Dr. Arden L. Bement, Jr.
Director
National Science Foundation

"Shaping the Cyberinfrastructure Revolution"

Designing Cyberinfrastructure for Collaboration and Innovation
National Academies of Science
January 29, 2007

As delivered

Good afternoon. I'm delighted that the National Science Foundation is co-sponsoring this gathering.

I don't need to convince this audience that cyberinfrastructure has become one of the keys to meeting national goals in innovation, economic growth, and education. At this workshop, you are addressing many of the factors that will determine the breadth and scope of its contribution.

Last year, the American Competitiveness Initiative laid out concrete steps for addressing the challenges confronting the United States in a highly competitive global economy. They include strengthening the nation's innovation enterprise, and training our youth to excel in a world that demands technical knowledge, creativity, and innovation.

The National Science Foundation was selected to play a key role in carrying out this initiative. NSF's mandate is to support fundamental science and engineering research and education that advances the frontiers of discovery, and equips the nation with a highly competitive innovation base.

Cyberinfrastructure, an emerging area of immense promise, lies squarely in that territory.

NSF's Cyberinfrastructure Vision for the 21st Century is about to be published after extensive review by the science, engineering, and education communities. NSF relies on those communities, including many of you, to help identify national needs and investment priorities, conduct peer review, and carry out our collective vision.

I would like to offer some perspective on carrying out certain aspects of the cyberinfrastructure vision.

I have titled my remarks, "Shaping the Cyberinfrastructure Revolution." This revolution -- the second one brought about by computing and computational capabilities -- is expected to usher in a technological age that dwarfs anything we have yet experienced in its sheer scope and power.

A majority of the people on this planet have been affected, directly or indirectly, by the first revolution. The information, computing, and communications technologies that have transformed so many aspects of our lives have created enormous opportunities for every citizen, and, as you well know, have thrown some challenges our way.

In the science and engineering community, these revolutionary technologies have enabled us to advance the research frontier at velocities unheard of just a decade or two ago.

Just consider two of the innovations in our toolkit: computer simulation and modeling. Combine these with new visualization and observational tools—such as sensor networks, satellites, and distributed observatories—and you have a flood of data that threatens to swamp our capacity to preserve, analyze, and apply it.

With these new capabilities comes the challenge to harness and use them.

The capabilities of the new tools are so superior to the ones that most of us grew up with, that fully exploiting their capabilities is well beyond the ability of one expert, one institution, or even one profession. And so that need has ushered in a new era of cooperation.

As we launch the CI revolution, the concept of shared and networked infrastructure generates the same delicious anticipation as did the silicon chip in years past.

It is abundantly clear that our supercomputers, as well as our desktops, need to be more fully connected to keep up with the demand for computational power and expertise. In just a short while -- probably sooner than I care to admit -- I anticipate that a younger generation of Googlers and "text messagers" will wonder how anyone *ever* "made do" with just one desktop computer, or just one supercomputer, plodding through algorithms or visualizations at a snail's pace.

The opportunities for creating synergy through cooperation blanket the cyber-landscape -- algorithms, software, middleware, sensor networks, modeling and visualization capabilities, data repositories, data mining tools, and high-performance computing.

It is important that we continue to shape the cyberinfrastructure with foresight and strategy, especially at times when it would be easy to be swept along by events.   For only through leadership, coordination, and strategic transition will we realize the outcomes in innovation and education that can propel the nation to new heights.

We must begin by acknowledging that the development of cyberinfrastructure is a two-way street. CI is both an object of research and a means to enable research.

We envision cyberinfrastructure as a potent tool for the creation of knowledge. Yet only through ongoing research will we enable the development of systems and connections that can drive those advances.

In past decades, Moore's Law was the singular principle that generated enormous sweat and toil. In the CI revolution, the road to a successful outcome is littered with a plethora of obstacles. They merely begin with computational ability, and grow quickly to include problems of connectibility, compatibility, and reliability.

Linking diverse computing and information systems, unlike the railroads and telephones of yesteryear, must take place in an environment of fragmented sources, decentralized providers, and multiple tiers.

The challenge further encompasses an array of social, economic, and legal factors affecting, and affected by, cyber science. These include policies; norms of practice; and rules, incentives, and constraints that shape individual and collective action. Many of these are being addressed in your sessions this week.

Within this context, we must consider flexible standards, flexible but robust gateways, coordination rather than control, and built-in ethical, social, and cultural principles. And we must do all of it at a fast pace, because the lion of competition is roaring at our back door.

What an opportunity! For those who like to design complex systems, this may be the grand-daddy of them all.

A robust network layer is a prerequisite for the nation's cyberinfrastructure, as are world-class high-performance computers.

