Project Summary: *Extending Campus Networks and the Research@UEN Optical Network in Support of the Utah EPSCoR Initiative*

Utah is one of two new EPSCoR cohorts this year. Externally sponsored research and training are highly concentrated among the three research universities in the state – the University of Utah (UU), Utah State University (USU), and Brigham Young University (BYU). Initial state EPSCoR activities have focused on the development of the requisite administrative infrastructure and the state Science and Technology Plan. However, faculty from all three institutions already have collaborated on two initial RII proposals this fall – a Track 1 proposal to enable transformative research into pressing environmental and energy issues impacting this relatively youthful, rapidly growing state and a Track 2 proposal targeting research strengths in computational material science in collaboration with the North Dakota cohort.

In this context, we propose two tightly integrated approaches to address the cyber connectivity needs of Utah EPSCoR and other meritorious researchers at the three research universities. These leads will be coordinated carefully by the project management team, which includes the Track 1 and 2 PIs, the state EPSCoR director, and respective campus cyberinfrastructure (CI) representatives. By leveraging the facilities, experience, and statewide reach of the Utah Education Network (UEN), we are in a highly scalable position to extend these new network capabilities, as needed, to support EPSCoR-related research, STEM, and other outreach activities engaging faculty, educators, and students across Utah higher and K-12 education.

The first approach will extend advanced network capabilities (initially provisioned at an aggregate bandwidth of 30 Gbps) of the *Research@UEN* optical network to BYU to complement those capabilities currently under development for the other two institutions. *Research@UEN* has been under development for over a year, and the initial design focused on a Salt Lake City metropolitan optical network and a fiber-based spur to Logan in support of UU and USU, respectively. This proposed southward extension to Provo for BYU not only will enhance the level of collaboration and computational engagement among the three EPSCoR institutions, but also will greatly expand their capabilities to collaborate with researchers elsewhere in the country and abroad through high-speed access to the national R&E networks, Internet2 and National LambdaRail (NLR).

The second approach will make strategic investments in local campus networking capabilities to better enable EPSCoR research and STEM activities at each of the three institutions. In each case, we are working to establish a standard of Gigabit Ethernet (1 Gigabit per second or 0.4 Terabytes per hour) as the threshold for researcher attachment to local area networks and with sufficient backbone uplink capacity (10 Gigabit Ethernet) to support the shared, congestion-minimized use by faculty and other researchers on the same local network. This capability will enable high-speed file transfer to/from local computing and storage capabilities, remote visualization of large data sets, high-quality videoconferencing (e.g., High Definition), and other state-of-the-art remote collaboration tools. Furthermore, the local high performance computing and research data storage capabilities on all three campuses will be closely integrated into these upgrades.

Intellectual Merit

These network improvements are essential for Utah's academic researchers to move vast amounts of research data, to establish short-lived experimental networks, to lead next generation network development efforts, and to collaborate with colleagues at peer institutions and national laboratories. *Research@UEN* is mission critical for the three research universities in Utah to compete effectively in recruiting and retaining faculty research leaders. The optical network also

enables the universities in Utah to share CI resources. An example from the recent Track 1 proposal is the Utah Environmental Data Repository, a Petascale data store that will enable interdisciplinary, discovery-based research incorporating a wide array of experimental observations, GIS data, and simulation data sets.

Broader Impacts

Utah's combined plan of research, equipment, and workforce development provides the framework necessary to launch a multi-institutional effort that will propel Utah out of EPSCoR status and result in a significant impact on the state through research into the science behind local issues and through enhanced STEM training of its youth. *Research@UEN* and the campus network upgrades will contribute to economic development in Utah through the training of CI- and networking-fluent students and staff and the facilitation of faculty research collaborations with local companies. We envision expanding this capability to other locations to provide a comprehensive optical networking infrastructure for all institutions of higher education as well as to key remote research sites that leverage the wide variety of opportunities for world-class field science (e.g., ecology, astronomy & astrophysics, geology, paleontology, atmospheric science) present in this state.

Integrating Research and Education

The combined investments in optical and campus networking proposed here will be made through both the state education network (UEN) and the campus organizations already supporting research and education networking. UEN has a strong history of supporting educational tools and shared classes and curricular materials. As such, it provides a natural platform for increased outreach and STEM activities conducted over UEN network, which connects of all of Utah's public K-12 schools.

Integrating Diversity

These network enhancements and the interconnection of the three campus research optical network with the rest of UEN will facilitate the diversity efforts of the other research- and STEM-focused EPSCoR programs. As an example, two public institutions with large enrollments of underrepresented students, Salt Lake Community College (SLCC) and the College of Eastern Utah San Juan campus in Blanding are already connected via UEN. Further, the RII C2 project management team will coordinate closely with the state EPSCoR office and the other EPSCoR funded programs in the state on the roles that the enhanced network capabilities can play in supporting the overall diversity and workforce development objectives of Utah EPSCoR.

4. Project Description: *Extending Campus Networks and the Research@UEN Optical Network in Support of the Utah EPSCoR Initiative*

I. Status and overview

The Utah System of Higher Education consists of ten public colleges and universities, which include two major research/teaching universities, three metropolitan/regional universities, one state college, three community colleges, and a college of applied technology. Differentiated institutional missions focus college and university efforts on excellence, avoid duplication of programs, serve traditional and nontraditional students, and promote efficiency and accountability. A large private institution contributes to the state's educational portfolio. Brigham Young University (BYU), located in Provo, is a Carnegie-classified doctoral/research (STEM dominant, high research activity) university [1] sponsored by the LDS Church and has the largest student enrollment in the State.

The University of Utah (UU), Utah State University (USU), and BYU perform over 95% of externally sponsored research and training in Utah (Table 1). The UU, in Salt Lake City, ranks 28th nationally in the number of faculty (19) who are National Academy members; the 2008 Nobel Prize in Physiology or Medicine was co-awarded to a UU faculty member (Mario Capecchi); a 2009 Nobel Laureate in Chemistry (V. Ramakrishnan) was a former UU colleague. USU, in Logan, is Utah's land-grant and space-grant university. USU's research funding total ranks among the top ten of non-medical universities in the West. USU's College of Education & Human Services is third in the nation in externally funded research, and USU is third in the nation in percentage of federal engineering research among public universities with more than $20 million in research. BYU is one of the nation's largest private institutions of higher education and is tenth nationally in the number of graduates who earn doctoral degrees. BYU is first in invention disclosures, patent applications, licenses and options executed, and startup companies per $1 million of research expenditures.

Table 1. Summary of research expenditures and student populations across Utah's three research universities. Since 1995, Utah's ranking for NSF funding by state has fallen from 24th to 28th.

Institution	FY2007[1]		FY2006[1]		Students (2008)[2]
	Total/rank	NSF/rank	Total /rank	NSF/ rank	
UU	$247,794/ 70	$20,925/ 52	$248,168/ 70	$19,935/ 52	21,526/ 6,685
USU	$138,065/ 108	$5,764/ 113	$138,670/ 106	$7,220/ 113	23,900/ 2,854
BYU	$26,653/ 214	$5,361/ 121	$25,973/ 215	$4,654/ 121	34,185/ 3,075
Totals	$412,512	$32,050	$412,811	$31,809	79,611/ 12,614

[1] Totals are in 1,000's of dollars; [2] Student counts are a) total headcount and b) graduate student headcounts including first-time Master's and Ph.D., professional, law, and medical students.

Research collaboration is an important aspect of our culture and already exists among the research universities and to some degree also with other state four-year and community colleges. USU, Weber State, and the UU have recently formed a University Research Institute for joint engineering research and education programs with Hill Air Force Base in Ogden, Utah. The UU and BYU regularly collaborate in combustion, gasification, and related research. As part of its land-grant outreach mission, USU maintains satellite campuses in rural Utah and supports members of the Ute Nation in the Uinta Basin and the Navajo Nation in its Blanding Center.

