Cyberinfrastructure Two Years after the Blue Ribbon Panel Report[1]

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INTRODUCTION

Thank you. I am very pleased to be with you this evening and I thank Ruzena and Fran for the opportunity to speak to this outstanding group from the SBE and CISE communities. Since chairing the Cyberinfrastructure Panel I have become a product of the "overview effect." I take this phase from a book by Frank Wright on Space Exploration and Human Evolution[2]. Using interviews with astronauts and cosmonauts, White shows how experiences such as circling the Earth every 90 minutes or viewing it from the moon have profoundly affected our space travelers' perceptions of themselves, their world, and the future. The privilege I have had to interact with hundreds of leaders around the world about the existent and emergent potential of CI-enhanced knowledge communities has had an analogous effect on me. I am driven to help achieve this potential for revolution and I am delighted to be with fellow travelers here tonight.

It is also especially meaningful to be asked to speak at this workshop because many of my career priorities have been driven by a passionate belief

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[1] Invited talk for NSF Workshop on Cyberinfrastructure and the Social Sciences, Mar. 15-17, 2005, Airlie House Conference Center, Warrenton, VA.

[2] http://www.aiaa.org/store/storeproductdetail.cfm?id=526

that a holistic, socio-technical approach to the design, analysis and applications of IT-based systems is absolute necessity to close the gap between the rhetoric and reality of IT impact. Pure technological determinism will not do it. This is especially true as IT becomes the substrate for enhancing the effectiveness of communities of learning, research, and societal engagement -- in some cases enabling new methods, new goals, and new participants.

THE CI ADVISORY PANEL AND THE REPORT

During her tour as AD for CISE Ruzena Bajcsy and other leaders at the NSF noted some trends and issues that called for strategic reflection.

First, through the ITR, the KDI, the DLI and other NSF programs, an increasing number of research communities were seeking funding - often large amounts -- for transformative application of computing-based technology to their research aspirations. Many of these proposals asserted that advanced IT was not just desirable, but absolutely essential to the pursuit of their research goals. They were not talking automation of the established, but rather doing new things in new ways.

Secondly, leaders noted that although NSF has had a long tradition of persistent support of physical or “built” infrastructure (examples) and special processes and budget categories for doing so, there was still work to be done on similar policies and procedures for IT-based infrastructure.

Ruzena and her colleagues were also of course well aware of the enormous ROI of prior NSF investments that contributed to the internet, the web, digital libraries, super computing, grids, middleware, smart sensors, collaboration technology, visualization tools and many other capabilities. “system components.” They now sensed that all this could now become integrated components in even more powerful knowledge work systems with even greater ROI in the future.

And fourth, Ruzena and her colleagues wanted to create compelling visions to motivate increased funding of research in CISE and other areas that would produce the breakthroughs for the future; and new funds for continuing the investments in advanced pilot projects across all the Foundation.

Although I have never actually asked her, I give Ruzena the credit (or blame some would say) for coining the phase *cyberinfrastructure*. Although the word does not roll off the tongue, it is useful and evocative to emphasize: 1) that we must now invest in IT as institutionalized, sustained, evolving but robust infrastructure that researchers will bet their careers on; and 2) the “cyber” prefix reminds us that IT has some important different properties than traditional “built” infrastructure. On the negative side, it generally depreciates much more rapidly than bricks-and-mortar, but on the positive it is generally more sharable and general purpose.

Infrastructure suffers from a lack of glamour. Good infrastructure is often defined as something you take for granted until you don’t have it. But My history of technology and civil engineering friends are quick to remind me that infrastructure is among the most complex and costly undertakings of

modern society. I have also learned in working at NSF that infrastructure -- especially cyberinfrastructure -- can also be defined as something that everyone wants; but wants someone else to pay for it.

Our Advisory Panel was formed and given a three part charge: 1) to articulate a vision of cyberinfrastructure, its potential impact on research and education in science and engineering, and the role for NSF in the vision; 2) to assess current investments in cyberinfrastructure; and 3) to advise on budget and organizational to carry out the vision.

