Supporting *demonstration projects* in these areas. These projects should be multi-community. They could, for example, show provide examples of CI-based, collaborative technologies and how these technologies help or hinder in communication and building trust.
e. The inclusion of social science research as a required component of networked infrastructures.

5. What are 3 key research problems important to communities in your session?
a. How best to manage *multi-modal data* (text, media, visual and audio files, source code, online virtual worlds).
b. How best to achieve *scalable collaboration in research practice & system development.*
c. How best to *study, model, simulate, visualize, and enact virtual and real collectives* (organizations, communities, dyadic and group interactions, social networks, learning and training environments).

6. What are 3 key technologies and their characteristics important for communities in your session?
a. Global multi-disciplinary *data collection and sharing infrastructure that supports multi-modal, multi-media repositories and virtual worlds*, including tools for annotation, analysis, visualization, and extraction of meaning. Key developments will revolve around the continuing evolution of devices as extensions of human memory and of human reasoning capacity. CI-mediated communication is likely to accelerate trends toward greater international and cross-cultural collaboration.
b. *Social network analysis* has developed the theoretical and methodological apparatus to conceptualize and analyze cybercommunities as *multidimensional networks*. The entities within these multidimensional networks include individuals, data sets, documents, analytic tools, and concepts. The network links between these entities include communication, collaboration, co-authorship, citation, and co-citations between these individuals. Additional links within the multidimensional network represent associations between individuals and specific data sets they generate or utilize, the

documents they publish or access or credential (rate), the analytic tools they develop or deploy, and the concepts they investigate.

c. *Meta-science portal*: Science projects online, indexed, searchable, analyzable, open source/content. Individual projects would elect to register their project or use the facilities of the portal to host their project, in terms of the common types of information artifacts (online documents, publications, models, web pages, project membership information, etc.) that each project might be willing to share with others in the larger research community. Such a meta-science portal would also enable social, behavioral, and economic studies of the scientific enterprise as a national resource and productive capability.

7. Give at least one "moonshot" for your area -- a problem in your area that is immensely important and compelling, and will require the combination of SBE, CISE efforts and cyberinfrastructure to solve.

A socio-technical initiative of multiple, inter-linked projects to *record, annotate, measure and extract meaning from mediated human interaction* in a number of contexts. with the goal of improving communication and collaboration, and enhancing trust, through cyberinfrastructure. Data sources would be diverse and multimodal. Connective middleware would integrate visual, spoken, haptic, facial, gestural and physiological data, information about emotional state, movement, place and location, discourse structure, and interaction, along with instant messaging, text, and information from other media. Adaptive approaches and interfaces would be essential in order to accommodate physical, linguistic, cultural, social and other differences.

In this initiative, human interaction would be studied at multiple scales of size and time and in multiple domains, from dyadic interactions through groups, communities and organizations, including populations with unique needs. Results of these projects would be made available, with appropriate privacy safeguards, for community research use, including a facility for feeding back researchers' interpretations and adaptations. Attention needs to be paid to the development of standards for describing interactions in ways that can be utilized by both the CISE and SBE communities.

This initiative, centered around communication and collaboration, would include the development of new theoretical and analytic approaches to facilitate effective CI-mediated interaction among networks of individuals and knowledge repositories. It would enhance the study of existing current modes of interaction (such as interviews, town meetings, virtual conferencing, distance learning, virtual communities (societies), economies, and educational and training environments) and the creation of new communities and modes of interaction.

Cyberinfrastructure support would be needed for acquisition, storage, coordination, searching, analysis and visualization from a variety of instrumentation and measuring devices and other tools and techniques. Examples include: video and audio recording; immersive virtual reality systems, including their use for the gathering of visual, auditory, gestural, and haptic information; physiological measurements; cognitive neuroimaging; distributed and embedded sensors and smart dust; geo-coding of data; and logging and recording of on-line interactions. Also important would be the development of easy to use (and reusable) toolkits that enable the rapid construction of data collection instruments and research applications, as well as providing on-demand interactive guidance for how to use existing CI tools and services to record, annotate, measure, and extract meaning from mediated human interaction.

Benefits of such an initiative are numerous and, in many cases the impacts would be profound. Examples include:

- Improving effective communication among diverse participants, including persons with disabilities.
- Addressing cultural, socioeconomic, technical, international, and linguistic differences.
- Providing important data for business and science and the nature of the interactive process.
- Guiding the creation of new, and improvement of existing, physical infrastructures.
- Facilitating the design of better CI-mediated tools, constrained by knowledge gained from ecologically-grounded behavioral and social data.
- Improving communication at a distance, including distance education and telemedicine.
- Improving training for business, industry and the military.

• Enabling communication in emerging cyber-communities, cyber-cultural literacies, and translation between communities.
• Finally, network-mediated experiments of different types can make it easier for certain kinds of researchers to connect with pools of human subjects, who may no longer need to physically visit a laboratory in order to participate.