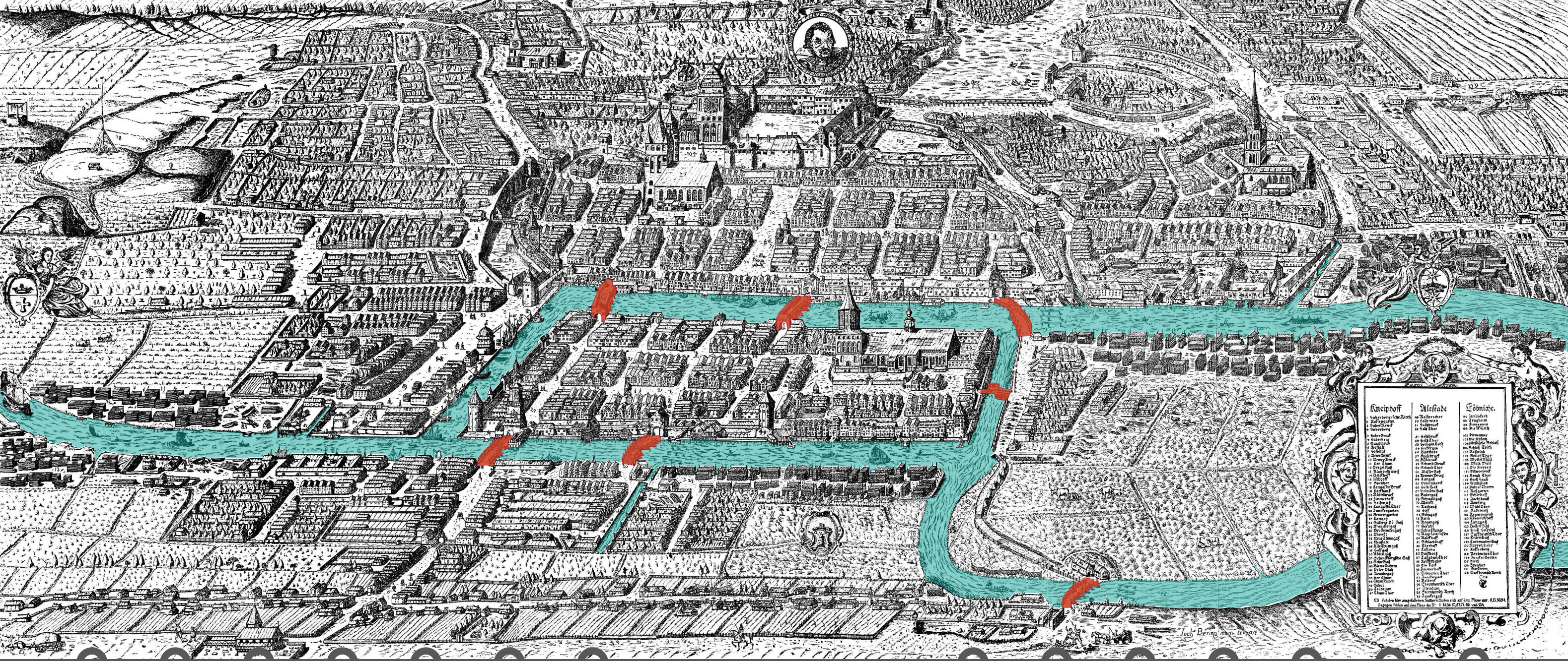

Campus Bridging

Campus Leadership Engagement in Building a Coherent Campus Cyberinfrastructure Workshop Report

October 11-12, 2010
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Other materials related to campus bridging may be found at: https://pti.iu.edu/campusbridging/

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The 39 workshop participants and their affiliations are listed below.

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Organizing committee

The workshop organizing committee consisted of chair Patrick Dreher (Renaissance Computing Institute), Stan Ahalt (Renaissance Computing Institute), Guy Almes (Texas A&M University), Michael Mundrane (University of California Berkeley), Jim Pepin (Clemson University) and Craig Stewart (Indiana University). Maureen Dougherty (University of Southern California) handled logistics for the workshop.

Executive Summary

The National Science Foundation (NSF) publication "Cyberinfrastructure Vision for 21st Century Discovery" argues that cyberinfrastructure (CI) is the critical component necessary to support science and engineering and enable discoveries, new knowledge, and scholarship. In the document, NSF articulates that the agency "will play a leadership role in the development and support of a comprehensive cyberinfrastructure essential to 21st century advances in science and engineering research and education."

In support of this vision, the NSF Advisory Committee on Cyberinfrastructure (ACCI) created a set of six task forces to investigate various aspects of the development of cyberinfrastructure, including the Task Force on Campus Bridging. The goal of campus bridging is to enable the seamlessly integrated use among: a scientist or engineer's personal cyberinfrastructure; cyberinfrastructure on the scientist's campus; cyberinfrastructure at other campuses; and cyberinfrastructure at the regional, national, and international levels; so that they all function as if they were proximate to the scientist. When working within the context of a Virtual Organization (VO), the goal of campus bridging is to make the 'virtual' aspect of the organization irrelevant (or helpful) to the work of the VO.

This report presents the discussions at and recommendations made at "Campus Leadership Engagement in Building a Coherent Campus Cyberinfrastructure," a workshop held in Anaheim, California from October 10-12, 2010. The main goals for this workshop focused on gathering the thoughts, ideas and perspectives of senior university administrators. The resulting report covers the topics of:

- The current state of campus bridging from the perspectives of the CIO and VP for Research.
- Challenges and opportunities at the campus leader level for enablement of campus bridging in the university community.
- The senior campus leadership advocacy role for promoting campus bridging.

The following recommendations emerged from this workshop:

Recommendation 1: Campuses should support both individual and collaborative research activities at their individual institution. Towards this end, campuses should cooperate with other campuses and institutions towards the goal of providing their educators and researchers a seamless cyberinfrastructure access and capability in support of collaborative research and education.

Recommendation 2: Campuses should develop and deploy a cyberinfrastructure master plan with the goal of identifying and planning for the changing research infrastructure needs of faculty and researchers.

Recommendation 3: The NSF should, to encourage academic institutions to implement a cyberinfrastructure master plan, fund a study and report on successful campus cyberinfrastructure implementations in order to document and disseminate the best practices for strategies, governance, financial models, and cyberinfrastructure deployment.

Recommendation 4: US colleges and universities should strive to include costs for research cyberinfrastructure in negotiated facilities and administration rates. The resulting facilities and administration income from grant awards should be used strategically within the context of a campus cyberinfrastructure master plan.

1. Introduction

Over the past decade, academic faculty and researchers from multiple disciplines have actively embraced computation-based techniques on an equal basis with theory and experiment. Together, they are the foundation that advances knowledge and discovery. Many universities and research institutions have reacted by creating new infrastructure capabilities to support computation-based techniques. Collectively, these new computation-based techniques are now commonly referred to as cyberinfrastructure (CI). CI has created opportunities for researchers, educators, and students to share ideas, expertise, tools, and facilities in new and powerful ways.

In this report we will use the definition of cyberinfrastructure as defined in the 2009 CASC/EDUCAUSE report "Developing a Coherent Cyberinfrastructure from Local Campus to National Facilities: Challenges and Strategies" [1]:

> *Cyberinfrastructure consists of computational systems, data and information management, advanced instruments, visualization environments, and people, all linked together by software and advanced networks to improve scholarly productivity and enable knowledge breakthroughs and discoveries not otherwise possible.*

As laid out in the National Science Foundation's (NSF) "Dear Colleague Letter: Cyberinfrastructure Vision for 21st Century Discovery," [2] cyberinfrastructure (CI) is a key and necessary component to support science and engineering. In the same document, NSF set for itself a vision to lead the development of a comprehensive cyberinfrastructure: "NSF will play a leadership role in the development and support of a comprehensive cyberinfrastructure essential to 21st century advances in science and engineering research and education." In support of this vision, the NSF Advisory Committee on Cyberinfrastructure (ACCI) created a set of six task forces to investigate various aspects of the development of cyberinfrastructure, including the Task Force on Campus Bridging.

The goal of campus bridging is to enable the seamlessly integrated use among: a scientist or engineer's personal cyberinfrastructure; cyberinfrastructure on the scientist's campus; cyberinfrastructure at other campuses; and cyberinfrastructure at the regional, national, and international levels; so that they all function as if they were proximate to the scientist. When working within the context of a Virtual Organization (VO), the goal of campus bridging is to make the 'virtual' aspect of the organization irrelevant (or helpful) to the work of the VO. Campus bridging is critical to supporting the ever-increasing level of cross-disciplinary and cross-organizational aspects of scientific research, as it enables not just the connection of scientists with CI beyond their campus, but also the connection of scientists with other scientists to support collaboration.