Our Panel worked for over a year in gathering testimony, surveying, studying prior relevant reports, deliberating among ourselves, and writing. We issued an interim report with a broad call for comments. We got many and incorporated them including a recurring theme that we were not stating the revolutionary potential strongly enough. We did title the final report Revolutionizing Science and Engineering through Cyberinfrastructure. Apparently the world agrees with assertion -- Close to a half million copies of the report have been distributed around the world to date and I have not gotten one complaint about hyperbole or over stating the potential impact.

Before I go further let me remind us of a very important point -- the scope of our findings -- and the billion dollar a year incremental funding we proposed is NOT just about research, development, and provisioning of advanced cyberinfrastructure as an end in itself --- it is about the U.S. National Science Foundation stepping up to true leadership for the US and the world to align and leverage R&D, the provisioning, and the application of advanced cyberinfrastructure to revolutionize science and engineering research and

allied education. We call for a broad Advanced Cyberinfrastructure Program (ACP) of continuing investment -- not just a five year initiative. The budget in chapter 6 is multi-faceted and much of the proposed budget is for interdisciplinary pilot projects involving teams of computer scientists, social scientists, and researchers from application communities. Cyberinfrastructure and its use is both an object of research as well as an enabler of research. An ACP is science working for science and is intrinsically multidisciplinary.

We need to talk not just about cyberinfrastructure but rather about cyberinfrastructure- enhanced science (CI-enhanced science) -- or bolder yet CI-enabled science -- or broader yet -- CI-enhanced research, learning and engagement (across institutions, cultures, nations, societies, etc.) or perhaps even more generally - global, CI-enabled knowledge communities.

Many of these communities are collaborative, multidisciplinary, geographically distributed, and inter-institutional. The multi-dimensional outcomes they are seeking include new ideas, new tools, education and career development, and engagement to nurture social relevance and civil society.

Before moving on to what's happened let me underscore one other point. Although leading edge, high performance computing in all its forms is a critical component of CI -- it is not synonymous with cyberinfrastructure. In addition to **High performance computation services** capable of simulating complex phenomena such as galaxy formation or social-physical models of global warming, The major components of cyberinfrastructure include:

A special type of software called "middleware", that makes it much easier to build community specific, inter-institutional virtual organizations in efficient, secure, and trustful ways.

Data, information, knowledge management services federating vast networks of digital libraries, archives, and museums (LAMs) providing content and persistent knowledge management services. We heard a lot about the need for preservation, interoperability and re-use of scientific data snd the growing unmet need for people and institutions to provide these services.

Observation, measurement and fabrication services including arrays of networked scientific instruments and sensors to measure and observe our world and beyond.

Interfaces and visualization services to support interaction between humans and technology in ways that are natural and exploit the full range of human sensory capabilities.

Collaboration service to enable distributed teams to work together effectively in all four variations of same and different time and place.

All of this is intended to allow specific, CKCs (called collaboratory, grid community, etc.) to be created efficiently and effectively using facilities, tools, and toolkits provided at the cyberinfrastructure layer.

A cyberinfrastructure program must include significant effort to capture and benefit from commonalities across science and engineering disciplines and

appropriate levels of coordination and sharing of facilities, best practice, and expertise to minimize duplication of effort, inefficiency, and excess cost.

As I tried to convey in Figure 3.2 in the report, an advanced cyberinfrastructure program should include a dimension of advancing the raw capacity of computation, communication, and storage -- but it also should also include a dimension to promote its ubiquity, functional completeness, uptake, and effective use measured in human terms.

SO WHAT HAS HAPPENED SINCE THE REPORT WAS ISSUED?

As often the case --- There is good news and bad news. First the good.

The Good News

SUBSTANTIATES AND BROADENS THE PERCEPTION OF A NASCENT GRASS ROOTS REVOLUTION

The report has been a best seller as such reports go. It has helped substantiate, sanction and diffuse the awareness of a nascent grass roots revolution underway. It describes a rich stew bubbling in the mix of activities called cyberinfrastructure, e-science, grids, collaboratories, and so forth -- all of these are complementary visions and activities that I assert add up to a cyberinfrastructure movement -- or more inclusively a CI-enabled science and engineering movement.