A clear vision for one aspect of Utah's future research has been articulated via the Utah Science and Technology (USTAR) Initiative [2], in which funds appropriated separately by the Utah

Legislature serve as seed grants for developing the science and technology to enable research groups to develop potentially commercial products and services. The target industries for the USTAR effort include biomedical sciences, alternative energy, nanotechnology, smart buildings, digital media and imaging technologies, and carbon sequestration.

Utah's K-12 population comprises ~20% of the total population and is projected to increase to 800,000 by 2020. In addition, underrepresented populations are rapidly increasing in Utah. STEM performances among most minority populations and much of the non-minority population are unacceptably low. Utah is experiencing a cultural, economic, and demographic transformation [3] that poses significant challenges for the K-16 education system and the state budget, but also creates potential opportunities to harness a youthful population involved in developing a new economy and environment in Utah. About 95% of Utah's high school students elect to attend college in Utah, providing us with a growing group of students to target with EPSCoR programs.

The universities in Utah long have recognized the importance of developing and maintaining a robust cyberinfrastructure (CI) to enhance faculty research collaboration and competitiveness. A state CI council meets regularly with representatives from Weber State, Utah Valley, and Southern Utah Universities in addition to UU, USU, and BYU. One university (UU) has an active, standing campus CI council that includes top administrators, CI-cognizant IT professionals, and key faculty engaged in computationally enhanced research. Top CI priorities in the state include increasing computational capacity for research, research data storage and curation, and additional bandwidth for advanced networking.

A project with significant potential for statewide and regional CI impact is the UU's new off-campus data center now being renovated in a former industrial facility (74,000 square feet) near downtown Salt Lake City. The facility will support both the long-term enterprise and CI-based computing and storage needs of the UU as well as partners around the state. Utah has some of the lowest industrial electric power rates in the country, and the UU currently pays less than five cents per kilowatt-hour – a factor that may influence the co-location of systems from other states. This project is now in the design stage with readiness by early 2011. During the recent NSF Academic Research Infrastructure (ARI) call, the UU submitted a proposal for the needed physical and network infrastructure to support high performance computing (HPC) in this facility.

Utah is fortunate to have one of the longest standing and continuously supported state education networks in the country – the Utah Education Network (UEN), hosted at UU. UEN provides Internet connectivity for all public (K-12) and state-supported higher education in Utah. UEN operates a statewide backbone and locates its regional nodes in higher education facilities around the state. In addition to commodity Internet services, UEN has high-bandwidth (10-Gbps) connectivity to national research and education backbones, Internet2 and National LambdaRail (NLR). BYU connects to UEN via a Gigabit Ethernet link to utilize these advanced networks.

UEN has relied most recently on mostly 1 and 10 Gigabit-per-second backbone connections provisioned through telecommunications carriers. Several years ago the UU participated in the acquisition of a dark fiber segment from its campus to a major telecommunication node (Level 3) near the SLC airport and housing the regional Internet2 and NLR nodes. Spurred in part by the development of the off-campus data center and the need for additional high-speed connections, UEN and UU jointly began planning in 2008 for an metropolitan optical network in Salt Lake City. Located in the Cache Valley far from major Interstate and rail routes, USU long has long suffered from a dearth of telecommunications options and advanced services. In August, UEN – in close coordination with UU and USU – submitted an NSF ARI proposal to develop the SLC metropolitan optical network and to extend an optical network spur to the USU campus in Logan.

II. Results from Relevant Prior NSF Support

Steven Corbató (PI) – vBNS Connectivity for the University of Washington (CNS-9617039, T. Gray-PI). This award established OC-3c (155 Mbps) connectivity to the NSF-sponsored vBNS backbone in 1996. This connection also served a number of research institutions in the Pacific Northwest and Alaska, including a related award on which Corbató also was a co-PI, A High Performance Connection for the University of Idaho (CNS-9729710, G. Wilde-PI). More recently, he has collaborated with network research colleagues at the University of Utah on the development of a system and network emulation environment – Emulab/protoGENI, which serves as a primary software model for the GENI next generation Internet testbed (MRI: Evolutionary Development of an Advanced Distributed Testbed, CNS-0723248, J. Regehr-PI). In addition to serving as a frequent peer reviewer of CI-related proposals for both NSF and DOE, Corbató served on the Committee of Visitors for the CISE Division of Shared Cyberinfrastructure (the predecessor of OCI) in 2005.

James Ehleringer (co-PI) - Isotope ratio mass spectrometer for environmental research (DBI-0722598, 2007-2010). An isotope ratio mass spectrometer was purchased, installed, and is fully operational as part of SIRFER, an open recharge facility (http://sirfer.net). The instrument meets the research needs of laboratories on- and off-campus, and the lab provides significant education and outreach. Over the last 3 years, we trained 81 graduate students and post-doctoral associates from universities across the USA, Europe, and South America at our annual "Stable Isotope Ecology" course (http://stableisotopes.net). Our lecture and laboratory classes achieve diversity goals, averaging ~55% female and 15-20% under-represented groups. Intellectual diversity is broad, including anthropology, biology, ecology, geology, limnology, meteorology, and oceanography. The mass spectrometer purchased through this award is used by undergraduate students in two university classes annually and by students from roughly ten labs.

Larry Baxter (co-PI) – Advanced Combustion Engineering Research Center (ACERC)(ERC, 1986-1997, now self supporting) Larry Baxter is associate director of the ACERC, a graduated NSF ERC and one of the few to maintain both full NSF funding for the maximum tenure and to continue as a functional center well after NSF support terminated. Diversity and outreach efforts initiated by Dr. Baxter include the Fluid Fest and Global Innovent. The former was a four-year program that involved students from local high schools working on semester-long projects with college juniors and presenting results at a culminating, public festival. The latter involved students from China, Denmark, and the US working in teams on processes to address global climate change. Both engage students across broad social spectra and to help existing students develop appreciation and sensitivity to different cultures, backgrounds, and disciplines.

III. Active NSF RII Awards

As the state of Utah has become eligible for EPSCoR participation just within the last six months, Utah institutions only have been able to submit proposals under the Research Infrastructure Improvement (RII) program this year. Thus, no RII awards have been received to date. At the present time, we are operating under an initial EPSCoR planning grant (EPS 0940499 – R. Pugmire, PI). A pending RII Track 1 proposal to support transformative research addressing Utah's pressing environmental and energy issues was submitted in October 2009 under the leadership of J. Ehleringer. An RII Track 2 proposal focusing on computational material science and developed in partnership with the North Dakota cohort will be submitted in November 2009 (state PI: J. Facelli).

IV. RII C2-enabled Research and Education

We propose two integrated approaches to address the cyber connectivity needs of Utah EPSCoR and other meritorious researchers at UU, USU, and BYU. These investments will be coordinated carefully by the project management team (see the Management Plan section) in coordination with the Utah CI Council and corresponding campus CI representatives. By leveraging the facilities, experience, and statewide reach of UEN, we are in an eminently scalable position to extend these capabilities as needed and with future funding to reach researchers, educators, and students across Utah higher and K-12 education.

The first approach will extend optical network capabilities (initially provisioned at an aggregate bandwidth of 30 Gbps) to BYU to complement those capabilities currently under development for UU and USU. This step not only will enhance the level of collaboration and computational engagement among the three EPSCoR institutions, but also will greatly expand their capabilities to collaborate with researchers elsewhere in the country and abroad through access to the national R&E networks.