CI has been implemented both within institutions and across institutions unevenly and in an uncoordinated fashion. For example, some institutions have not aggressively embraced new technologies. Similarly, even among campuses which have implemented some elements of a robust cyberinfrastructure, there are locations and researchers that are struggling to achieve the CI access and support that their research requires. This uneven distribution of capabilities, both within and between institutions, poses significant challenges for faculty and researchers as they strive to utilize, collaborate and share a modern cyberinfrastructure in support of their research and scholarly work.

The Renaissance Computing Institute organized a workshop to discuss these challenges, and suggest solutions, at a workshop titled *Campus Leadership Engagement in Building a Coherent Campus Cyberinfrastructure*. This workshop was convened in Anaheim, California on October 10–12, 2010, preceding the annual EDUCAUSE conference. The collocation with EDUCAUSE permitted the workshop organizers to invite a wide range of senior campus leadership with minimal additional financial expense, and allowed the committee to utilize space that EDUCAUSE had available for side meetings.

The purpose of this workshop was to gather the thoughts, ideas and experiences for cyberinfrastructure capabilities and implementations among academic and research institutions from the perspectives of senior university administrators, which is the focus of this report. The meeting explored how senior university administrators view CI challenges and opportunities on their campuses, as well as ideas and suggestions faculty and researchers might use to bridge their resources among various campuses and research institutions. This report summarizes their observations and recommendations. It is the hope of both the organizing committee and the workshop participants that many of the ideas, suggestions and recommendations contained in this report be implemented in the academic community.

In the remainder of this report, we discuss the current state of campus bridging from the perspectives of the CIO and VP for research, then workshop discussion, findings and recommendations. Workshop materials, including presentations and submitted white papers, may be found on the Campus Bridging web site [3]. Related documents on the general topic of campus bridging are also available [4-6].

2. Current state of campus bridging from the perspectives of the CIO and VP for Research

The rapid expansion and application of computational hardware and storage capabilities across the spectrum of academic disciplines is a strong testament to the fact that numerical calculations, simulations, and electronic storage and analysis of data have become central components to most fields of scholarship and research in the 21st century. Faculty and researchers have come to realize that computational elements, storage environments, and associated software and networks are essential tools needed to effectively conduct research and generate new knowledge in their respective disciplines. This realization has led faculty and researchers to actively invest in these capabilities, causing an evolution of computing over the past twenty years, as viewed from the NSF funded perspective, along two general paths.

The first path is built on the creation of small resources deployed in support of individual or small groups of researchers and outside of the campus IT organization. This approach has been largely supported by both the relentless reduction of the price-to-performance ratio of computing and storage, coupled with the willingness of NSF and other funding agencies to award grants with targeted support equipment components. These resources are often deployed in space managed by a research or department and hence nicknamed "closet clusters". This "closet cluster" model has historically served individual researchers well when scale was not a factor and institutions effectively subsidized infrastructure operating costs (e.g., power and air conditioning).

The second path consists of large-scale infrastructure typified by the national supercomputing centers and a community of sophisticated researchers often performing large-scale science. Access to national supercomputer resources involved a regular process of formal proposal, peer review, and resource allocation. Unless the computational problem was sufficiently demanding of supercomputer resources and capabilities, researchers often chose the "closet cluster" model rather than the national supercomputer resources.

In many cases, funding agencies and university administrations are both supportive of these efforts. However, as noted in the 2009 CASC/EDUCAUSE report [1], progress has been uncoordinated, both within an individual campus and among various campuses. There is a record of mixed success when faculty and researchers try to bridge among campuses, regional, and national CI resources. As stated in the CASC/EDUCAUSE report:

> *The expanded and sophisticated capabilities of cyberinfrastructure, however, have evolved in a disjointed manner. In many cases, faculty, staff, students and researchers who have tried to access and integrate the information technology resources on a local level through campus infrastructure and/or national resources have encountered serious roadblocks with interoperability, usability and/or availability. These problems have been exacerbated by budget and organizational choices made at each level. Each infrastructure layer has focused on growing functionality within that layer without considering how such capabilities interrelate to the other layers of the national cyberinfrastructure ecosystem.*

Simultaneously, research and education has evolved from single-investigator activities centered at an individual college or university campus to a more complex set of communities of knowledge creation and learning [7]. This evolution has changed the landscape of computing and networking that is necessary to support these community activities. Today it is common to have large virtual organizations (VOs) tackling research topics, and learning communities being consumers of social networks. These trends are creating CI ecosystems and changing the methods of how we work and learn.

The CI ecosystem our research community deploys is a complex environment that must accommodate explosive technology change coupled with improvements in both the quality and quantity of resources, including an increasing number of research ideas. Indeed, the current research environment is influenced by the fact that limited, key opportunities to compete for large research grants hinge on successfully pursuing complex research questions, and these pursuits require very sophisticated CI. While opportunities (numbers of programs) for funding have increased, the increasing numbers of researchers pursuing these opportunities has increased at a far faster rate, resulting in vastly greater competition and distressingly low funding rates.

It can be argued that this explosion in competitiveness has been, in part, triggered by an expansion of sophisticated CI. Indeed, the ability to quickly and cheaply provision large resources can result in a leveling of the playing field. That is, a leading researcher should not have to be at one of the top 10 (or 50, or 100) schools to be competitive.

These trends lead to the idea of ubiquitous campus bridging and the interconnecting of departmental, campus, regional, national, and international CI resources. These CI resources include all computing, storage, and data resources that a research or education community creates and consumes to accomplish and publish their research and scholarship. The interactions between the resources and user communities are of utmost importance and have effectively replaced the old model where a campus is an island. This has profound implications on how we design, build, support, and use campus networks and other resources we traditionally have viewed with a campus-centric lens.

3. Challenges and opportunities at the campus leader level for enablement of campus bridging in the university community

Cyberinfrastructure deployment and support creates interesting institutional challenges, but also offers significant opportunities. As the requirements of our communities evolve, the support fabric, both human and computational, must also adapt. Institutions must evolve in a challenging, resource-constrained environment, while simultaneously meeting the legal and operating requirements of day-to-day administrative computing [8]. Campuses are re-inventing themselves and incorporating large-scale research communities with exponential growth in computing and storage capability [9]. Efficient and robust CI design options must balance local cultural mores, institutional priority conflicts, and narrow definitions by which funding agencies consider what constitutes central support and direction. There are examples of universities such as the University of Virginia [10-13], UC San Diego [7], and many other where the dialog has begun and the process is well underway.

3.1. Coherent computing and data infrastructure

As discussed previously, there are a number of economic and sociological trends that can lead to the dispersal of computing equipment into independent, stand-alone facilities dedicated to a single purpose or researcher. While these trends are not trivial to overcome, there are compelling arguments to pursue the maximum scale aggregation that is practical for both computation and data environments. Combining the resources of multiple researchers encourages a more efficient use of the combined resources. Similarly, quality data center space and centralized storage contribute significantly to the option of building a smaller number of much larger clusters to meet the needs of researchers. This argument scales beyond a campus, and economies of scale for state or multi-state resources are well documented.

The reasons for the economies of scale are relatively straightforward. The dispersal of computing into "closet clusters" tends to produce significant associated economic inefficiencies. It is simply not cost effective to replicate quality data center space on a per researcher basis; such replication requires an infrastructure investment that is highly disproportionate to the benefit. A campus consolidation trend is largely driven by the high capital investment required for data center space and a need to control power and cooling demands in a consistent fashion at the campus and building level. A similar argument can be made at the trans-institutional, or regional level.

This also aligns with "green" initiatives that encourage deployment of energy efficient infrastructures. Server virtualization and advances in lights out management is one component of the trend. A campus of significant size can function effectively with a very small number, or one, high quality data center(s). Research and administrative activities will both benefit greatly from high quality power and cooling, but researchers may not require high availability power and its associated cost. Data center space should be capable of providing differentiated services that are tailored to both administrative and research needs. We note that while current trends suggest that many campuses may eventually outsource data centers, there will remain a need in the near term for some data center space. This interim infrastructure can best be leveraged by greatly accelerating its use for the overwhelming majority of historically distributed computing, at the department or individual level of need.

Turning to data storage, the challenge is managing the expanding risk that accompanies the exploding quantity of data. Having institutional and national intellectual property sitting on unmanaged and unmaintained storage systems represents an unacceptable level of risk. It endangers research progress and does not ensure that institutions will meet granting agency requirements to provide public access to supported data for a specified period of time. Perversely, this situation has not been entirely mitigated (and in many cases has been exacerbated) by trends in storage costs that have encouraged replication, as inexpensive consumer disks have permitted local storage of even greater quantities of data by individual researchers. Campuses may partially resolve this quandary through outsourced options or by constructing and managing centralized storage pools. The outsourcing option can put pressure on external connections, but may be highly cost effective as it allows the institution to take full advantage of scale. Data sensitivity, as well as needs not met by standard service levels and specific performance requirements, make institutional centralized storage attractive. In either case, pooling storage needs for multiple researchers allows institutions to achieve the benefits of economies of scale coupled with the additional benefit that individual researchers receive the benefit of professionally managed and maintained infrastructure. And, as noted earlier, the same argument applies at the trans-institutional level. However, at the end of the day the data risk must be mitigated by good systems and applications hygiene; there is no network, cloud, or appliance magic bullet.

