Realizing the Promise of Cyberinfrastructure

Cyberinfrastructure is an essential precursor to social and economic progress. Whether it is upgrading and expanding the electrical grids that power society or improving the roads and bridges that link people and commerce, infrastructure is essential to the future. Today, a new type of strategically important infrastructure may be less publicly visible but is, arguably, more essential to the future success of colleges and universities: cyberinfrastructure. This infrastructure began to take shape in the 1980s when the higher education community and the U.S. government created NSFNET—the first Internet. A decade later, U.S. colleges and universities came together again to address the network needs of scholars and researchers with a solution that surpassed the services made available by commercial Internet providers. Thus Internet2 was born, with a commitment to providing advanced networking and to drawing on regional network aggregations.1 Now, in this first decade of the new century, the advanced networking community of higher education is again at work to develop, deploy, and sustain continuing innovation in cyberinfrastructure in order to meet our future needs.

Cyberinfrastructure refers to the array of high-speed networks and advanced computational resources, applications, and expertise that connect researchers and educators around the world in a new digital environment for discovery and education. The encompassing definition of cyberinfrastructure also includes an array of complementary resources such as software services, tools, identity services (middleware), information resources, digitally enabled sensors, instruments, and virtual organizations. This infrastructure links colleges and universities, government agencies, and private companies into a knowledge grid that is generating major advances across a variety of fields. Sustaining and extending this computational environment must be viewed as a high priority if the pace of research, discovery, and innovation is to continue.

So, what started as a research project has grown into an international platform for communication and commerce—a platform that has literally transformed the world. Entirely new sectors of the global economy have been created, while more traditional sectors have been revolutionized. Our ability to interact and communicate down the hall or around the world has increased dramatically, both in degree and in kind. E-mail, instant messaging, blogging, streaming audio and video, voice-over-IP; audio and video podcasts, web conferencing, and virtual environments allow us to communicate and share knowledge when and how we like. And access to learning opportunities has expanded greatly, with courses, programs, and the source materials for entire college/university curricula available online to anyone, anywhere the Internet can be accessed.

As great as these advances are, the cyberinfrastructure currently developing is already demonstrating the potential to produce yet another quantum leap in the lives of people around the world. Researchers nationally and internationally have nearly instantaneous access to unprecedented amounts of data across a range of disciplines, along with the high-performance computing resources, analytical tools, and virtualization applications to transform that data into new discoveries. Perhaps even more important, cyberinfrastructure is giving them ready access to each other, allowing for the development of research communities that can collaborate within and between institutions, countries, and disciplines without regard to time or location. As a result, critical opportunities—such as identifying and addressing the key factors behind climate change or creating models for truly individualized, personalized health care—are now within our grasp.2

Imagine the potential when researchers and students anywhere in the world can collaborate in real time with high-definition audio and video that is “better than being there”—when cyberinfrastructure is powerful enough to serve the most academically demanding needs, flexible enough to support new modes of cooperation, extensible enough to accommodate the development of new tools, reliable and secure enough to serve our most important activities, and so easy to use that technicians are not needed on site.3

Increasingly, academic fields of study rely on cyberinfrastructure to make progress in their disciplines, with amazing results. Today, “big science” initiatives require many academic researchers with cross-disciplinary expertise. For example, a Syracuse University researcher is involved in a global effort in the Laser Interferometer Gravitational-Wave Observatory (LIGO), funded by the National Science Foundation. Designed and operated by the California Institute of Technology and the Massachusetts Institute of Technology, this project involves the scientific collaboration of close to 600 scientists at colleges and universities around the United States and in eleven foreign countries. The Syracuse University scientist will use new dynamic circuits provided by the regional network...
In another example, the U.S. National Library of Medicine at the National Institutes of Health is developing network-based tools and techniques that leverage the speed and capability of advanced research networks to enable oncologists, gynecologists, and healthcare workers from around the world to more effectively participate in cancer research studies and enable more comprehensive analysis of cancer research data. These tools have transformed the way geographically distant cancer researchers are able to collaborate (involving over forty researchers and medical professionals across six countries). These breakthrough tools are currently being utilized for cervical cancer research, but there is significant potential for extending their use broadly in the biomedical field.