The second approach will be to make strategic investments in local networking capabilities in support of EPSCoR research and STEM activities at each of the three campuses. In each case, we are working to establish a standard of Gigabit Ethernet (1 Gbps – the equivalent of a maximum of 0.4 Terabytes of data per hour) as the requisite level for researcher attachment to local area networks and with sufficient uplink capacity (10 Gigabit Ethernet) to support the shared, congestion-free use by faculty and other researchers on the same local network. The provisioning of full-duplex Gigabit Ethernet to the desktop enables high-speed file transfer to/from local computing and storage capabilities, remote visualization of large data sets, high-quality videoconferencing (e.g., High Definition), and other state-of-the-art remote collaboration tools.

A. *Research@UEN* optical network extension for Brigham Young University

As the southward extension of the *Research@UEN* optical network from Salt Lake City, we will upgrade substantially the existing research networking capabilities of the Utah Education Network (UEN) in support of BYU in Provo. The objective is to deploy a facilities-based optical network under UEN provisioning and operational control to link BYU to UU and USU, to the UU's new off-campus data center, and to the Internet2 and National LambdaRail (NLR) national research networks. As noted earlier, UEN has submitted a pending NSF ARI proposal to extend these same capabilities to UU and USU, so those needs are not addressed in this proposal.

This network will enable the rapid provisioning of dedicated bandwidth in support of individual research activities and research-oriented high performance computing while existing UEN connections – provisioned through commercial carriers - will continue to support the typical commodity Internet traffic loads for these institutions. The wider deployment of optical networking connections is viewed as critical to continue these universities' ability to collaborate aggressively and to share large volumes of data with colleagues across the country and the globe. With similar optical networks now either in operation or under development in most other states, *Research@UEN* is essential to the three Utah research universities' ongoing research competitiveness and collaborative capabilities.

A key benefit of *Research@UEN* will be to establish optical connectivity for research applications to the Utah off-campus data center, now in the design stage of a renovation process targeted for completion by early 2011. This data center – located in a former industrial facility south of downtown Salt Lake City and along a major fiber corridor – will consolidate the UU's

significant HPC activities and related research computing efforts into a single dedicated facility. In addition, it is envisioned that the HPC/CI facility in this data center will serve as a statewide CI center for research collaborators at institutions around the state. As an example, the Petabyte-scale data storage facility envisioned for the Utah Environmental Data Repository in the concurrent Track 1 proposal will be easily accommodated in this new facility.

The renovated network will be based on single pairs of fiber optic cable, which will be illuminated with dedicated optical electronics (optronics) with an aggregate capacity of at least 800 Gigabits per second (Gbps). Under the funding envisioned in this RII C2 proposal, we propose to configure this network by lighting sufficient wavelengths at the outset to support identified HPC and other CI related applications for BYU. Additional applications and anticipated growth in existing applications over time may be addressed through the lighting of additional wavelengths, which then can be procured at incremental cost. We expect that initial base service on the *Research@UEN* optical network will be 10-Gigabit Ethernet. However, we will mandate that the optronics technology ultimately selected support the emerging high-speed Ethernet standards at 40 and 100 Gbps as well as Fibre Channel connections (1 and 2 Gbps initially and eventually 4 and 8 Gbps) for distributed storage applications.

Currently, the University of Utah, which hosts one of the principal UEN backbone nodes, is connected to UEN via 10 Gigabit Ethernet. Utah State's connection to UEN is delivered via a single 10 Gigabit Ethernet connection from Logan to the Salt Lake City node. Notably, both universities' current connections carry both commodity (that is, directed toward the commercial Internet) and research (directed toward Internet2, NLR, ESnet, etc.) traffic. BYU has a single Gigabit Ethernet link to UEN, but its use is primarily devoted to research applications as BYU maintains separate commodity (general) Internet arrangements. The *Research@UEN* network will establish the following benefits for researchers at both universities:

- Dedicated research network connections for both universities
- Ability to interface researchers directly with new national research network offerings for short-term, point-to-point connections (e.g., Internet2 ION, formerly the Dynamic Connection Network)
- Scalability in both network speed and circuit multiplicity
- Ability to partition experimental research (e.g., network protocol research) traffic from commodity and more production research (e.g., computational chemistry data sets) traffic

Research@UEN will include an optical network ring in the Salt Lake City metropolitan area to provide research connectivity among the main campus of the UU, its off-campus data center, the Level 3 Communications telecommunications point of presence including the facility housing the regional Internet2 and NLR nodes, and other research partners in the vicinity (e.g., the Salt Palace, the local convention center that will be the venue of Supercomputing 2012). The second phase of this project will extend a fiber-based optical network spur from Salt Lake City to the Cache Valley, the home of USU and a historically underserved area for telecommunications and data services availability.

In the third phase of *Research@UEN*, which is the subject of the wide area component of this proposal, UEN will establish a 50-mile regional optical spur from Salt Lake City to Provo, Utah in support of the EPSCoR research and STEM activities at BYU. On the basis of recent productive discussions with a state government partner, the Utah Department of Transportation (UDOT), we will be able to acquire – at no additional cost to this proposal – the long-term rights to a pair of dark optical fiber already provisioned in UDOT highway conduit. This fiber segment will span between the highway (I-15) intersection closest to the planned *Research@UEN* optical

node at the new UU data center and the point where UDOT's fiber network closest approaches the BYU campus. A map showing this extension in context with other *Research@UEN* segments is presented in Figure 1. It should be noted that UDOT and BYU already collaborate on transportation research projects conducted on the BYU campus

To complete the Salt Lake-Provo optical extension, we will need to acquire fiber laterals in both Salt Lake City and Provo and to provision two nodes of the planned optronics systems at the UU new data center and BYU. For the budgetary purposes of this proposal, we have proposed deploying Cisco 15454 optronics as this was specified for the other segments of the *Research@UEN* network after receiving competitive quotes this summer. Financial details of this design are included in the Budget Justification section. Due to the relatively short distance on this span, we do not anticipate having to deploy amplification or signal regeneration at any intermediate point on this span. However, we are designing for the options of a) inserting an add/drop capability in Orem, Utah (close to BYU) for Utah Valley University and b) also extending the network south along the I-15 corridor to permit the ultimate attachment of Southern Utah University in Cedar City, Dixie State College in the rapidly growing St. George/Washington County area of southwestern Utah, and the state disaster recovery data center in Richfield.