A Google-metrics search on some of the concepts in the stew yield the following:

Phase	Google Hits (approx.)
cyberinfrastructure	54,000
e-science or escience	384,000
collaboratory or co-laboratory	231,000
“grid computing”	1,290,000
grid communities	5,200

I also noted that none of these terms except grid computing have yet made it into Wikipedia. Let’s do something about that.

Dozens of disciplinary workshops have been held in and about the NSF community since the report was issued with many affirming the importance of CI-enabled science. Some repeat the theme that advanced CI is essential to reach their communities research goals over the coming decade. Some are seeking a CI-enabled community that is functionally complete in the sense that members can reach all of the colleagues, information resources, and tools that they need for their work through the internet and can easily and naturally work in all four variations of same and different time and place.

It is especially gratifying to me that minority serving institutions see the potential for broadened participation in science and engineering for their students and faculty in a CI-enabled world. A coalition of Native American, Hispanic serving, and historically black universities are now working together to build capacity and secure funding for exploration. CI also offers better participation by the physically challenged in ways that are of advan-

tage to all of us -- the so-called cut curb effect -- sidewalks with cut curbs are simply better curbs for all -- not just for those confined to wheelchairs.

The report has increased conversation on the topic within and between international research teams and sponsors. I have first hand knowledge of such activity in Canada, the UK, the EU, Japan, China, South Africa, India, New Zealand, and Australia

The CI movement has made impact on strategic visioning and planning activities with in the higher ed community -especially in research universities. The US National Academies are now engaged in a continuing forum to help the executive officers of research universities understand and act upon the implications of CI for their future. A similar process is now underway through the OECD -- a think thank and statistical benchmarking activity based in Paris serving the 30 richest nations. CI-sessions are now common in many professional meetings. And the humanities community through the HAYSTACK coalition as well as a study commissioned by the ACLS is exploring the role of CI in the humanities.

There are also profound implications in CI for homeland security broadly defined to include both man-made and natural disasters; and a huge opportunity space coming at the intersection of cyber and built infrastructure (see Priscilla).

IT HAS STIMULATED A LOT OF ACTIVITY AT NSF (EXAMPLES)

As others have mentioned, the CI movement has stimulated a lot of activity at the NSF.

1. Thee is a lot of excitement, vitality, and expectation at the NSF around the CI movement.

2. CISE was reorganized to include a directorate for shared cyberinfrastructure.

3. Debbie Crawford chaired an excellent internal study of CI including an inventory of current investments in CI broadly defined (the number is about $500M per year)

4. Explicit mention of CI as a priority has found its way into the President's FY2006 budget:

- NSF's current focus on the development of a comprehensive cyberinfrastructure, which integrates advanced computing engines, federated data archives and digital libraries, observing and sensor systems, and other research and education instrumentation into a common framework, builds on the agency's long history of leadership in this area.

- NSF's FY 2006 investments in cyberinfrastucture will continue to promote science and engineering advances enabled by cyberinfrastructure, and will foster the integration of a range of state-of-the-art heterogeneous research and education tools.

There are new solicitations specific to CI including CI-TEAM, next generation cybertools, broadening participation in computing, and an initiative in dynamic data-driven application systems (Triple D AS).

There is a new NSF Director, Arden Bement who I have known for many years and who I believe intends to step up to the opportunity - and I would say the responsibility - for NSF to provide real leadership in the CI area. Among other things Arden is addressing the internal organizational and incentive issues around a cross-foundational CI program. As mentioned earlier Priscella Nelson is chairing a process to provide him advice on this topic very soon.