3.2. Digital curation and data services

The increasing rate of data creation is also stressing our ability to curate the resulting data resources. While the declining unit cost of storage has helped mitigate the direct capital investment associated with institutional storage appetites, it is clear that data creation has already scaled past our collective ability to manage metadata creation in an efficient manner. This is an entirely different facet of the research data challenge, and one that would benefit greatly from the domain expertise of campus libraries and leadership at a national level.

Additionally, institutions are beginning to recognize that we are moving to a write once and store forever model (or at least data creation is far outpacing data retirement). This has profound implications on the data management and maintenance challenge and creates a corresponding need to identify and implement data curation capabilities and standards for an exponentially increasing data pool.

3.3. Data networking in research cyberinfrastructure

It is an unfortunate reality of networking that the overall performance is governed by the least effective element along an end-to-end path. Thus, it is simply not possible to ignore institutional infrastructure when discussing overall CI capability. At the campus level, most institutions do not present a uniform infrastructure to their communities; that is, a networking infrastructure with consistent, location-independent quality. Sporadic funding and shifting priorities have conspired such that institutions have often met the needs of researchers based on a "point in time / squeaky wheel" perspective. While this has often produced high bandwidth connectivity to regional infrastructure, typically in the form of Regional Optical Networks (RONs) and high bandwidth campus backbones, on-campus infrastructure typically varies by building or unit, and highly capable networks are frequently limited to select locations on the campus. The variability in the quality of local area networks, or "this-building" connectivity remains extreme, with researchers in adjacent buildings frequently experiencing vastly different capabilities. This handicaps the potential of faculty at arbitrary locations in the campus infrastructure, precluding them from leveraging remote resources supporting their research. Even worse, a significant number of campuses are disadvantaged because they lack high bandwidth backbones, high bandwidth external connectivity, or both.

While it is understood that there will always be select researchers with needs that exceed the average, it is vital that future campus infrastructure provide services that are largely decoupled from location. Failure to achieve this goal will greatly limit emerging research opportunities in non-traditional CI centric disciplines, and will prevent even historically networking-intensive research activities from remaining competitive.

Institutional data networks can be thought of as existing in three distinct regions and should function in a balanced and complementary fashion. These are

- Regional networks provisioning access to the campus
- Core campus infrastructure
- Building infrastructure

Each of these relies on a coherent, high performance national research and education network. Permanent external connectivity – the regional network – should suffice to meet typical research and academic bandwidth needs to external resources, including peer institutions, national centers, and commodity internet. The backbone, or core, infrastructure typically represents the inter-building portion of the network and it should be architected using common, high bandwidth elements and realize a consistent, simple topology. There are numerous new core technologies being deployed on campuses, many based on fiber optic switching and wave division multiplexing. Deploying many 10Gbps (and up) capacity wavelengths (lambdas) empowers new network research and also enables high capacity data flows. Finally, the "in-building infrastructure", also called the local area network, should be switched and high bandwidth regardless of campus location. Even higher performing infrastructure may be needed in order to meet the needs of select researchers, or of select campus CI resources, whose persistent requirements exceed the capabilities of the general campus infrastructure.

3.4. Cyberinfrastructure support and expertise

Discussions of CI tend to focus on technology, but people play a critical role in creating, deploying, and supporting CI. The lack of readily available CI expertise represents a significant workforce development challenge. Consequently, we need to increasingly leverage the available expertise, both within a campus and bridged among campuses, and among CI projects.

Providing CI support creates interesting organizational and support challenges. The inherently diverse ways that CI can be used challenges many campus governance models. Furthermore, cultures vary between campuses, so it is hard to collect appropriate best practices that capture readily transferrable campus governance models. A reasonable CI governance model will match the campus research and instruction communities' existing operational structures. For example, one campus may have a distributed support environment based on revenue centers, where another might be considerably more centralized, and based on top-down funding. In either case the CI needs to be supported. Further, a very large, private Research-1 institution may have a different CI support and governance approach than a medium-sized, state land grant campus.

3.5. Relationship of cyberinfrastructure and administrative computing

Another challenge is the exploding requirement for administrative computing services which eat into the ability of campus technology support organizations to pay sufficient attention to the CI needs of the campus academic community. The constant drumbeat of small but important requirements for reports, changes, and improvements, both mandated and perceived, all consume finite CI resources and inordinately distract senior technical staff and senior leadership of the campus from CI needs and requirements.

There are also trends that are shifting the CI implementation and support resources from the 'academic' side of the university to the financial or administrative. For example, due to the increasing administrative support requirements, far fewer CIOs are faculty, and thus increasingly CIOs are less inclined to be focused on the requirements of CI that solves research needs. This trend, in turn, distances the relationships between the IT leadership and the research faculty, research staff, and students that existed in the past. This is a troubling prospect for our CI leadership, unless there is a corresponding transfer of the research vision to another computing organization on the campus, perhaps an academic and research organization directly under the provost [14].

Another critical component of future CI support is how to effectively pair CI providers with the research community. This is a complex political problem on many campuses. As an example consider the challenge of determining who will be the PI on a proposal that has both critical domain science and CI components. Many times, non-academic staff are precluded from competing with faculty in submissions. Excluding staff technologists from a proposal has often caused the neglect of the "nuts and bolts" issues, and this encourages the creation of research facilities that are one-off and dependent on the transient knowledge and attention of a specific post-doc or graduate student. The corresponding problem, if researchers are not included in "nuts and bolts" proposals, creates a facility with no direct research community need [14].

We conclude that campus leadership needs to create processes that allow staff CI technologists to participate with faculty in building and support CI structures. These can be formal arrangements such as a requirement for CI review as part of a sponsored research program office, or informal such as collaboration between faculty and staff on specific areas of research.

3.6. Cyberinfrastructure governance models

In this chapter we have concentrated on CI in general, but bridging campus-to-national scale CI is a particularly hard problem. Bridging is really a peer-to-peer problem, not a hierarchical relationship established among centers or sites. We observe that creating a plan to establish a peer-to-peer relationship is difficult, and it is even harder to create a specific implementation.

The reasons for these difficulties are based in the coupling of rapidly changing technology and rapidly changing scholarship requirements. That is, a well-crafted campus CI plan must accommodate disruptive change in both the dimensions of technology and scholarship. To exacerbate these challenges, the two are mutually affective – the technology and the scholarship are linked in both obvious and subtle ways. As an example, mobile technologies create IT challenges (e.g., keeping documents synchronized across a plethora of platforms, security) as well as concomitant scholarship challenges (e.g., capturing and documenting the motive force for change represented by Twitter or Facebook, which can change form and function extraordinarily rapidly as APIs evolve). Other examples include the explosion of data and new scholarship requirements concerning the retention and availability of data.

These disruptive changes do not lend themselves to a typical three-to-five year IT planning cycle, in either technology or financial dimensions. Senior institutional leadership must be able to react when a new research problem presents itself, and must also be able to adapt to new CI technology that can enable solutions to the problem. One way to accomplish this might be to couple the IT and research communities and empower them to take risks. Taking risks will require that IT groups and academic researchers be aligned so that there is mutual respect for their respective roles, as well as reward systems that accommodate very different roles.

The support fabric, that is, the corresponding governance and compliance processes and policies that also exist on each campus, must also adapt. We note that on most campuses, the governance and support models are far more rigid than is optimal in fluid environments. The senior administration must build flexible structures, processes, and support models that incent rapid adaptation to sudden and profound changes. There is not a one-size-fits-all model. Campuses are unique communities, with some common themes and structures. Campus leadership should understand the role CI plays in the academic ecosystem and then adapt their local leadership model.

3.7. Financial structures in academic research

Financial structures and processes also affect campus and national cyberinfrastructure. The systematic inclusion of cyberinfrastructure costs (facilities and personnel) and the use of such funds for cyberinfrastructure is important to making campus cyberinfrastructure sustainable as research infrastructure over the long term. The workshop participants noted the empirical observation that cyberinfrastructure facilities and personnel seem infrequently to be included in calculation of facilities and administration (F&A) rates, even though they are clearly allowable as such within the Office of Management and Budget Circular A-21 [15]). Cyberinfrastructure facilities (clusters, storage systems, networking equipment, etc.) are allowable under the category of capital expenditures. Data centers housing cyberinfrastructure facilities would seem to be eligible for inclusion under the category of large research facilities. Personnel who support cyberinfrastructure should similarly be properly included within the category of general administration and general expenses. This should be done with care, but including cyberinfrastructure costs as part of F&A calculations may be useful for universities and colleges not doing so now.

It was also noted during the workshop discussions that the distribution of F&A monies received by universities and colleges sometimes promotes extremes in distribution of small computing clusters. These can be inefficient in use of energy and personnel, and may exacerbate the challenges of effectively using the nation's aggregate cyberinfrastructure.