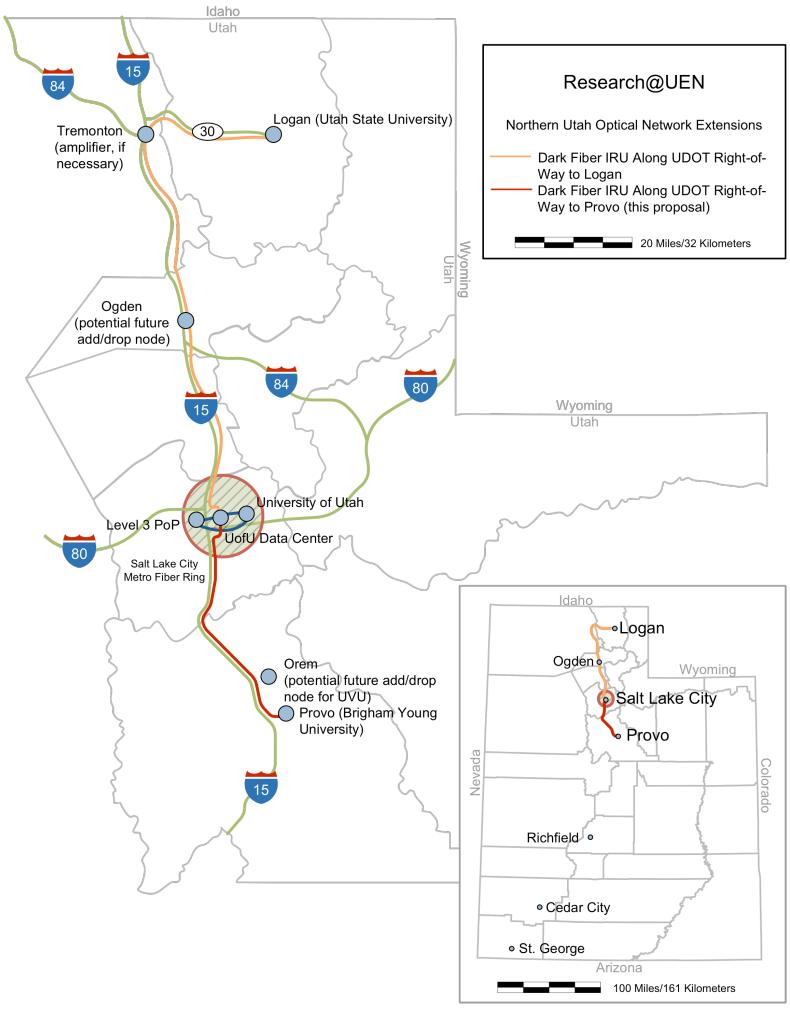

Figure 1: Maps showing the geographic extent of the fiber-based *Research@UEN* optical network. The Salt Lake City-Provo segment proposed here to connect BYU is shown in red.

A future objective for *Research@UEN* will be the completion of a fully redundant fiber rings linking Salt Lake City, Logan, and Provo. This step will require the location (and potential construction with partners) of available dark fiber through the rugged Sardine Canyon route (US 89/91) south of Logan and a redundant fiber path between Salt Lake City and Provo, but these steps are beyond the budget and scope of this proposal. However, we are very encouraged by the level of support for this endeavor demonstrated to date by our state government partners.

The state of Utah has been a national leader in research networks, state networks, and high performance computing. In late 1969, the UU's Computer Science Department became the fourth node (and the first outside California) on the ground-breaking ARPANET, the network that is viewed today as a key predecessor of the Internet. UEN stands as an exemplar in the deployment of shared network infrastructure in support of education and research across the state. The proposed extension of the *Research@UEN* network represents the next step in the linked evolution of advanced network capabilities, research IT infrastructure, and broader educational technology for teaching and outreach.

As an example, this type of fungible, partionable network is viewed as critical for advancing the national leadership role in network research played by the Flux Research Group at UU. Its Emulab project [4] has already had a strong impact on research and education in computer networking and distributed systems: over 2,600 researchers, educators, and students from more than 370 institutions around the world have used the facility at the University of Utah. In addition, over two dozen sites use the software produced by the Emulab project to run testbeds of their own. Over two hundred and fifty papers have been published based on experiments done on the Utah facility, and classes have been taught at dozens of universities that made use of Emulab based testbeds. A strong focus of the current Emulab work is to grow it to fulfill the NSF GENI (Global Environment for Network Innovation) vision: an environment for networking research that spans the country, and enables entirely new ideas for how the next instantiation of the Internet and other networks should be designed and built. This project, called ProtoGENI [5], is one of the core projects in the national GENI effort: it is a *control framework*, leading integration for projects from many institutions as well as providing a nationwide prototype backbone through a partnership with Internet2.

B. Network Upgrade in support of Research at the University of Utah

The UU campus and its medical center maintain a large, complex network that supports all academic, research, medical buildings and other facilities on the main campus in Salt Lake City. This network has direct extensions to remote University of Utah campuses, clinics, and the Utah TeleHealth Network. The campus network backbone is a redundant 10 Gigabit Ethernet fabric based on Cisco and Foundry hardware. This core supports all buildings on campus and peers directly with UEN in two geographically distinct locations. Over the next two years, the UU network backbone will expand to include the new downtown data center via the metropolitan optical network with multiple 10-Gbps wavelengths.

On campus, the network backbone connects all buildings through a network distribution layer and a network access layer. Within the buildings, the access layer comprises local area networks that are a mixture of campus maintained services to the nearest wall jack supporting the end user and individual department maintained networks. Most of the department LAN networks and portions of the central campus maintained ports are in need of upgrades. Over 80% of the ports on the campus access layer infrastructure still only support 100 Mbps (Fast Ethernet) connections. Some areas contain computationally intensive researchers who routinely move large data sets.

Many of the departments have growing real-time collaboration needs with video and voice. The University of Utah is attempting to solve some of these upgrade issues and requirements by strategically placing Gigabit Ethernet ports through switch upgrades. These ports will accommodate groups with large data requirements and simultaneous needs of real-time collaboration. The UU Office of Information Technology is actively working with departments to identify the greatest need and provide or supplement research groups with requirements. The Office of Information Technology is simultaneously trying to provide base level of network service and pre-position the users of the network to take advantage of upcoming technologies. Figure 2 presents an architectural diagram of the UU campus network.

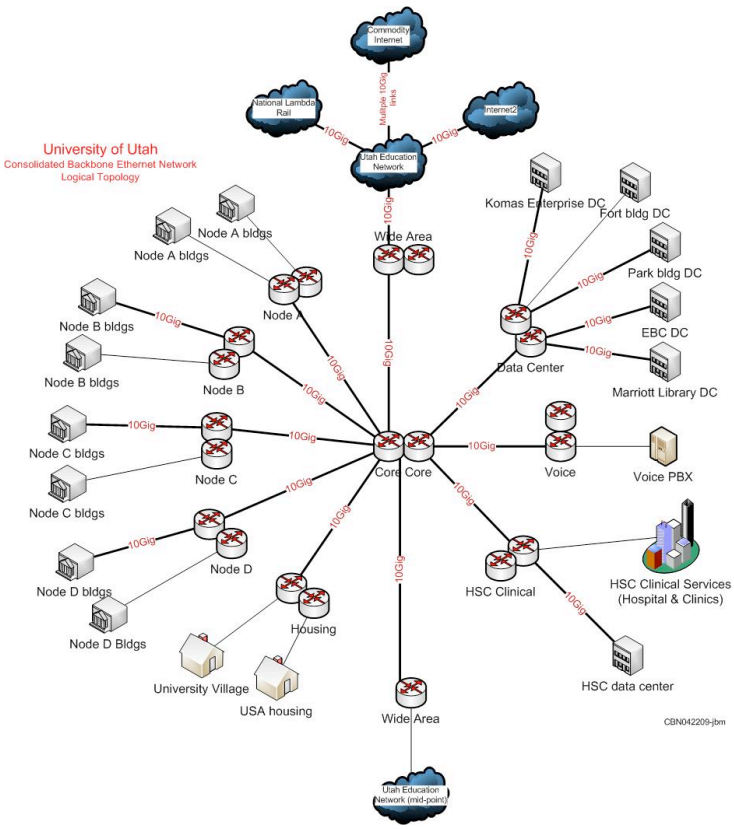

Figure 2: Current UU campus network backbone and edge architecture with mixture of 1 Gbps and 10 Gbps building switch uplinks.