Already, connections among networks are enabling virtual collaborations in research and education around the world on a 24/7 basis. There are many more options available in the control of major instrumentation, facilities, and observation networks.

NSF has been a leader in supporting the establishment of supercomputing centers and high-broadband interconnections, such as the Teragrid. And, if the history of computing power is any indication, petascale computing may one day be the norm, just as the laptop today exceeds the capabilities of the supercomputer two decades ago.

These capabilities represent merely the tip of the iceberg. The vast area below the waterline -- absolutely critical to the evolution of CI-enabled knowledge -- will require the participation and collaboration of individuals from all fields and institutions, across the entire spectrum of research and education.

At the heart of the cyberinfrastructure vision is the development of virtual communities that support peer-to-peer collaboration and networks of research and education.

The sea change in the way science, engineering, and education are conducted involves more multidisciplinary work, greater collaboration, and a trend toward international connections. These “boundary-crossing” experiences require more than technical knowledge and skills. They rest on competencies in collaborating and communicating across disciplines, distances, and cultures.

We are witnessing a worldwide increase in what we at NSF call *distributed knowledge communities.* These research and education communities extend beyond traditional brick-and-mortar facilities, becoming virtual organizations that transcend geographic and institutional boundaries.

These collaborations are becoming much more prevalent among NSF investments. For example, scientists in a wide range of projects -- in particle physics, gravitational-wave science, and bioinformatics, to name a few -- are using the distributed capabilities of the Open Science Grid to advance their research.

Yet cyberinfrastructure is not just for elite researchers . . . just as it is not only for teenage chats. We would be missing a significant source of its potential if we did not recognize that both extremes are legitimate features of the research and learning communities.

Another characteristic of a cyber-oriented society is the demand for a dexterous *human-technology interface*. This, too, is an area that boasts a rich reservoir of research.

During the early stages of the IT revolution, technology was a rare resource that individuals sought out and struggled to operate. In the CI revolution, the technology is ubiquitous and its complexity so great that, usually, the inner workings are opaque to the individual. Instruction manuals are rarely consulted, especially by the young members of the millennial generation, who haven't the patience for it.

Many students -- and probably some scientists -- long for that Matrix-like world in which instructions, skills, and experiences are simply downloaded into their brains. It would be fast and efficient.

To address the interface challenge, NSF's investments in operational CI are coupled with research on how humans and organizations adopt and use technology. These research programs foster collaborations among computer scientists; social, behavioral, and economic scientists; and educators that will employ cyberinfrastructure in classrooms.

I want to emphasize a very important point here. Considering the human, organizational, and social factors from the very beginning will help ensure that the cyberinfrastructure effort, bolstered by good systems and tools, does not stall out when it confronts the complexity of human and institutional behavior.

That's why it's a great opportunity for NSF and the other organizations here to participate in exploring these factors from the outset, with an eye to shaping CI policies and practices that will enhance its sustainability.

The final aspect of cyberinfrastructure I want to address -- which is essential to carrying out the CI vision -- is the need to support the national goal of strengthening science and engineering education.

NSF's mandate is to prepare the science and engineering workforce to not only participate, but to excel, in the nation's innovation enterprise. The power of cyberinfrastructure to enhance education and provide new learning opportunities is central to this mission. Ironically, the reverse is just as important: educating and training a tech-savvy workforce is vital to CI success.

As we move forward, I urge that we explicitly include strategies that integrate education -- not as an afterthought, but at the very core of our CI design and development efforts.

Of course, the strategies outlined in NSF's vision for cyberinfrastructure demand extraordinary levels of investment. As we meet this week, the budget outlook for science and engineering is not nearly as rosy as what was projected a year ago.

The FY 2007 budget submitted to Congress last February requested a record $6.0 billion for NSF -- nearly an 8 percent increase over FY 2006. Those additional funds would have helped boost CI-enabled research and education -- and secured the initial investments in a new, petascale computing system.

It would be disingenuous to pretend that a year-long continuing resolution won't affect those plans. The much-anticipated increases for NSF programs will be slower in coming, if they arrive at all. And cyberinfrastructure investments, like other important programs, face possible delays.

NSF will continue to support world-class CI research and education, but with fewer resources to fund the fundamental sciences that support computer and information technology, to provide greater computational power, and to build networks for scientists and students.

Regardless of the current budget, the development of cyberinfrastructure will require resources well beyond those of NSF and the federal family -- investments that can be leveraged through the multiple and diverse partnerships being formed among academia, industry, and government.

And it will require a sustained national will to continue moving forward, despite obstacles and budget constraints, in anticipation of a comprehensive cyberinfrastructure that will strengthen innovation, economic growth, and education.

The way forward lies squarely in our collective hands.