4. The senior campus leadership advocacy role for promoting campus bridging

The national cyberinfrastructure ecosystem includes an eclectic combination of high-end research universities. It extends to the comprehensive four-year schools and has at its base the massive community of two-year schools. We need to keep in mind that all of these institutions are part of one community. At the two-year school end of the spectrum the emphasis is on teaching and learning. We need to be aware that this portion of the community needs to access resources and be an equal participant to create the next generation workforce. The four-year comprehensive campuses are primarily teaching and learning based, but also participate in the research space. Terminal degree level education should include access to creative inquiry research to prepare BS/BA level students for success after graduation. Faculty at four-year schools are often active members of the academic research community and they typically need access on par with their peers at research institutions in order to be equal partners. The large span of missions and governance models in this heterogeneous environment is a classic example of what bridging means. It is not one simple structure; advocates in any one part of the environment need to be aware of the complex diversity in the whole system.

To measure our success we need to define the goals we are trying to achieve in both research and instruction. We can then apply the metrics that take into account our inter-campus and intra-campus CI tools and resources. There will be different measures of success for various types of campuses and we must take into account the local governance structures when metrics are applied. This is one of the most difficult things to do. We know how to determine if a project is completed on time, but complex sets of resources are hard to measure and quantify. It is also hard for people (single researchers or even campuses) to give up local control. We must find ways to incent behaviors that create group success. This is not a natural act. There are negative measurements that can be employed. If a campus is not competitive in an area it wants to excel at, this matters. If the future research directions require larger team (big science) projects to be effective, and if a given campus fails to enable its community's participation, that campus will not succeed and the community will migrate to campuses that invest in effective resources. There is also inertia built into the academic community, and this must be overcome to change how a campus views collaborative group efforts and shared resources.

Senior campus leadership needs a set of principles outlining important CI topics they can effective advocate. The development of this framework, now referred to as CIF21, will lead naturally to a holistic and comprehensive vision for a national cyberinfrastructure that builds on prior guidance in important documents such as the 2007 NSF document "Cyberinfrastructure Vision for 21st Century Discovery" [16]. Other federal agencies should have basic requirements and a vision where infrastructure needs to evolve over the next five years to complement the NSF's direction in this space. This can provide a roadmap that a president or provost could use for policy, financial planning and fundraising purposes. An additional set of guidelines might be helpful for provosts to use in the academic context. National societies and organizations such as the AAU at the president/provost level and EDUCAUSE at the CIO/IT layer would also be part of the advocacy ecosystem. Campus leadership should also engage advisory committees like PITAC at the national level to elevate the discussion to ensure that it is addressed at the highest level. We also need to engage groups like the National Academy of Sciences to advocate for the tools and facilities needed to advance our national science agenda as it relates to campus bridging.

As described above, there are significant challenges facing campuses, in terms of both the evolving nature of science and the evolving nature of computing and data. Effective campus leadership is critical to creating a coherent CI that can be used bridging between and among groups, and which is commonplace and as frictionless as possible. Leadership will start in the president's office and permeate the campus fabric. The academic side of the university, led by the provost or equivalent position, will be a focal point.

5. Recommendations

In this section we capture the overall recommendations that arose from the workshop discussions and information exchanges.

The first recommendation focuses specifically on the need to consider the new paradigm of collaborative research, while recognizing the critical role of individual-investigator science as a motivator for the need for coherent cyberinfrastructure and campus bridging:

> ***Recommendation 1: Campuses should support both individual and collaborative research activities at their individual institution. Towards this end, campuses should cooperate with other campuses and institutions towards the goal of providing their educators and researchers a seamless cyberinfrastructure access and capability in support of collaborative research and education.***

To support collaborative research, our second recommendation is for campuses to develop a plan, with support from the apex of their leadership, for coherent cyberinfrastructure. As stated by the CIC CIOs in their identification of planning as best practice [8]: "Maintaining a viable campus cyberinfrastructure is an ongoing process of responding to the co-evolution of technology and the scholarship it enables." Having coordination of campus cyberinfrastructure represents a significant benefit in terms of that cyberinfrastructure being more effective, both for producing research benefits and cost effectiveness. Hence:

> ***Recommendation 2: Campuses should develop and deploy a cyberinfrastructure master plan with the goal of identifying and planning for the changing research infrastructure needs of faculty and researchers.***

The NSF and other federal agencies can inculcate the urgency and need for a coherent approach. When a coherent message is presented by the national funding agencies, senior academic leaders from the president down will take the message seriously. However, if the IT department makes the same argument, it will be regarded as yet another technical fad of the month.

Additionally, the NSF can foster the process by providing the community with best practices for such plans. We have now a set of campuses that have undergone the planning process [7, 14, 17, 18], and a study of successful strategies for governance, deployment, sustainability, and support approaches would benefit and encourage other institutions to follow.

> ***Recommendation 3: The NSF should, to encourage academic institutions to implement a cyberinfrastructure master plan, fund a study and report on successful campus cyberinfrastructure implementations in order to document and disseminate the best practices for strategies, governance, financial models, and cyberinfrastructure deployment.***

Over the last few years, universities have come to recognize the relationship between successful faculty research projects that require cyberinfrastructure resources on campus and the rising costs for universities providing that infrastructure [18]. For universities with strong research in areas requiring substantial cyberinfrastructure, these associated university costs can become quite substantial. This recommendation emphasizes planning cyberinfrastructure in ways similar to planning for the development and implementation of other institutional assets, including buildings, laboratories, and libraries. Findings from the workshop discussion on cyberinfrastructure planning include the following points:

- The cyberinfrastructure master plan should be developed in collaboration among campus intellectual leadership, infrastructure providers, and faculty in order to achieve maximum buy-in and address as broadest set of needs and requirements.
- The senior campus leadership must be involved and committed to the cyberinfrastructure master plan's success with the senior campus officer responsible for campus CI (usually the CIO or equivalent) regarded as part of the campus intellectual leadership rather than just a service provider.
- The cyberinfrastructure master plans must place value on people, in the form of research and professional staff, who deploy, operate and support CI technology and systems.
- The cyberinfrastructure master plan should distinguish and separate funding for research CI as opposed to other IT infrastructure and include an analysis for sustainability of these CI systems.
- Addressing the needs of high-end researchers can change the entire campus. For example, the 2-3 supercomputer users on each campus in 1985 drove campus-wide change.
- We are at a 'once in 20 years' phase transition in CI driven by new data creation capabilities, the exploding growth rates of data and networking capabilities, and the requirement for collaborative science to address the most challenging problems in science and engineering. The new NSF data management policy requirements are symptoms of this change.
- Our current economic challenges are straining IT budgets, along with all other budgets on our campuses. The most obvious path of across-the-board budget reductions is less desirable than focusing on what an organization does best; this requires appropriate planning.
- There are advantages in the economies of scale [19] for CI provisioning and support at the campus, state, national, and international levels that can act to relieve economic problems. Having a plan allows a campus to take advantage of these economies.
- The new emphasis on the NSF data management plan requirement [20], will be a key driver for many cyberinfrastructure master plans.
- A potential mechanism that may help provide better CI support for faculty and researcher needs and requirements, and assist in campus planning for research infrastructure facilities, would be to engage with the researchers at the proposal writing stage.

> ***Recommendation 4: US colleges and universities should strive to include costs for research cyberinfrastructure in negotiated facilities and administration rates. The resulting facilities and administration income from grant awards should be used strategically within the context of a campus cyberinfrastructure master plan.***

The key considerations in this matter are as follows:

- Cyberinfrastructure that generally supports research activities of a university may fairly be included in F&A calculations.
- F&A is capped at 26% of direct costs for administration, and the effective rate (the rate universities actually collect as opposed to the negotiated rate) tends to be lower than this.
- In some cases it is possible to fund some computing as direct costs in grant awards (obtained competitively through grant proposals). In this case, 100% of the cost of equipment may be included as direct costs.
- The cost or value of equipment obtained through monies included in F&A calculations cannot also be counted as part of a matching commitment in a grant proposal or grant award budget.

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Appendix 1. Workshop announcement

The National Science Foundation (NSF) Advisory Committee on Cyberinfrastructure (ACCI) has assembled a Campus Bridging Task Force (CBTF) to identify the broad issues for improving campus Cyberinfrastructure (CI) including such areas as networks, data, middleware and campus implementations. The findings and recommendations from this workshop will be incorporated into an overall Campus Bridging task Force report to the ACCI and may help shape and the National Science Foundation's CIF-21 influence and also recommend how best to encourage and incorporate campus CI development and support as part of future NSF proposal solicitations.