In order to sustain the continued exponential growth of the UU's campus network, a robust cable plant infrastructure is necessary. For many years, the UU has worked to bring the campus cabling infrastructure up to a consistent standard that supports both current and new network technologies. The University has successfully deployed Category 5e structured cabling to approximately 85% of the buildings. The University of Utah is continuing this build-out and is also implementing Category 6e and Category 6a standards for new building projects. This structured cabling allows delivery of Gigabit bandwidths to the desktop in a cost-effective fashion. In addition to the copper cable plant, the University of Utah has aggressively deployed air-blown (Sumitomo) fiber infrastructure. One of the first of its kind in the US, this air-blown fiber plant enables the quick deployment of large counts of fiber between buildings and to dedicated points on the campus. For specialized research needs, fiber technicians can deliver

dedicated resources to the desktop or to localized groups. When resources are no longer in service or additional fiber counts are needed, fiber technicians can easily remove the fiber from the conduit and either leave it empty or blow in higher counts of fiber. With new buildings and increased resource needs of research, this system allows for flexible growth.

However, the growth also dictates and requires higher density fiber patch racks and additional conduit. In support of EPSCoR research and STEM activities at the UU, we are proposing add more fiber racks as well as seven building switches (Cisco Catalyst 3750's) that will support up to 48 Gigabit Ethernet ports with two 10-Gigabit Ethernet uplinks to the backbone. The exact location of these switches will be coordinated through the project management team, which includes the PIs of the Track 1 and 2 proposals.

C. Network Upgrade in support of Research at Utah State University

The Center for High Performance Computing at USU (HPC@USU) currently maintains a separate network, the HPC Research Network (Research Network), which is used exclusively for research activities at the campus. This network hosts clusters, storage, servers, workstations, and other services necessary to support researchers across the University's colleges and departments. Researchers from the Departments of Mechanical & Aerospace Engineering, Biology, and Physics represent the heaviest users of the Network, and it is common for them to generate large datasets. For example, Mechanical & Aerospace Engineering faculty researchers perform computational fluid dynamic simulations producing large datasets that must be maintained and manipulated at different stages in the dataset's lifecycle. Within that lifecycle, a dataset may be filtered through any number of analytic tools, including data visualization tools. A dataset may be shared collaboratively among researchers within Utah State University or at another institution. And finally, the lifecycle of that dataset may require backup protection and long-term archiving. This scenario is similar for researchers in Biology and Physics and represents the growing trend across the University's colleges and departments. In particular, the amount of water related research from Civil and Environmental Engineering is growing rapidly and has begun to rival the amount of research data generated by Mechanical & Aerospace Engineering, Biology, and Physics. The Plant, Soils, and Climate researchers have increased needs to access, accumulate, and analyze data from other institutions to incorporate into their research – satellite weather and climate data being common examples. At this time, the Research Network has bandwidth and latency limitations that hinder the ability for researchers to generate, move, manipulate, and share datasets. This proposal will address the specifics of these limitations.

The Research Network currently uses an aging, fixed-port core backbone switch that primarily supports Gigabit Ethernet and is inadequate for deploying services widely in the HPC research environment. An example of one such service is high performance parallel storage. The ability to provision a high-performance, parallel file system across all the clusters as well as some key support servers and workstations is the only way in which HPC@USU can affordably offer this necessary tool with economies of scale. NFS servers, backup servers, cluster schedulers, and resource managers are other examples of services that need to be globally available within the environment. A core switch with an architecture that supports both port scalability and performance will allow global services to be offered consistently across the entire environment.

The current Research Network core supports a single 10 Gigabit Ethernet (10GE) uplink to the Campus Network, which for the moment provides the only path to a broader set of research resources such as Internet2 and national labs. Also, researchers have often expressed frustration at the time required to move and manipulate large datasets to and from the Research Network. The addition of a new Research Network Core, as well as additional 10GbE port modules for the

Campus Network, will allow an additional 10-Gbps uplink, thus providing the Research Network greater bandwidth to research resources beyond the Utah State campus. Further, the new Core will allow us to prepare for a future, dedicated path to these resources that will not burden the campus network.

Uplinks from the clusters to the existing Core consist of trunked Gigabit Ethernet (GigE) pairs and are inadequate to the task of moving datasets to and from different segments of the network. Uinta, one of HPC@USU's most heavily used clusters, is interconnected across two aging, fixed-port switches that provide isufficient bandwidth between cluster nodes. These two switches have a trunked pair of GigE ports as an uplink to the current core. This arrangement causes inconsistent latencies between cluster nodes as well as the inability to move and manipulate large research datasets. Replacing Uinta's two switches with a single switch connected via a pair of trunked 10-Gbps uplinks to the new core will give researchers the ability to use Uinta to its fullest potential. Wasatch, HPC@USU's newest cluster, has an adequate switch to interconnect the cluster nodes, but uses a pair of trunked GigE ports as an uplink to the current Core. This results in the same impediment in moving and manipulating large datasets. An upgrade to the Wasatch switch to support a pair of trunked 10GE uplinks will alleviate this issue.

HPC@USU also supports a visualization lab known as the Viz Lab. The current Viz Lab switch supports a single uplink back to the Research Network core. This switch is also an aging, fixed-port model that primarily supports GigE. Given these limitations, servers and workstations in the Viz Lab are limited to GigE and are often unable to consume datasets residing on the shared storage and support servers both within the Viz Lab and connected to the Research Network core. This limits the ability of researchers to use the latest forms of data visualization in their research. A new Research Network core, coupled with a new Viz Lab switch capable of a pair of trunked 10GbE uplinks and support for 10GbE to the key servers and workstations residing in the Viz Lab, will allow researchers to take grater advantage of visualization capabilities.

The overall architecture for the HPC@USU Research Network upgrade is displayed in Figure 3.

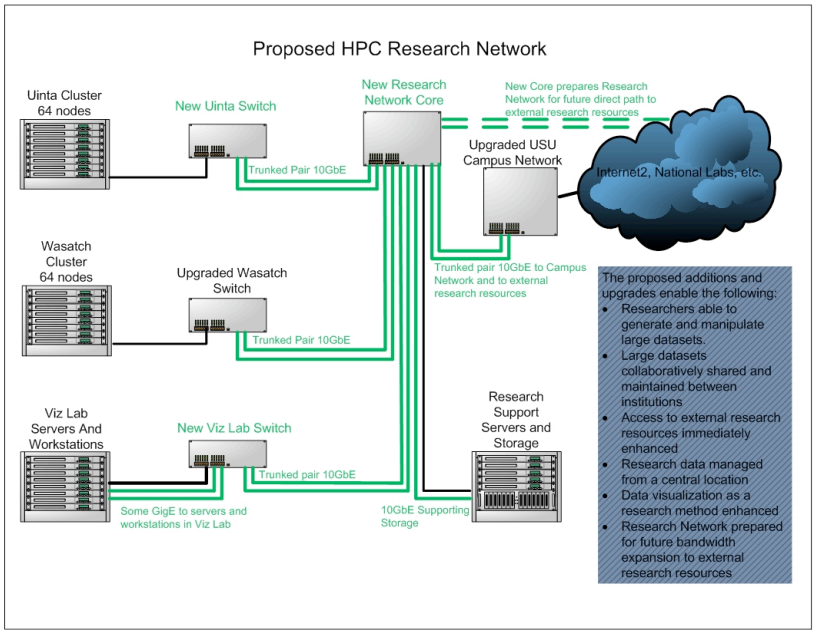

Figure 3: Proposed architecture for the USU Research Network supporting computational faculty and high performance computing

D. Network Upgrade in support of Research at Brigham Young University

BYU envisions further collaboration and research effectiveness as the Research@UEN optical network is extended to the main BYU campus in Provo. Currently, the University enjoys a general UEN connection (1 Gbps) that supports both administrative and academic networking capability. University researchers are connected to the campus network and can utilize this general network to access off-campus resources, as well as facilities provided on campus. The core network connections to all campus buildings currently operate at 1 Gbps. The default network connection to the faculty office generally operates at 100 Mbps. Gigabit connections may be installed to the research office when need warrants it. To preserve the bandwidth off-campus, the general campus networking traffic is flow-controlled to prevent frivolous use. However, due to the demands of the campus, some research is being impaired because the campus does not have access to sufficient off-campus bandwidth to support innovative applications that may be available through the various research and education networks.