What will it take to realize the full promise of cyberinfrastructure—to bring forth the next generation of innovation and discovery that will dwarf the global advances we’ve witnessed thus far? The United States—government, industry, and higher education—has provided great leadership in the early generations. Other nations are now making large investments in cyberinfrastructure to be competitive with the very best and to gain positioning in the global economy. Certainly, a sustained commitment on the part of government, private companies, and colleges and universities will be essential for the United States to be among the world’s leaders. Collaboration and a shared vision continue to be essential components of an effective strategy. By connecting the advanced computational resources and the expertise of individual institutions, agencies, and corporations, cyberinfrastructure exponentially increases the scope, complexity, and power of the resources available to any one of them. Thus it also exponentially increases what they are capable of achieving. However, the failure of these partners to maintain and extend their investment in cyberinfrastructure likewise has a network effect—degrading the capabilities of the overall knowledge grid.

The sustained commitment to maintaining and extending the capabilities of cyberinfrastructure involves more than investments in hardware, software, networks, and the experts who support them. It entails also an ongoing commitment to continuing collaboration and to balancing individual needs with shared goals and priorities. By necessity, individual researchers and institutions have unique networking and computational needs, driven by the demands of their various disciplines and research programs. These individualized needs have to be respected within the context of the overall shared environment created by an interinstitutional, national, and global cyberinfrastructure. Yet careful coordination and collaboration on cyberinfrastructure standards and access protocols will ensure a flexible environment in which the contributions of any one participant can meet the needs of many others without sacrificing required capabilities.

This sustained commitment also encompasses openness to a range of institutions and uses beyond the major research institutions and programs at the core of cyberinfrastructure. Precisely because cyberinfrastructure provides ready access to flexible, high-performance resources, it can make capacities available to faculty and institutions that otherwise would not have them, opening potential new sources for discovery and innovation. Moreover, cyberinfrastructure provides opportunities for innovation in student learning. A novel exemplar in music is the collaboration of the New World Symphony with Case Western Reserve University, the Cleveland Institute of Music, the Manhattan School of Music, and the Thornton School of Music at the University of Southern California in using advanced networks to conduct live interactive music master classes, symposia, and coaching sessions with faculty and students.

In addition, college and university faculty are using cyberinfrastructure to engage students directly in research projects, allowing them to actively contribute to scientific discovery while gaining hands-on experience in research methods. Likewise, the virtual environments and data visualization capabilities of cyberinfrastructure enable students to experience disciplines such as physics and history in ways not previously possible. Whether they are “feeling” atomic forces or “seeing” the sweeping social and economic impacts of the Civil War in a dynamic, integrated model, students have the opportunity to deepen their learning by connecting with academic concepts at an experiential level.

Thus we can see that colleges and universities around the world should view capitalizing on the promise of cyberinfrastructure as a significant priority. It is not an overstatement to say that the continued development and expansion of cyberinfrastructure will allow those of us in higher education to pursue our traditional academic and research missions to a revolutionary degree, generating transdisciplinary advances that may truly transform the world yet again. However, fully realizing this potential requires a sustained commitment on the part of higher education institutions to investing in cyberinfrastructure in partnership with government and the private sector. It also involves an ongoing commitment to engaging in collaboration and shared responsibility in the design and implementation of a cyberinfrastructure that balances individual and common needs. And finally, realizing this potential entails a commitment to making the benefits of cyberinfrastructure available to faculty, institutions, and teaching and learning applications throughout higher education. By embracing these commitments, colleges and universities can fulfill their responsibility for global leadership and can drive the next wave of discovery and innovation.

Notes
1. I have served on the Board of Directors of Internet2 since its inception, most recently as a member of the Strategic Planning Steering Committee. Several references in this article are drawn from the work of Internet2.

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