The CI Movement has nurtured boarder understanding and appreciation of the fact that cyberinfrastructure has not only technological, but also institutional, and social dimensions. In a recent paper Paul David, for example, asserts that fulfilling the promise of CI-enhanced science will require a lot more than innovation in technology and in the design on new systems and tools by scientists and their organizations. “No less important will be appropriate institutional contexts to facilitate collaboration with communities of scientific and technical researchers – both on the ground and in cyberspace.” Included in his definition of institutional and social infrastructure are the following:

- formal institutional infrastructure and legal support layer;
- research funding agencies administrative regulations;
- host institutions statutory regulations and administrative rules; and
- informal community norms of scientific and academic work groups – governing data access, publication credit, relations with colleagues, staff and students, etc.

This workshop is evidence of this broadened awareness and buy-in. I do want to remind us, however, that we are here to discuss the scale up and broadening of participation in work at the intersection of the CISE and SBE -- we are not here to invent it. There is a long history of smaller scale but high impact work in this area sponsored by the NSF including the pioneering efforts of the late Larry Rosenberg through the Coordination Theory and Collaboration Technology (CT squared) program beginning in the early 1980's, the collaboratory movement initiated by Bill Wulf in the mid 80's, the controversial but bold Knowledge and Distributed Intelligence (KDI) initiative, and the current programs managed by Suzi Iaconna.

The Bad News and Comments about What to Do

So what is the bad news? Let me say a little about that at the same weave in a bit about what I think needs to be done.

Our Panel opined that an Advanced CI Program could not be a business as usual undertaking for the NSF, and that I believe this has turned out to be true. It is taking longer than many had hoped to implement a comprehensive plan of action appropriate to the scale and complexity of an ACP. There is external concern about increasing opportunity cost for delay and some external criticism of NSFs performance to date. But there is still plenty of energy in the system -- this is an organic movement that will not go away soon . Many NSF program officers and members of the community are working very hard to determine the right thing to do and then to do it. And as I mentioned earlier I expect Arden Bement to make some important decisions to move the program ahead.

The most obvious bad news is that the NSF is at best holding its own with respect to its over all budget. The train to doubling its budget over the next few years has been derailed. Increased funding of research and education in science and engineering in this country is trumped by other national priorities.

But NSF can not and is not waiting for significant budget increase to move ahead and must find ways to reallocate funding and invest the estimated $500M it already informally labels cyberinfrastructure more effectively.

In the longer term, however, we must as community find better articulations of what this CI-movement is and what it means for the Nation, and a rationale for increased investments in terms that politicians, policy makers and the general public can better understand and appreciate. What is the elevator speech for your congressman? I have had some success, for example, with the following: *Advanced cyberinfrastructure is critical to innovation. Innovation is critical to leadership in global, knowledge-based economies.*

What is the “moon shot” analog that might help galvanize increased support. I think it can be done and I think even in the current national situation more funding could be secured by the appropriate marketing of the CI-vision.

While CI holds the promise to enhance a new wave of collaboration across boundaries of space, time, institution, and discipline; achieving this will itself require a new wave of collaboration between a large array of patrons and stakeholders in its creation, use and impact. CI-enabled ways of work-

ing fundamentally change the boundaries between when to cooperate and when to compete at the individual and institutional level. We need to solve the Prisoner's Dilemma for cyberinfrastructure at many levels and within and between the NSF, other federal agencies, industry and universities. As much of the business world has learned -- we need to cooperate in new ways in order to compete. As some of my colleagues have graphically put it, NSF and the communities in supports must engage in some un-natural acts.

APPEAL TO THE SBE AND CISE COMMUNITIES

I will conclude with some remarks addressed to you as members of the SBE and/or CISE communities. It is terrific that the SBE community sees roles for itself as both users of, and contributers to cyberinfrastructure. The role as contributer is multi dimensional -- you need to ground, inform, and use your theoretical talents to create principles of design for more effect CI-enabled communities; we need your help with instrumenting CI-enabled communities to understand their impact and effectiveness; we need you to be the advocate of a human-centered design perspective.

