Advances in networking and information technologies underlie most of the 10 flatteners that Thomas Friedman, in his book *The World is Flat*, asserts have leveled the playing field for 21st Century global, knowledge-based, economic competition. While the world may be flat, its landscape is not without spikes and occasional peaks—technological advances creating powerful spires of excellence for discovery, learning, and innovation and broadening participation.

Economic leaders will not only create the tallest spires of excellence, but will connect spires into effective distributed virtual organizations that assemble complementary expertise, distributed information, observatories, computational resources, and other unique facilities. Using the same “collaboratory” platforms to support not only discovery but also learning and rapid response to unexpected events will offer even further leverage and advantage.

National Science Foundation investments in cyberinfrastructure, cyber-enabled discovery and learning, and computational thinking are defining and pursuing a revolutionary vision of 21st Century discovery appropriate to leadership in a competitive, flat world with spires on its skyline. Collectively, outcomes are expected to produce paradigm shifts in our understanding of a wide range of science and engineering phenomena and socio-technical innovations that create new wealth and enhance the national quality of life.

Achieving this vision requires virtuous circles of interaction among three types of activity: 1) research, advanced development, and provisioning of shared and connecting cyberinfrastructure for supporting and bridging science and engineering, research, and learning; 2) transformative application of cyberinfrastructure to produce transformative research; and 3) identification and transfer of the relevant results of technological and social research into future generations of cyberinfrastructure.

First, cyberinfrastructure creation and provisioning are cross-foundational at NSF, but coordinated and catalyzed by an executive-level Cyberinfrastructure Council (CIC) and the Office of Cyberinfrastructure (OCI). The activities are organized around four themes: high-performance computing, data and data interaction, virtual organizations for distributed communities, and learning and workforce development. The creation of infrastructure, cyber or otherwise, is a long-term, socio-technical process to build diverse systems, nurture interoperability and consolidation among systems, build supporting institutions, conduct evaluation, and create enhancements.

Advanced cyberinfrastructure investments in leading-edge shared computational resources include the recent petascale (“Track1”) award to NCSA at the University of Illinois, and the continuing investment in interoperable computational resources (“Track2”) through the TeraGrid. The aggregate peak compute power for the Teragrid will soon be over 1.6 petaflops and is growing. Digital data are increasingly both the products of research and the starting point for new research and education activities. New investments address infrastructure for data curation, stewardship, interoperability, and interaction through a new solicitation for sustainable digital data preservation and access network partners (DataNet). Investments in cyberinfrastructure to support virtual organizations include international networking partnerships, middleware, portal, and workflow environments, as well as the practical applications of academic understanding of social architecture for collaboration in distributed teams. Learning and workforce activities address both learning about cyberinfrastructure and learning with cyberinfrastructure.

The second and third activity types—transformative application to produce transformative research and the regeneration of even more revolutionizing cyberinfrastructure—comprise the new NSF-wide initiative entitled “Cyber-enabled Discovery and Innovation” (CDI). CDI is intended to create revolutionary science and engineering research outcomes made possible by innovations and advances in cyber-enabled computational thinking. Computational thinking is comprehensively defined to encompass computational concepts, methods, models, algorithms, and tools. Applied in challenging science and engineering research and education contexts, computational thinking promises a profound impact on the nation’s ability to generate and apply new knowledge.
An Expert Opinion

In August 2007, the National Science Board approved a resolution authorizing the National Science Foundation to fund the acquisition and deployment of the world’s first sustained-petascale computing system for open scientific research at NCSA. Blue Waters, as the system is known, will be capable of sustained performance of one quadrillion calculations per second. It is expected to come online in 2011.

Blue Waters is a joint effort of the University of Illinois at Urbana-Champaign, NCSA, IBM, and the Great Lakes Consortium for Petascale Computation. This partnership is dedicated to encouraging the widespread and effective use of petascale computing to advance scientific discovery and the state-of-the-art in engineering, to increasing regional and national competitiveness, and to training tomorrow’s computational researchers and educators.

The details of the Blue Waters contract are now being finalized.

CDI seeks ambitious, transformative, multidisciplinary research proposals within or across three thematic areas: From Data to Knowledge: enhancing human cognition and generating new knowledge from a wealth of heterogeneous digital data; Understanding Complexity in Natural, Built, and Social Systems: deriving fundamental insights on systems comprising multiple interacting elements; and Building Virtual Organizations: enhancing discovery and innovation by bringing people and resources together across institutional, geographical, and cultural boundaries, perhaps in ways better than being there.

Congruent with these thematic areas, CDI projects will enable transformative discoveries that have the potential to identify patterns and structures in massive datasets; exploit computation as a means of achieving deeper understanding of natural and social systems; simulate and predict complex, stochastic or chaotic behavior; explore and model nature’s interactions, connections, complex relations, and interdependencies, scaling from sub-particles to galactic and from cellular to societal; and train future generations of scientists and engineers in the use of cyber-resources.

Creative, cyber-enabled, boundary-crossing collaborations, including those with industry and international partners, will contribute to advancing the frontiers of science and engineering, broadening participation in science, technology, engineering, and math (STEM) research, and educating an inclusive STEM workforce for the 21st Century.

Numerous community workshop and study panel reports contend that we have entered a nascent revolution through computational thinking in what, how, and who will be involved in future discovery and learning. These emerging cyber-enabled foundations will support the development of new and valuable technologies and services that will keep America globally competitive in today’s world, a goal to which NSF is fully committed.