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Global Dimension of CI: Compete or Collaborate

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Presentation to "CI Days at Purdue"
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I am delighted to be invited to participate in CI days at Purdue and present remarks on the importance of CI to international competitiveness in research and education. Most economists will agree that national economic development, productivity, and international competitiveness are linked to investments in education, research, and infrastructure, especially CI infrastructure. Hence, when I arrived at the NSF six years ago, I considered increased investments in CI to be an imperative.

A "blue ribbon panel" was commissioned by the NSF early in the new millennium under the leadership of Dan Atkins to examine what role NSF should play in advancing U.S. leadership in CI. The panel recommended a greatly enhanced NSF budget for CI of $1 billion per year to expand substantially the scale and scope of their future CI investments. In other words NSF should be comprehensive in its support of all essential elements of CI to include:

- High-end computing at both teraflop and petaflop scales;
- Software tools for high-end, ubiquitous computing for solving "sophisticated" scientific and engineering problems;
- Connection, interface and visualization services;
- Open data, information and knowledge management services;
- Networking at global, national, regional, local, and campus levels;
- The means for establishing virtual organizations, observatories, and collaboratories with open, "free to access" environments; and
- CI for learning environments to educate students at all levels as well as a future CI workforce.

The panel members also identified a number of issues:

- While the TeraGrid was an important tool for high-end practitioners, it lacked the middleware and connectivity to make it readily accessible to all users, to accommodate the needs of virtual communities, and to facilitate interoperability with global networks.
- While the PACI centers had provided the STEM (**S**cience, **T**echnology, **E**ngineering, and **M**athematics) community access to high-end computation capabilities and expert technical support staff, the centers seemed to be "locked in" for grant renewals. There were concerns among members of the National Science Board that the lack of competition was denying other capable universities from developing top-end capabilities.
- Since STEM research was continually expanding among institutions of higher learning, to include four-year education institutions and predominantly minority-serving institutions, the provisioning of both wired and wireless CI connectivity to the TeraGrid for this broader community was of growing interest.
- There were organizational barriers at the NSF that impeded in an integrated way **supporting research** into advanced CI science and technology, **exploring**

innovative applications of CI to solve complex problems, and **providing advanced CI capabilities and services** to a broader STEM community.

- Furthermore, there was a need for NSF to pay closer attention to other issues, such as:
    - Giving early attention to software tools before deploying "the next big thing" in computing hardware;
    - Integrating CI in the conceptual design stage of major instrumentation and facility developments,
    - Addressing the social dimensions of establishing virtual networks, developing protocols for openly sharing data and knowledge, and developing standards and operating procedures for the interoperability of national and global networks;
    - Applying CI tools to enable digital libraries to organize, curate, archive, and openly distribute data, information, e-documents and courseware on the internet and to convert "dark archives" or "data mortuaries" into "light archives" where data can see the light of day; and
    - Developing collaborations with other federal agencies and global partners to find synergies in financing and using CI to find answers to grand-challenge global problems.

It became apparent after I had been at the NSF for about six months that much work had to be done to change the organizational structure, overcome interface barriers, and build much larger budgets to address a new CI vision and step up to the national leadership role that the panel had called for.

A number of steps were taken thanks to the willing participation of NSF's senior leadership, program directors, and administrative and technical staffs:

- The first step was to develop an agency-wide vision document based on recommendations from the "blue ribbon panel" report and reports from previous workshops and studies. Dr. Deborah Crawford, now provost at Drexel University, led a working group in developing the initial version of the document and improving it over several months based on comments from the science and engineering community at large.
- Second, it was necessary in order to build a larger budget for CI investment to elevate the NSF CI provisioning organization from a division within CISE (**C**omputer and **I**nformation **S**cience and **E**ngineering Directorate) to a self-standing office within the Office of the Director. Hence, the Office of Cyberinfrastructure (OCI) was born with a charge to become more interactive, strategic, visible, and transparent.
- Thirdly, it was essential that a governance structure be established for which the directorate and office leaders would be the internal stakeholders "in fact" of NSF's total CI enterprise. This led to the establishment of a CI Council that would be supported by both an external advisory committee and an internal coordinating committee.
- Fourthly, a FACA, CI advisory committee (ACCI) was established, reporting to the director and supported by the OCI director as the cognizant federal official.
- Finally, we were able to recruit Dan Atkins, the chair of the "blue ribbon committee", as OCI director. He immediately set strategic objectives for OCI and incorporated them into the vision document. He also established a representative internal coordinating council of program directors to assist the CI Council in organizing a

cross-foundation integrated program. One of Dan's major contributions was to assist the director and deputy director in selecting the nation's top experts in the CI field for the ACCI.

- The leadership of Dan Atkins at the formative stage of OCI was pivotal. He kept the assistant directors and office directors informed of important developments, and he structured and defended the OCI program before OMB examiners and Congressional staff members. He also recruited additional staff for OCI and through them built significant momentum for the program.
- High accolades are also due to others who did much to translate NSF's vision into reality. Credit is due to:
    - Jose Muños and Steve Meacham for implementing a high performance computer strategy that resulted in the procurement and installation of three petaflop-class computers and the transitioning of the TeraGrid to an X-Grid with multi-petaflop capacity, greater ease of connectivity, and enhanced capabilities for data retrieval, transfer, and storage.
    - Ed Seidel, who in partnership with NSF's directorates and offices, gave greater attention to investing in software and data management tools, expanding research collaborations through virtual organizations, and initiating research and education programs to advance the field of computation science and engineering. Ed also charged the ACCI with providing new forward-looking perspectives for future NSF CI investments.
    - Jeannette Wing, who engaged with the private sector in providing access to substantial "cloud" computing capabilities for NSF grantees. She also worked in partnership with the Education and Human Resources Directorate in exploring new modalities for bringing CI technologies into the classroom to advance computational thinking among the nation's youth.
    - The National Science Board, which played several pivotal roles to include approving NSF budget submissions for CI across the foundation and issuing an important and timely report on data management.

These actions have gone far in achieving NSF's initial CI vision.

But NSF has done much more than this brief outline would indicate in building U.S. leadership in CI:

- By incorporating a track II component to EPsCOR infrastructure grants NSF made it possible for a broader community to build out their inter- and intra-campus networks and achieve greater access to the TeraGrid.
- A number of network grants have been issued to connect U.S. with international broadband networks. These include the TransPAC2 (U.S. – Japan and beyond), GLORIAD (U.S. – China – Russia – Korea), Translight/PacificWave (U.S. – Australia), WHREN (U.S. – Latin America), and TAJ (Singapore – India – Middle East – Europe) networks. While there are still "dark" regions that are not yet connected (such as in sub-Sahara Africa), these are likely be in place in the near future. These connections have resulted in substantial growth in cooperative research between U.S. investigators and their partners around the world.
- Advances have been made in pursuing synergies between NSF's investments with those by other agencies both in the U.S. and abroad. The installation of the "Kraken" computer at Oak Ridge National Laboratory greatly enhanced collaborations between university and ORNL investigators in modeling and simulating problems of high complexity. NSF is now engaged more fully with the Department of Energy in software development through their SciDAC (**Sci**entific **D**iscovery through

Advanced **C**omputing) program. Furthermore, a software competition among the G-8 research councils is now in place to develop advanced application software concepts to employ exaflop computers of the future.