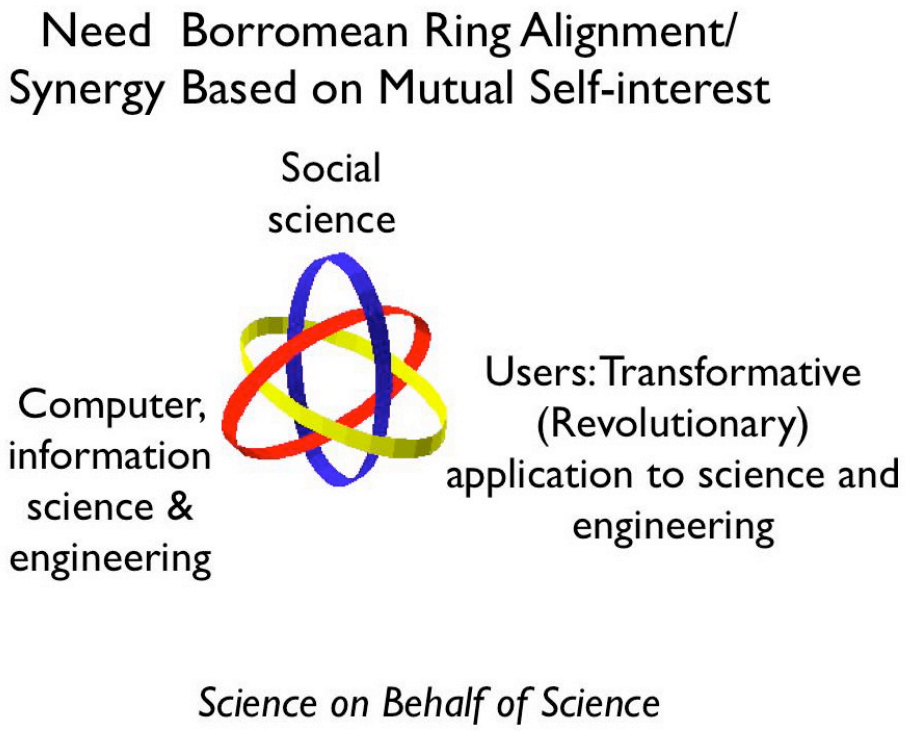
It is important that more and more social scientists are interested in not only in the analytic but also the synthetic side of CI-enabled knowledge communities. The emergent multi-disciplinary field of Incentive Centered Design at Michigan and elsewhere is a case in point.

To the CISE community I say if you haven't already -- consider stepping into the Pasteur Quadrant research model. This model, proposed by Donald Stokes in a book of the same name, is a rework of the linear model of

basic and applied research used by Vannevar Bush in establishing the NSF. In this model basic and applied are not at odds -- Like Louis Pastuer-- strive for contributions a both the basic and applied level and strive for synergy between the two. Revisit the NRC report *Computing the Future* calling for increased focus on experimental CS and asserting the benefit of grounding and informing basic work in real applications.

Long ago I adopted a topological construct called Borromean rings (see Google) as a personal logo to represent the mutually beneficial, collaborative autonomy required between three research communities: 1) computer and information science and engineering; 2) social and behavioral sciences, and all types of scientists who want to apply technology in transfor-

mative ways to their fields. Borromean rings are three rings mutually intertwined (none is subsumed by the other) and removing any one destroys the entire construct. Some of us also like the fact that Borromean rings cannot be circles -- you must be a bit eccentric to work in such multidisciplinary teams.



Borromean ring teams need to be linked by relationships of mutual respect and serve the mutual self-interest of the participants. These teams need to engage in collateral learning driven and informed by projects of theory building grounded and informed by iterative, human-centered design and experimentation.

At a recent workshop on software for cyberinfrastructure I gave by Borromean Ring pitch and then made reference to people becoming members of a B-Team -- B for Borromean. Later one of the participants joked that he didn't want to have anything to do with a B-Team -- meaning B-Team, as in not A-team , as in not first string.... It was a joke but a telling one in some ways -- actually we do need to join together in B-teams and humble our disciplinary and personal competitive egos to the collective opportunity and responsibility we have before us.

I hope this group here tonight *will* join B-teams, *will* experience the CI overview effect, and *will* directly and indirectly help make the cyberinfrastructure vision a reality.

Thank you.