As an example of the types of data intensive applications that will benefit from this upgrade, Dr. Julie Vanderhoff (Track 1 senior personnel) performs research into computational methods and analysis for fluid mechanics and environmental fluid dynamics. In addition, there are Advanced Combustion Engineering Research centers at both BYU and UU. The collaboration between these centers is leveraging more bandwidth-intensive, remote collaboration tools such as high-definition videoconferencing and telepresence. BYU recently has constructed a telepresence facility in the Harold B. Lee Research Library for use by faculty across research disciplines.

Figure 4 depicts how campus research will be improved with additional bandwidth and equipment in a dedicated research network. In this view, campus research is not constrained by the demands of the general campus network. A 10 Gigabit Ethernet network is utilized to bring together the research locations and facilities about campus, and to provide off-campus connectivity at the same data rate. In addition, the Fulton Supercomputing Laboratory, one of the on-campus research facilities, will utilize this high-speed network to improve connectivity to off-campus resources that would augment its value to researchers. BYU has sufficient campus fiber infrastructure in place to transport the additional UEN provided bandwidth throughout campus. We propose acquiring a core router to serve as the hub of the BYU research and HPC network.

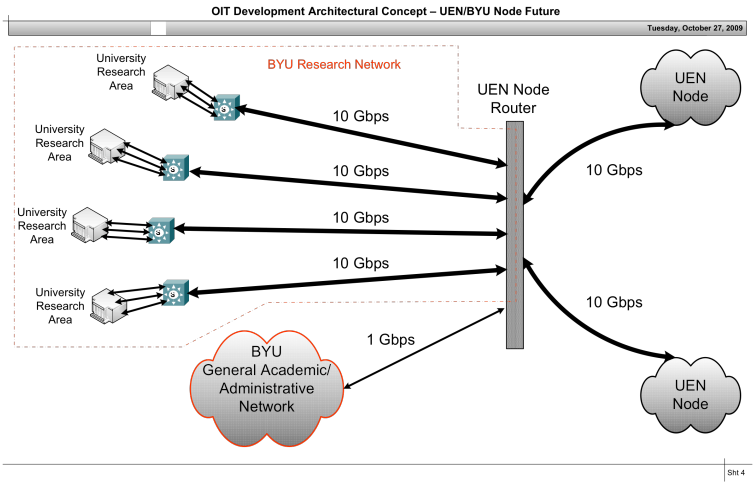

Figure 4: Proposed architecture for BYU Research Network in support of EPSCOR researchers and educators and the Fulton Supercomputing Lab.

V. Diversity

Several demographic factors influence the Utah EPSCoR Diversity Plan. First is the rapidly growing Hispanic population in Utah. Twelve percent of the Utah population consists of persons of Hispanic or Latino origin – compared with 15.4% nationally [6]. Minorities contributed 35% of the Utah's population growth in the 1990's and over 40% of the growth in the new century [3]. Hispanics have a high school credential of 67% compared with 94% of whites. Only 16% of Hispanic young adults enroll in college compared with 45% of the whites. Many members of the Hispanic community have low household incomes resulting in less financial ability to attend college. Utah also has a significant population of Native Americans and Native Hawaiian and other Pacific Islanders, whom we must strive to reach through EPSCoR. Native Americans account for 1.4% of the population in Utah, compared with 1.0% nationally. Native Americans comprise the majority population in southeastern Utah's San Juan County, adjacent to the Navajo and Ute Mountain Ute Indian Reservations. Roughly 19% of Utah's Native American population attends college. Of Utah's population, 0.8% is Native Hawaiian and Other Pacific Islanders, compared with 0.2% nationally. Many of the Pacific Islanders in Utah are located in the greater Salt Lake City area, with ~30% of them attending college.

Utah women are slightly less likely to have college degrees than are women in the rest of the nation. In contrast, Utah men, on average, have higher college educational attainment compared with the rest of the nation [3]. The Utah Commissioner of Higher Education has commissioned a year-long study, "Women and Higher Education in Utah: Challenges and Solutions," to design and develop strategies, programs, and initiatives to improve the number of women completing their college degrees. Utah colleges and universities struggle with lower levels of female enrollment and completion in STEM disciplines. We do not yet have the conclusions of that report, but will dynamically integrate them into our program as applicable when they become available.

The EPSCoR diversity plan is woven throughout all activities in this proposal and the concurrent RII Track 1 and 2 proposals. Many of the details of these plans are explained in the Workforce Development Section; others are summarized below. As first highlighted in the RII Track 1 proposal, our efforts will include:

- Development of a model for how a university research program can work with a regional high school and feeder middle schools. The high schools selected for this program will contain minority populations greater than the Utah average to demonstrate the model's effectiveness in working with teachers of Utah's diverse populations.
- A summer research experience for two-year and four-year college instructors will intentionally focus on programs with large enrollments of underrepresented students. Instructors will be recruited from Salt Lake Community College (SLCC) and the College of Eastern Utah (CEU)'s San Juan campus. Over 50% of the students enrolled at the latter campus are Native American. SLCC has an excellent track record of graduating female students and an improving record of recruiting and retaining Hispanic students, and roughly half of the engineering students at the University of Utah transfer classes from SLCC. The two-year and four-year program instructors will become important recruiting and retention partners.
- The Research Experience for Undergraduates Program will actively seek students from Utah's Native American, Hispanic, and Pacific Island population as well as female STEM majors.

- Significant effort will be focused on recruiting underrepresented graduate students. Recruiting funds in the Track 1 budget have been set aside to support recruiting trips to ensure a diverse graduate student population.
- Science-fair fairs will be held to help students select a project for the regional science fair, which has broad participation and support throughout the state. These Science-Fair Fairs will link mentors with students and their parents at key locations throughout the state. An annual diversity forum will be held at the state EPSCoR meeting to share with EPSCoR faculty the lessons learned from programs such as NSF-ADVANCE on ways to recruit and retain female faculty members in STEM colleges.

The Utah EPSCoR project is committed to the following diversity goals:

- Doubling the number of Hispanic, Native American, and Pacific Islander populations enrolled in undergraduate STEM programs in the EPSCoR partnership,
- Doubling the number of female, Hispanic, and Native American STEM doctoral students, and
- Thoroughly evaluating the effectiveness of the high school-middle school plan and the REU program to understand the program factors that contribute to increasing the diversity of the students in STEM. The evaluation results will be shared with the Utah System of Higher Education Consortium for Science and Math Education.

The campus network upgrade and the substantial interconnectivity expansion in this and related pending proposals have the clear potential for a direct impact on STEM and other diversity enhancing programs at the three leading EPSCoR institutions in Utah – UU, BYU, and USU. At the same time, the role played by UEN as a key project partner (its executive director is a co-PI) cannot be underestimated. Since UEN already interconnects these three campuses with the rest of higher and K-12 education in the state and will operate the *Research@UEN* optical network, key activities such as distance education, mentoring, and other forms of outreach and collaboration will be facilitated immediately and without further investment.

VI. Workforce Development

The Utah EPSCoR workforce development plan involves middle schools and high schools; two-year and four-year colleges; research universities; and the private and public sector in the EPSCoR research enterprise. The intended outcomes are an increased STEM-literate workforce and an improved capacity to conduct STEM research. An advisory board and an internal evaluation program provide quality assurance. Both intended outcomes lead to improved innovation and competitiveness as illustrated in Figure 5.