The Task Force strongly recognizes the key role exercised by senior university administrators in overseeing the implementation of Cyberinfrastructure (CI) on their campuses. The CBTF is interested in assembling a group of senior university officers to meet with some of the Task Force members to focus on these issues. On behalf of the Campus Bridging Taskforce (CBTF) of the National Science Foundation Advisory Committee on Cyberinfrastructure (ACCI) we would like to invite you to participate in the workshop ***Campus Leadership Engagement in Building a Coherent Campus Cyberinfrastructure.***

This workshop will be exclusively focused on gathering the thoughts, ideas and perspectives of senior university administrators. It is important for NSF to understand how senior university administrators view CI challenges and opportunities on their campuses. The Task Force is also interested in how campus CI should be presented to senior university administration officials to gain both the support of senior campus leaders from among numerous other campus requests as well as their assistance in the development and implementation of a coherent campus CI. This output from this workshop will be part of a report to the National Science Foundation and will help them construct future program solicitations that will more coherently include campus bridging capabilities within the university's campus Cyberinfrastructure.

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Appendix 3. Workshop presentations

Leadership Engagement in Building a Coherent Campus Cyberinfrastructure

Campus Bridging Taskforce Workshop

October 10 – 12, 2010

Outline

- Logistics
- Acknowledgments
- Introductions
- Workshop Agenda
- Workshop Goals and Objectives

Logistics

- Wireless, power cords, meeting room info
- To post a message to all of your colleagues
  nsf-oct10-wkshp-list@renci.org
- The web page to access this mailing list is:

  https://mm.renci.org/mailman/ext/listinfo.cgi/nsf-oct10-wkshp-list
- To see the collection of prior postings to list
  Nsf-oct10-wkshp-list Archives

Monday Agenda

October 11th Laguna Room A/B

• 8:00 am – 9:00 am	Registration, continental breakfast
• 9:00 am – 9:20 am	Welcome, Introductions Workshop goals and objectives
• 9:20 am – 10:00 am	Professor Sally Jackson CIO University of Illinois, Urbana
•10:00 am – 10:30 am	Michael Mundrane, Deputy CIO, UC Berkeley
•10:30 am – 10:40 am	Topics for breakout discussions
•10:40 am – 11:00 am	Mid-morning break
•11:00 am – 12:30 pm	Breakout discussions
•12:30 pm – 1:30 pm	Lunch
• 1:30 pm – 2:15 pm	Professor Larry Smarr, Director Calit2
• 2:15 pm – 2:30 pm	Topics for breakout discussions
• 2:30 pm – 3:30 pm	Breakout discussions
• 3:30 pm – 3:45 pm	Mid-afternoon break
• 3:45 pm – 4:45 pm	Reports from breakout discussions
• 4:45 pm	Adjourn

Dinner Laguna Room A/B

• 6:30 pm – 7:00 pm	Cocktail reception
• 7:00 pm	Dinner


Tuesday Agenda
October 12th Laguna Room A/B
8:00 am – 9:00 am Continental breakfast
9:00 am – 9:30 am "Parking lot" issues from Monday
9:30 am – 10:15 am CBTF Task Force chair (Craig Stewart)
10:15 am – 10:30 am Topics for breakout discussion
10:30 am – 10:45 am Break
10:45 am – 11:30 am Breakout discussions
11:30 am – noon Reassemble, report outs, final thoughts, summary
Noon Box lunch to go
Noon -- 3:00 pm Working session – writing assignments
Organizing Committee
Campus Bridging Task Force


Acknowledgments
– National Science Foundation
– EDUCAUSE
– Univ of Southern California - Maureen Dougherty Director, Center for High Performance Computing and Communications
– The participants


Issues and Challenges


Issues
University research is being transformed with national/international large scale
– Computing
– Data management
– Collaborations and Virtual Organizations
New approaches needed to address learning and workforce needs and opportunities

Challenges

- Changes in
  - Computational systems and architectures
  - Sustainable software and tools
  - Collaborations and Virtual Organizations
- Discover and implement new ideas/practices
  - Utilize new computational paradigms
  - Write, share, sustain complex software & tools
  - Seamless access among
    - Individuals/groups
    - Campuses (intra and inter)
    - Regional and national resources

Cyberinfrastructure Framework CF-21

- CF21 is an NSF-wide CI Framework for 21st Century Science & Engineering
- Need an eco-system rather than a stovepipe set of components
- Goal
  - "…integrated system of hardware, software, data resources & services… to enable new paradigms of science…" *

  * http://www.nsf.gov/pubs/2007/nsf0728/index.jsp

Advisory Committee for CyberInfrastructure (ACCI) Task Forces

- Advise NSF regarding these challenges
- Workshops, town hall meetings, discussions
- Input will help shape CF-21 Programs & CI Vision Plan
- Six task forces
  1. Campus Bridging
  2. Computing
  3. Data and Visualization
  4. Education and Workforce
  5. Grand Challenge Communities and Virtual Organizations
  6. Software

Identifying Opportunities to Summon the Future

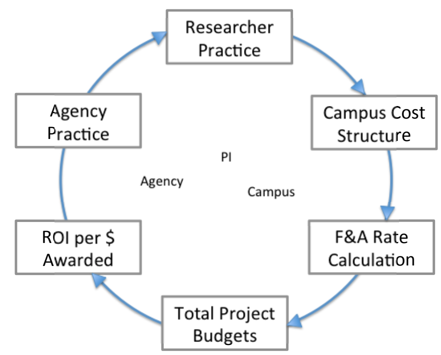
- What are the appropriate coupled mix(es) of campus services and resources (HW SW data)
- Network challenges having campuses fundamentally & comprehensively linked (intra, inter campus, regional, national level)
- Campus CI access, management, policies and support to realize this vision


Workshop Deliverables
A critical evaluation of these challenges and issues from the perspectives of the senior campus officers responsible for CI
Input, advice, recommendations from this group
Deliverables incorporated into the Campus Bridging Task Force final report to NSF
We thank you in advance for your service to the larger campus/university community


Questions
Comments
Suggestions

What Can Campus Leaders Do About Cyberinfrastructure?

Sally Jackson
For the workshop on Campus Leadership Engagement in Building a Coherent Campus Cyberinfrastructure
October 11, 2010



Researchers & research officers

Funding agencies

Campus planning & budgeting

pas-de-trois

twister

Who can do what to get all of us off the rubber mat?

Another paper on cyberinfrastructure

advice *to the CIC Provosts from their Chief Information Officers*

Note: Nebraska will join in 2011.

Effective voluntary collaboration among research universities

-- better outcomes for each member

-- innovative solutions to problems for the common good

HATHI TRUST

Good Practices

- Actually plan.
- Share at highest level possible.
- Treat funding models as alignment tools.
- Design good governance structures.
- Assess cyberinfrastructure impact.

6 High Priorities

- Federated identity management.
- State-of-the-art networks.
- Institutional stewardship of research data.
- Consolidation of computing resources.
- Expansion of CI support to all disciplines.
- Exploration of cloud computing.

Provostial Response: "Blueprints for Action"

- <u>Federated identity management.</u>
- State-of-the-art networks.
- <u>Institutional stewardship of research data.</u>
- Consolidation of computing resources.
- Expansion of CI support to all disciplines.
- Exploration of cloud computing.
- <u>*Scholarly communication.*</u>

Provosts in the Blueprints

- Thought leadership
- Direct personal advocacy among peers
- Lobbying for regulatory change
- Assistance in engaging other interests on campus
- Sparingly: financial commitment

CIOs in the Blueprints

Joint & individual projects
- InCommon "compact"
- Shared storage initiative & curation projects
- Big Digital Machine
- Shared clusters

Influence attempts
- On campus
- Among research universities CIOs
- Within our own reporting units

What Can Campus Leaders Do About Cyberinfrastructure?

Campus Leadership Engagement in Building a Coherent Campus Cyberinfrastructure

Opportunities and Challenges

Michael Mundrane
University of California, Berkeley
11 October 2010

Basic Infrastructure Exists

- Open networks
- Gigabit intra-building
- 10G core
- 10G edge
- CENIC partnership
- I2 relationship
- Central data center
- Services for purchase
- But ..... uneven LAN infrastructure

2

Environment Reality

- 40/60 central/distributed
- Varied needs
- Varied wants
- Culture of uniqueness
- B2B vs. B2C
- Resource constraints mean tradeoffs
- Perceived zero sum game
- Value driven instead of cost driven

3

Definition of Value

$$\text{Value} = \frac{\text{Benefit}}{\text{Cost}}$$

There is a simple working definition that can be applied in a business sense.

4

Better Definition of Value

$$\text{Value} = \frac{\text{Realized Benefit}}{\text{Total Actual Cost}}$$

A more accurate definition reflects real world tradeoffs and compromise.

5

Evolving Support

- Data Network Recharge (DNR)
- Capital Investment (Core/Riser)
- Common good funding (OE)
- Investment towards higher base level
- Scale beyond department
- Regent resolution

6

Strategic Partner

- Lawrence Berkeley National Laboratories (LBNL)
- Proximity
- Joint appointments
- Research connectivity
- Pursuing 10G direct connectivity
- HPC (5/200/15,400)
- Broad participation (73)

7

Faculty Support

- Engagement
  - Cyberdays
  - Data services
- Consultation pre-proposal
  - Valued by PI
  - Fast startup post award
- Increased utilization
- Diverse faculty

8

Questions

Questions?