- Funding for high-end computers and associated capabilities has now been totally unbundled to enable competition for new grants for leadership computers by new participants. There are now a number of new university entrants outside of the previous PACI centers which rank among the top ten with computing capacities ranging to the petaflop scale. Among these are the University of Colorado, University of Texas at Austin, University of Tennessee, Georgia Institute of Technology, and Purdue University. The computers selected by these universities represent a range of vendors and computer architectures. This picture continues to change dramatically.
- NSF has issued a new call for open access to data generated under NSF grants, and now requires PI's to submit data management plans with their proposals to show how this requirement will be satisfied. This call responds to Congressional mandates, and focuses reliance on universities to address various faculty and institutional open access issues at the data, metadata, and e-publication levels. This continues to be a challenging area for universities, requiring innovative approaches in establishing standards and modalities to meet the growing needs of research communities for open data and information access.

In addressing "Global Dimension of CI: Compete or Collaborate", I have recounted NSF roles in addressing these dimensions from a national perspective during my time as director of the agency. In my concluding remarks, I would like to address this topic from a global perspective.

As a result of growing investments by nations throughout the world in research, education and CI, the world is, allegorically speaking, shrinking as well as flattening. I believe that NSF in fulfilling its CI vision has enhanced the global competitiveness of U.S. universities. However, in fulfilling this objective attention has also been given to increasing investments in global collaborative research because of the need to collaborate in order to compete.

Research at the frontier is a quest being pursued by researchers throughout the world. Two factors are of significant importance in supporting the competitive potential of U.S. researchers working at the frontier:

- Other nations are increasing the intensity of their research investments relative to GDP with the result that the U.S. world market share in research investment will continue to decrease.
- A growing fraction of the world's Ph.D. researchers will be outside of the U.S. due to greater investments by developing nations in providing graduate education for potentially much larger student populations.

As a result of these trends the impacts of U.S. leadership in most fields of research will become more diluted over time. This also means that an increasing fraction of new scientific concepts and breakthroughs will more likely occur outside of the U.S. in the future.

CI now makes it possible for U.S. researchers to be linked virtually on a 24x7 basis with research communities throughout the world. Not to pay attention to this opportunity is to accept greater risk of becoming 'blind sided' to important movements at the frontiers of science.

The movement to share data openly around the world is intensifying. Modern major research facilities and observational networks will require embedded CI and backbone networks to accommodate the increasing volumes of data generation, transfer and storage. However, institutions are discovering that the more difficult barriers to achieving progress toward this goal are more social than technological in nature.

While the world's societies are continually challenged by an ever changing and interlaced world, they are also the potential beneficiaries of CI advances. Global grand challenge problems are multi-variant, complex-coupled systems for which the interrelationships among variables are subject to change in unpredictable ways and the optimization of one part of the system can lead to unintended consequences in other parts. It is now more than ever before that high-end computing is available to help investigators understand the inherent complexities of solving complex-coupled problems. This is a challenge worthy of the emerging worldwide collaborative culture … one that is becoming ever more virtual, but also one that is ever mindful of its basic need to compete.

A word of caution is appropriate in contemplating this emerging world of open-access publishing and data transfer on the internet. E-publishing overcomes the page limitations and time delays of journal publications and facilitates continuous, instantaneous publication and critique. However, the publications are less likely to be understood or useful without adequate attention to semantics, ontology and tagging. It could be much like having free reign of the palace but without the keys to the most interesting and important rooms.

Furthermore, armed with information management tools, such as AI, knowledge robots ("knowbots"), cloud filters, and pattern recognition algorithms, the single investigator may become the premier collaborator of the future. Collaboration in this instance would not be "active collaborations" with other individuals or groups, which is time consuming and requires interpersonal and communication skills, but rather "passive collaborations" linking with the hunches, insights, and concepts, provided by many other scientists through their e-publications and data. These new knowledge management and interpretation tools may become the new connective tissue of the future between collaboration and competition. The lesson here is that CI tools may be necessary but not sufficient for the future advancement of science in the information revolution. Considering the measures and countermeasures inherent in this "glass bead game*", all fields of science will be well challenged.

Thank you.

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* The "glass bead game" refers to the famous novel *Glasperlenspeil* by Hermann Hesse, for which Hesse was awarded the Nobel Prize for Literature in 1946