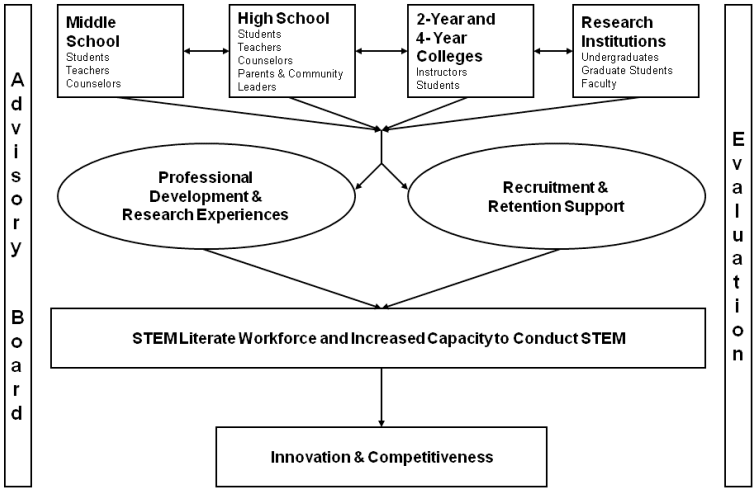

Figure 5: Utah EPSCoR Workforce Development approach.

High School Bridging to Middle School Program: As identified in the Track 1 proposal, the EPSCoR program each year will select one high school in Utah and its associated middle school. The high school will be selected because of (a) its proximity to one of the EPSCoR measurement network sites and (b) the demonstrated support from the local school district to participate in the program. The selection process will ensure a reasonable mix of rural and urban schools. The key stakeholders in the development of a STEM-enabled workforce will participate in this program: teachers, students, counselors, and representatives from parent groups and community leaders.

- During the summer, high school teachers will work in an EPSCoR laboratory. With support from curriculum specialists, teachers will develop K-12-standards-based STEM modules based on their summer research experience. For example, the teachers' classrooms will have access to the EPSCOR distributed atmospheric-dust-climate measurement network real time data so it can be incorporated in both standards-based mathematics and science classes. High school counselors will tour multiple EPSCoR laboratories and meet with research faculty, graduate students, and undergraduate students. The counselors will develop a workforce plan that focuses on ways to prepare underrepresented students for STEM careers. The school district and high school will recommend parents and community leaders to form a "Community Advisory Panel" (CAP). Members of the CAP will tour the EPSCoR laboratories to learn the importance of the research on Utah environment and energy and to understand career paths of the scientists and engineers at the research sites. Two-way discussions will be encouraged so that the EPSCoR program can learn from the CAP.
- EPSCoR will support a Family Science & Engineering Day on the high school campus. Students will highlight their STEM work and EPSCoR scientists and engineers will provide posters and demonstrations. The CAPs will help design the Science and Engineering Day to be most effective in informing parents, families and students about STEM work in their community.
- A daylong workshop will be held where high school teachers, counselors and the CAP members meet with middle STEM teachers and counselors. The workshop will provide opportunities for the middle school teachers to learn about the STEM research as well as STEM career opportunities.

Two-Year and Four-Year College Instructors: Summer research experiences, and year-round field experiences, will be available for two-year and four-year college instructors. The EPSCoR program proposes to focus on institutions that have track records of graduating women, Hispanics, and Native American students in STEM programs. Instructors will be recruited from Salt Lake Community College (SLCC) and the College of Eastern Utah (CEU), San Juan campus.

Research Experiences for Undergraduates (REUs): In the second and third year of the project, ten underrepresented students will be recruited for REU experiences. In years four and five, over 15 REUs will be available. REU students will spend 10 weeks working closely with EPSCoR faculty. Interested students will be encouraged to become involved in CI-related projects such as research computing, computational science and engineering, and advanced networking at UU, USU, and BYU.

Build Research Capacity: Across Utah EPSCoR, the graduate and post-graduate students will meet twice a year for workshops that focus on a variety of topics including methods training to familiarize the students will all of the EPSCoR equipment and on the responsible conduct of research. As appropriate, relevant CI and, in particular, advanced networking topics will be highlighted in these workshops with an emphasis on the impact on particular research topics.

Diversity Forum: A diversity forum will be held at the annual EPSCoR meeting to share with EPSCoR faculty the lessons learned from programs such as NSF-ADVANCE on ways to recruit and retain female faculty members in STEM colleges.

Advisory Board: The Workforce Development Plan will be guided by an Advisory Board that consists of members of the Utah Science and Mathematics Education Consortium. This entity reports to the Utah System of Higher Education Board of Regents. It includes representatives from business and industry as well as the Deans of Science and of Engineering of Utah colleges and universities.

The important outcomes of the workforce development plan are:

- Middle school and high school teachers, counselors, parents and community leaders have increased awareness of possible STEM careers for ALL students as well as an appreciation for the importance of the EPSCoR research to the state of Utah's economic competitiveness.
- High school teachers and students conduct inquiry-based projects in their classrooms by using data available from the EPSCoR distributed atmospheric-dust-climate measurement network.
- Underrepresented students are active participants in summer REUs as well as graduate programs.
- EPSCoR faculty understand how they contribute to the development of a national science and engineering academic workforce that includes the full participation of women in all levels of faculty and academic administration.
- Stakeholders such as the State Governor's Office for Economic Development and the State Board of Education, as well as members of the private sector, will fund and support a number of the workforce plan initiatives, especially the middle school and high school projects.

VII. Evaluation and Assessment

The Project Management Team (PMT - see below) will meet regularly to monitor progress towards the annual objectives and project goals. The teams for each core project will submit progress reports to the PMT every 6 months, and will meet at least quarterly with PMT representatives for informal progress updates. To facilitate interactions between and within teams, which will be spread across the state, we will leverage existing videoconferencing capabilities as well as 7x24 videoconference "rooms" to be established for Track 1 core projects as well as the overall state EPSCoR program office.

We will use a goal-based evaluation system that combines close and frequent evaluation by Utah personnel with regular but more global evaluation by external review teams, in consultation with the PMT. The PMT will provide the external reviewers with detailed data on goals and outcomes, with analysis of perceived successes and weaknesses. The goal of the evaluation is continuous improvement of outcomes, through feedback to project leadership, the universities, the state science committee, funding agencies, the private sector, and the public education system. Progress of each component toward annual benchmarks and stated goals and objectives, including both research and outreach/workforce improvement, will be the metric used to evaluate success. We will strive to have "full cycle" evaluations, meaning that we will evaluate how each component of the project performs for its entire life cycle.

Several mechanisms for external evaluation will be used, as indicated on the following chart of project goals and metrics below (Table 2). At each annual State EPSCoR meeting, we will convene the EPSCoR State Committee, which will meet with the PMT and with the external

evaluators (e.g., guest speakers). In addition, the State EPSCoR Office will coordinate formal reviews organized by the American Association for the Advancement of Science (AAAS) Research Competitiveness Program Office at the six and eighteen month points of the project, and these teams will provide completely independent evaluation of the program as a whole and of the infrastructure improvements and the associated workforce and diversity activities.

Questions and Metrics for Review: Projects will be reviewed on how they are progressing toward the desired goals, based on the example outcomes and metrics described in the following table.