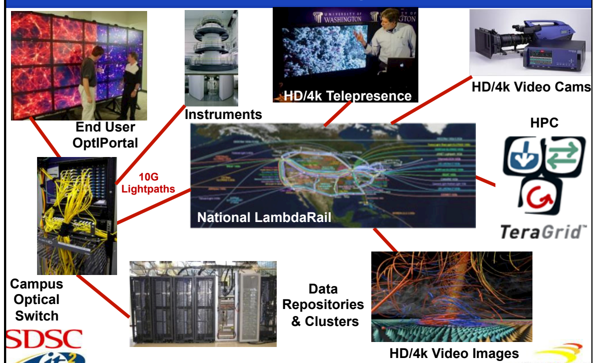
9

A High-Performance Campus-Scale Cyberinfrastructure: The Technical, Political, and Economic

Presentation by Larry Smarr to the NSF Campus Bridging Workshop
October 11, 2010
Anaheim, CA

Dr. Larry Smarr
Director, California Institute for Telecommunications and Information Technology
Harry E. Gruber Professor,
Dept. of Computer Science and Engineering
Jacobs School of Engineering, UCSD
Follow me on Twitter: lsmarr

Academic Research "OptIPlatform" Cyberinfrastructure: An End-to-End 10Gbps Lightpath Cloud

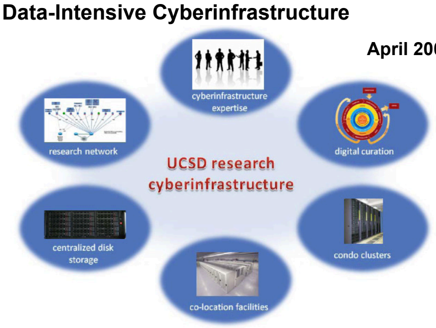


"Blueprint for the Digital University"--Report of the UCSD Research Cyberinfrastructure Design Team

- Focus on Data-Intensive Cyberinfrastructure

April 2009

No Data Bottlenecks --Design for Gigabit/s Data Flows



research.ucsd.edu/documents/rcidt/RCIDTReportFinal2009.pdf

Broad Campus Input to Build the Plan and Support for the Plan

- Campus Survey of CI Needs-April 2008
  - 45 Responses (Individuals, Groups, Centers, Depts)
  - #1 Need was Data Management
    - 80% Data Backup
    - 70% Store Large Quantities of Data
    - 64% Long Term Data Preservation
    - 50% Ability to Move and Share Data
- Vice Chancellor of Research Took the Lead
- Case Studies Developed from Leading Researchers
- Broad Research CI Design Team
  - Chaired by Mike Norman and Phil Papadopoulos
  - Faculty and Staff:
    - Engineering, Oceans, Physics, Bio, Chem, Medicine, Theatre
    - SDSC, Calit2, Libraries, Campus Computing and Telecom

Why Invest in Campus Research CI?

- Competitive Advantage
- Growing Campus Demand
- Leadership Opportunities
- Complementarity With National Programs
- Preservation of Digital Knowledge is Vital to the Scientific Method
- Institutional Obligations to Preserve Data:
  - OMB Circular A-110/CFR Part 215
  - Preserve Data for 3 Years After Grant
- Escalating Energy/Space Demands
- Integration with UC-Wide Initiatives

SDSC it² OptIPuter

Why Invest Now?

- Doing More With Less
- Exploit UCSD's Under-Developed Synergies
- SDSC Deployment of the Triton Resource
- The Longer We Wait
  - The Harder It Will Get
  - The More Opportunities Will Be Lost

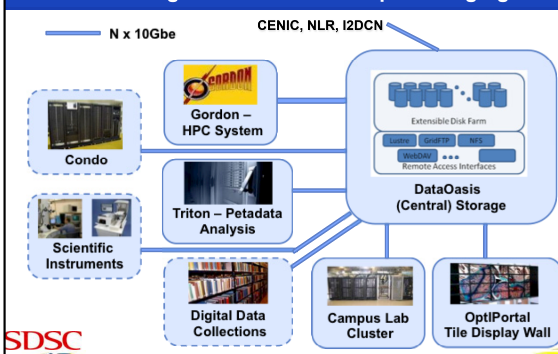
SDSC it² OptIPuter

Implementing the Campus Research CI Plan

- Cyberinfrastructure Planning & Operations Committee
  - Chancellor Fox Appoints Fall 2009
  - Mission: Develop a Business Plan for the Self-Sustaining Operations of a Research Cyberinfrastructure
  - Report Delivered April 2010
- Business Plan Components
  - Direct Campus Investment
  - Energy Savings
  - PI Contributions
  - ICR
  - Separate Budgets for Startup and Sustaining
- Create an RCI Oversight Committee

SDSC it² OptIPuter

UCSD Campus Investment in Fiber and Networks Enables High Performance Campus Bridging CI



Source: Philip Papadopoulos, SDSC, UCSD

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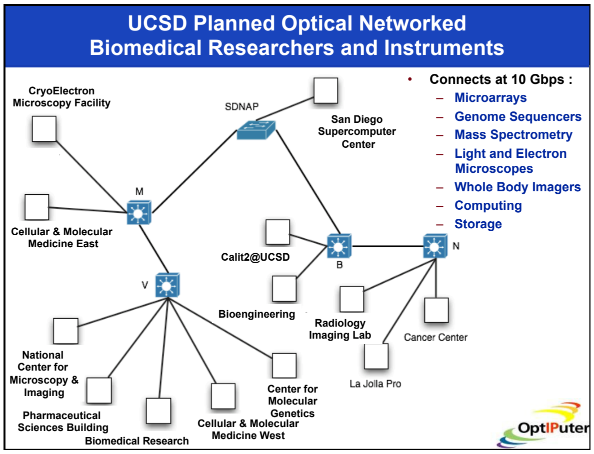
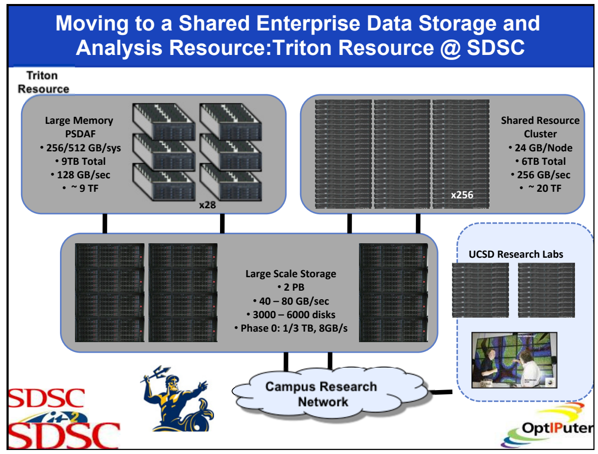
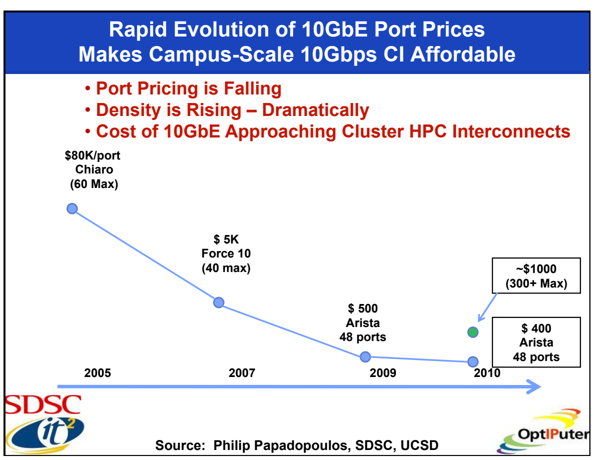
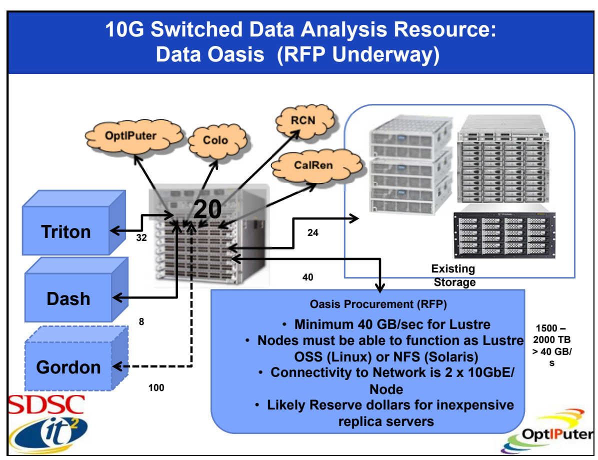

UCSD Planned Optical Networked Biomedical Researchers and Instruments
Connects at 10 Gbps :
Microarrays
Genome Sequencers
Mass Spectrometry
Light and Electron Microscopes
Whole Body Imagers
Computing
Storage
CryoElectron Microscopy Facility
SDNAP
San Diego Supercomputer Center
M
Cellular & Molecular Medicine East
Calit2@UCSD
B
N
V
Bioengineering
Radiology Imaging Lab
Cancer Center
National Center for Microscopy & Imaging
Center for Molecular Genetics
La Jolla Pro
Pharmaceutical Sciences Building
Cellular & Molecular Medicine West
Biomedical Research
OptIPuter


Moving to a Shared Enterprise Data Storage and Analysis Resource:Triton Resource @ SDSC
Triton Resource
Large Memory PSDAF
• 256/512 GB/sys
• 9TB Total
• 128 GB/sec
• ~ 9 TF
x28
Shared Resource Cluster
• 24 GB/Node
• 6TB Total
• 256 GB/sec
• ~ 20 TF
x256
Large Scale Storage
• 2 PB
• 40 – 80 GB/sec
• 3000 – 6000 disks
• Phase 0: 1/3 TB, 8GB/s
UCSD Research Labs
Campus Research Network
SDSC
OptIPuter


Rapid Evolution of 10GbE Port Prices Makes Campus-Scale 10Gbps CI Affordable
• Port Pricing is Falling
• Density is Rising – Dramatically
• Cost of 10GbE Approaching Cluster HPC Interconnects
$80K/port Chiaro (60 Max)
$ 5K Force 10 (40 max)
$ 500 Arista 48 ports
~$1000 (300+ Max)
$ 400 Arista 48 ports
2005
2007
2009
2010
SDSC
Source: Philip Papadopoulos, SDSC, UCSD
OptIPuter


10G Switched Data Analysis Resource: Data Oasis (RFP Underway)
OptIPuter
Colo
RCN
CalRen
20
Triton
32
24
Dash
40
8
Gordon
100
Existing Storage
Oasis Procurement (RFP)
• Minimum 40 GB/sec for Lustre
• Nodes must be able to function as Lustre OSS (Linux) or NFS (Solaris)
• Connectivity to Network is 2 x 10GbE/ Node
• Likely Reserve dollars for inexpensive replica servers
1500 – 2000 TB
> 40 GB/s
SDSC
OptIPuter

High Performance Computing (HPC) vs. High Performance Data (HPD)

Attribute	HPC	HPD
Key HW metric	Peak FLOPS	Peak IOPS
Architectural features	Many small-memory multicore nodes	Fewer large-memory vSMP nodes
Typical application	Numerical simulation	Database query Data mining
Concurrency	High concurrency	Low concurrency or serial
Data structures	Data easily partitioned e.g. grid	Data not easily partitioned e.g. graph
Typical disk I/O patterns	Large block sequential	Small block random
Typical usage mode	Batch process	Interactive

Source: SDSC

Grand Challenges in Data-Intensive Sciences

October 26-28, 2010

San Diego Supercomputer Center , UC San Diego

Confirmed conference *topics* and speakers :

- ***Needs and Opportunities in Observational Astronomy*** - **Alex Szalay, JHU**
- ***Transient Sky Surveys*** – **Peter Nugent, LBNL**
- ***Large Data-Intensive Graph Problems*** – **John Gilbert, UCSB**
- ***Algorithms for Massive Data Sets*** – **Michael Mahoney, Stanford U.**
- ***Needs and Opportunities in Seismic Modeling and Earthquake Preparedness*** - **Tom Jordan, USC**
- ***Needs and Opportunities in Fluid Dynamics Modeling and Flow Field Data Analysis*** – **Parviz Moin, Stanford U.**
- ***Needs and Emerging Opportunities in Neuroscience*** – **Mark Ellisman, UCSD**
- ***Data-Driven Science in the Globally Networked World*** – **Larry Smarr, UCSD**

Campus Bridging Taskforce
0^{th} Draft of Recommendations

Craig Stewart
Chair, ACCI Campus Bridging Taskforce
Executive Director, Pervasive Technology Institute
Associate Dean, Research Technologies
Indiana University

So there is no doubt what we mean…

- From the EDUCAUSE CCI / CASC REPORT:
- *Cyberinfrastructure consists of computational systems, data and information management, advanced instruments, visualization environments, and people, all linked together by software and advanced networks to improve scholarly productivity and enable knowledge breakthroughs and discoveries not otherwise possible.*
- Note #1: The issue of cyberinfrastructure vs. research infrastructure is interesting … and takes some thought
- Note #2: Nothing in the above creates boundaries on what is CI based on who owns it

Bridging from what to what?

- Desktop or lab to national infrastructure (both compute and data oriented approaches)
- Campus networks to state, regional, and national
- Campus-to-campus and campus-to-state/regional approaches
- Wherever to commercial service on demand providers
- In terms of the Branscomb pyramid - how do we create and enable connections within and between levels of the computational pyramid; create appropriate connections with data sources; and enable researchers to move their activities manageably (and ultimately transparently) between levels as appropriate to meet researcher needs? (Or as Larry Smarr put it ‘how do we get people out of their digital foxholes?’)

Who is the audience?

- NSF
- Campus decision makers
- Scientific communities
- Individual researchers

Overarching basic findings

- The nation's existing cyberinfrastructure – broadly considered – is not adequate to meet the needs of the current U.S. science and engineering community
- We are not using the existing cyberinfrastructure effectively or efficiently enough, due at least in part to the barriers of migration between campus and national CI
- CF21 presents a great vision for what cyberinfrastructure within the U.S. should be – the hard work is achieving the vision
- These challenges cannot be met with NSF monies alone but they are unlikely to be met without NSF monies to coordinate national investment
- Coordinated effort is required if the U.S. is to continue as a global leader in cyberinfrastructure / networking

Identity management

- Identity management is one of the critical obstacles to more effective use of the nation's human resources and CI assets and effective campus bridging
- Campuses should when practical become members of InCommon and adopt use of InCommon (SAML) credentials
- Service providers should build in authentication mechanisms based on use of InCommon credentials
- There are third-party providers who can provide credentials for campuses that cannot easily become InCommon members
- NSF has funded creation of an "InCommon Roadmap"

Data and networking

- The new capabilities of digital instruments (such as next-generation sequencers) will create requirements for dramatic changes in campus networking – data production rates are growing faster than networking
- Overprovisioning the entire campus network is impractical
- Making effective use of all of the data now being created requires more eyes on the data than we currently have
- Even if all of the local problems were fixed, we could not move data around effectively on and off campus to manage and understand it effectively
- Data collected at universities (with and without NSF funding) are a national asset and should be managed and preserved as such, but storing everything is impossible

Key finding from another survey

- "Cyberinfrastructure resources at doctorate-granting institutions are substantially greater than at institutions that do not grant doctorates, according to new data from the biennial Survey of Science and Engineering Research Facilities, sponsored by the National Science Foundation (NSF). This is reflected both in networking capacity, reported here as network speed or bandwidth, and in computing capacity, characterized here by the number, type, and characteristics of the computing systems." (http://www.nsf.gov/statistics/infbrief/nsf10328/)

Recommendations - networking

- CIOs particularly and campus leadership generally should adopt new, targeted strategies for meeting intra-campus CI needs
- NSF should explicitly encourage incorporation of all needed network costs in Major Research Infrastructure proposals
- NSF should create a new program funding connections from campuses to nearest dynamic network provisioning services provider landing point
- NSF should continue research, development, and delivery of new networking techniques

Recommendations - data

- We must restore replicability to science and enable a 21st century workforce to use effectively all of the data we are collecting (indeed making that available widely is perhaps the best way to generate an excellent 21st century workforce)
- But we need a business model other than 'keep everything forever'
- NSF data policy is a starting point
- The NSF should support the creation of a national system for data retention – perhaps a system of repositories with non-TCP/IP interconnections
  - One way to meter use may be to require creation of high quality metadata as a prerequisite
  - Should leverage existing VOs and promote creation of new VOs
- Need to recognize value of data in perpetuity
- Clearly called for within CF21

Software – key findings

- There is a general lack of visibility with regard to resources that makes resources outside of one's local domain difficult to discover – discovering policies and negotiating access is worse
- CI support services and expertise are difficult to discover outside one's local domain
- Finding communities of users is difficult for CI providers
- Measuring effort spent on campus bridging and research computing is challenging; measuring impact is also difficult
- There is often no or little interoperability and coordination between institutional and project support infrastructures

Recommendations – software (and sometimes beyond)

- Establish a National CI Support Service – end to end CI solutions and support
  - Technology and project neutral
  - Minimum: provide CI training (with travel expenses) and recognition of support staff
  - Provide a feedback mechanism for gathering user experiences
- Establish a CI Blueprint
  - Consider NSF and CI of other federal agencies
- Encourage mature CI
  - Fund software as infrastructure (as and even more than already planned)
- NSF leadership is critical – as or more important than NSF $s

Findings – compute

- There is not enough
- Growth curve of demand and NSF budget make it clear NSF budget can't solve the problems

Recommendations - compute

- Economies of scale in computing are unequivocal
- Value of diversity and flexibility
- No single answer!!!! (at least for the foreseeable future)
- The recommendations on identify management, software, and support will improve 'ability to migrate' have as a natural side effect
- NSF should fund connections to on-demand providers to change price structure and fund support for scientific development and support of on-demand services
- NSF should continue investing in campus CI, expand investment in state-level CI, and reward 'greenness' in the process

A survey of cluster owners?

- National survey of NSF-funded PIs
  - Do you have your own cluster?
  - If so, why?
  - What would you have to get in order to happily give up the ability to touch your own cluster?

Campus leadership perspectives - findings

- Coordinated campus infrastructure is better than lack thereof
- There have been a number of institutional agreements; someone should read them all and try to make sense of them
- Incremental chipping away at budgets (and CI) is the lowest common denominator solution and thus easiest to settle on … and it's wrong [Note to self – Mitch D., Dresden]
  - There are economies of scale to be had in CI provisioning and support at the campus, state, national, and international levels
  - A campus with a CI strategy will produce newer or quicker insights than one without; the most effective approach engages campus intellectual leadership and campus advanced IT leadership

Campus leadership perspectives - recommendations

– NSF should fund studies of best practices in CI relative to campus governance and financial models
– Campuses should create a cyberinfrastructure master plan
  - This should be based on co-leadership of campus intellectual leadership, infrastructure providers, and faculty
  - Plans must place value on people (staff?) who can make advanced CI work
  - We (collectively) should be identifying and measuring metrics of impact [without letting the perfect be the enemy of the good enough]
    – Value = (realized benefit) / (total actual cost)

Campus leadership perspectives – recommendations (2)

– We are at a phase transition in CI driven by data creation capabilities and the growth rates of data and networking capabilities – a 'once in 20 years' change point
– NSF data policy, OMB Circular A-110/CRT part 215, NSF GPG changes create new opportunities for us. There's a key need for NSF to lead!
– Funding for research cyberinfrastructure
  - Funding should be separated from other (IT) infrastructure [at the campus level] and from research discovery [at the federal funding level]
  - We should all distinguish between those things that can be made commodities and that which must remain specialized
  - F&A recovery should be systematically reanalyzed and re-constructed
– If we believe that the most challenging problems in science and engineering require teams (VOs), then the reward structure for faculty must be changed to reward team work more than being the n+1th 'lone ranger'

International bridging

- The U.S. should be very involved in international standards setting and implementation – NSF should give priority to funding activities that incorporate adherence to international standards
- NSF should continue research in international networking and supporting research that requires international networking – particularly international access to sensor nets across the globe and internationally shared networks
- The U.S. generally should be cognizant of the issues of physical possession of data

National strategies & competitiveness

- U.S. national competitiveness in science and engineering is under greater threat today than in decades
- Cyberinfrastructure and 21st century workforces are just not catchy but also important – relationship to brain wiring
- Observations of Machiavelli (Florence), Napoleon (England), Diamond (several) should be remembered – is this a case of Hannibal ad portas?
  - [Are the gates the U.S. border, or the border between where we are now and a tipping point in the global environment, or the border between our collective student enrollments and those of the University of Phoenix]
- Hannibal's criticism of the Romans
- If we really believe what we say about VOs, changing nature of science, and global warming, then we really must change the reward structures within US academia so that the incentives to individual faculty match incentives that serve the best interests of humankind, the U.S., and U.S. academia

Documents to be produced

- Workshop reports
  - Data and networking workshop (Jent & Almes)
  - Software workshop report (Welch)
  - Campus leadership engagement (Dreher)
- Other Documents
  - A Roadmap for InCommon and NSF Cyberinfrastructure (Welch / Barnett)
  - Taskforce Final Report
  - Documents likely to be published through print-on-demand service and as downloadable .pdfs

Final thought

- Screw the low hanging fruit. We should want the best fruit.

Thanks

- Thanks to all who have contributed input (position papers, attended workshops, filled out survey)
- Thanks especially to taskforce members
- NSF for grant support:
  - 0948142 (Jent) for data / NW workshop
  - 0829462 (Wheeler) for software issues workshop
    - NB: report "Cyberinfrastructure Software Sustainability and Reusability: Report from an NSF-funded workshop" is available online as a .pdf at: http://hdl.handle.net/2022/670
  - 1059812 (Dreher) for Campus Leadership workshop
- RENCI – underwriting Campus Leadership workshop
- Von Welch – writing
- Pervasive Technology Institute – funding final push of writing
- Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the NSF.

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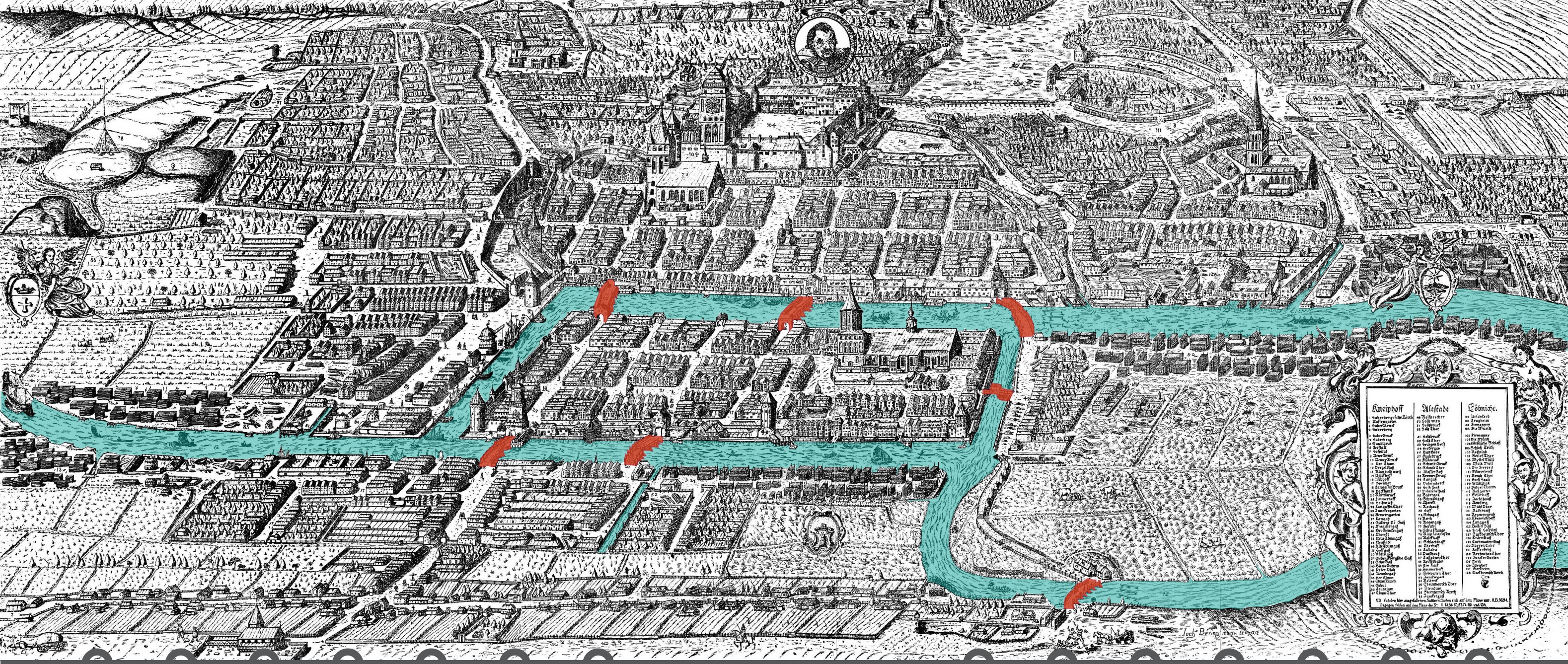

The cover image is based on Joachim Bering's etching of the city of Königsberg, Prussia as of 1613 (now Kaliningrad, Russia). Seven bridges connect two islands in the Pregal River and the portions of the city on the bank. The mathematical problem of the Seven Bridges of Königsberg is to find a path through the city that crosses each bridge once and only once. Euler proved in 1736 that no solution to this problem exists or could exist. This image appears on the cover of each of the Campus Bridging Workshop reports.

The goal of campus bridging is to enable the seamlessly integrated use among: a scientist or engineer's personal cyberinfrastructure; cyberinfrastructure on the scientist's campus; cyberinfrastructure at other campuses; and cyberinfrastructure at the regional, national, and international levels; so that they all function as if they were proximate to the scientist. When working within the context of a Virtual Organization (VO), the goal of campus bridging is to make the 'virtual' aspect of the organization irrelevant (or helpful) to the work of the VO. The challenges of effective bridging of campus cyberinfrastructure are real and challenging – but not insolvable if the US open science and engineering research community works together with focus on the greater good of the US and the global community. Other materials related to campus bridging may be found at: https://pti.iu.edu/campusbridging/