Desired Outcomes	*Activities*	*Metrics*
Address Utah EPSCoR themes	Identification of key issues, Project design, team selection	Identification and upgraded connections for Utah EPSCoR research needs
Focus area research productivity - quantity	Publications, patents, new products, Submitted proposals, new curricula	Number of active research faculty; Research grants number/dollars
Research quality	Federal funding by NSF and others; Peer-reviewed research; Review papers; Mentorship; REU applications	Faculty retention; Increased student research; Graduate student quality; External recognition of faculty
Workforce development, and education improvement	Broaden participation, educational quality; Young faculty development; USTAR synergy; Outreach; Student enrollments; 2 & 4 yr. college participation; Teachers in the labs; K-12 Science presentations	Demographics (increased diversity), Numbers served, Increased STEM degrees/jobs, Improved junior faculty retention; USTAR hires; # of qualified and certified teachers
Advanced network architecture	Integration of state optical network with advanced campus research networks, improved performance experienced by campus end users and HPCCI applications	Network throughput, latency, and loss; Aggregate network utilization and growth trends; Time to provision new services across networks; deployment of perfSONAR measurement devices across three campuses
Future network investments	Further deployment of campus network upgrades and research focused statewide optical network	Campus and UEN investment; aggregrate *Research@UEN* bandwidth; fraction of research end users attached at Gigabit Ethernet or higher
Support for enhanced CI framework	Ability to support high-bandwidth/low-jitter applications (e.g., HD videoconferencing); support for high-capacity data storage supporting researchers at all three institutions	Number and capacity of videoconferencing nodes deployed on campuses for researchers; data transfer rates observed between EPSCoR research institutions

Table 2: Evaluation areas and metrics for the Utah EPSCoR RII Cyber Connectivity Project.

VIII. Sustainability

The principal case for the long-term sustainability of the cyber connectivity investments proposed above for the Utah EPSCoR consortium is that they will be woven from the start into existing network, IT, and CI organizations with oversight by cross-institutional, interdisciplinary groups focused on CI, research, and STEM. The optical network extension for BYU will be implemented and operated by the long-standing, state-supported Utah Education Network (UEN) in conjunction with optical networks already under development for UU and USU in the Salt Lake City area and Logan corridor. The PI of this proposal is a member of the UEN Steering Group as a representative of the university research community, and in light of his CI leadership role on the UU campus, is actively involved in CI-related components of other Utah EPSCoR proposals. The PI and five senior personnel (Julio Facelli, Thomas Hauser, Kelly McDonald, Steve Hess, and Jim Stewart) have been active members of the statewide Utah CI Council.

UEN brings considerable expertise and resources and a statewide reputation for network breadth and operational stability over a large state with geographically remote populations. UEN for over 30 years has provided critical distance learning and educational opportunities for learners and researchers of all ages in Utah. UEN manages critical telecommunications, Internet, and educational systems to deliver applications and interactive services to and from schools, colleges, universities and leading national and international education materials providers to students, teachers, faculty, and parents each day. Over the past five years, with support from the State Legislature and the federal E-rate program, UEN has successfully managed an aggressive broadband build-out project to complete the migration of over 300 public education secondary schools and 41 school district offices, colleges, universities, and higher education facilities from copper-based DS1 services to fiber-based broadband Gigabit Ethernet services, including the building and completion of a statewide Gigabit Ethernet backbone spanning almost 400 miles of the state from Logan (north) to St. George (south) and to all rural communities of the state. UEN worked with Qwest Communications and nine independent rural telephone companies, and a national digital microwave provider on these important projects. UEN has a core team of professionally certified network engineers, field engineers, and network operations and security professionals supporting the network. During 2008 in less than three months, UEN successfully deployed a 10-Gigabit core diverse ring within the state's central WAN network with Qwest to keep up with growth and demand on the UEN backbone. This past fall, UEN began the process of deploying broadband Ethernet connections to elementary and charter schools and many public libraries.

The campus network upgrades will be performed by the respective organizations supporting research networking and CI on their respective campuses – the Office of Information Technology and its Center for High Performance Computing (CHPC) at UU, the Center for High Performance Computing (HPC@USU) at USU, and the central Information Technology organization and the Fulton Supercomputing Lab (FSL) at BYU. All three proposed projects will be designed and deployed in modular and scalable fashions that will both permit subsequent expansion at a later time and also incent follow-on investments by the respective universities. These research network upgrades also will serve as paradigms for later general campus network upgrades. In addition, we plan to focus considerable attention on end-to-end network performance in this collaboration by leveraging the UU's experience in deploying perfSONAR [7] measurement servers for performance characterization and problem resolution.

The UU's CHPC provides large-scale computer and networking resources (i.e., hardware, software and expertise). These resources facilitate advances in academic disciplines that require computing and network capabilities beyond those available in individual colleges, departments or

groups. These entities use computers as a core instrument in their research. CHPC's director, Prof. Julio Facelli, is a past present of national Coalition for Academic Scientific Computation (CASC) and has extensive experience in operating large scale computing facilities. These centers are the foundation on which the U.S. research universities building the CI framework recommended by the NSF. As such, CHPC provides a wide range of services and acts as an advocate to encourage the development of the local and statewide CI necessary to support the research goals of the University of Utah and the region as a whole.

CHPC has a part-time director (Prof. Julio Facelli) and an approved staffing level of 28 FTEs. Its current base budget is roughly $2.6 million, plus one-time appropriations from both internal and external sources. CHPC has supported University research for more than 20 years and has developed a great deal of skill and experience in the operation of HPC facilities. Under the leadership of assistant director Joe Breen, relevant CHPC capabilities include the operation and monitoring of physical data center facilities and advanced network operations.

As another example of the existing organizational fabric, HPC@USU – now in its fifth year of existence – has made great strides in providing CI capabilities to campus researchers. Currently, the center provides 80 TB of parallel storage, a large archival storage pool, more than 800 cores for large parallel simulations, and visualization capabilities. The *Research@UEN* optical network will connect directly into the main data center switch of the HPC@USU infrastructure.

The broad overview of the project plan for the RII C2 effort is as follows:

Year 1:

- Formal acquisition of optical fiber pair between Salt Lake City and Provo from UDOT and associated laterals
- Acquisition of optronics for this path leveraging earlier *Research@UEN* purchases
- Installation and testing of Provo optical network extension
- Integration of the Provo network into the existing UEN operational model
- Prioritization of campus network upgrade targets by Project Management Team
- Acquisition and installation of campus equipment by respective organizations
- Engagement with external evaluative team

Year 2:

- Consultation with EPSCoR Track 1 and Track 2 teams to assess network performance and identify future requirements
- Identification of network and other CI deficiencies and gaps
- Planning for future network and CI investments in support of EPSCoR research and STEM activities
- Engagement with external evaluative team

IX. Management Plan

At the state level, the EPSCoR State Committee provides oversight for all Utah EPSCoR activities. This committee is composed of members of (a) the Utah Legislature – Sen. Lyle Hillyard and Rep. David Clark; (b) the Governor's Office – Dr. Tamara Goetz (State Science Advisor) and Gary Harter (Economic Development); (c) USTAR – Dinesh Patel (venture capitalist & Managing Director, vSpring); (d) private industry – Richard Nelson (Utah Technology Council) and Craig Bott (Grow Utah Ventures); (e) a member of the State Board of Regents (unfilled); (f) the Vice Presidents for Research (VPRs) at UU, USU, and BYU (Thomas Parks, Brent Miller, and Brent Webb, respectively); and (g) the state director of the Utah EPSCoR

Office (currently vacant). On September 17, 2009, the state committee met and formally endorsed this proposal and its concepts. While the State Science & Technology (S&T) Plan is still undergoing revisions, they agreed that the proposed projects will support areas of considerable research strength in Utah and are fully consistent with the goals and objectives to be defined in the final State S&T Plan due for completion next year. The Executive Committee of the Utah EPSCoR State Committee is known as the Utah EPSCoR Office; this committee consists of a state director and the three university VPRs. The Utah EPSCoR Office will directly oversee this project.

We will contract with the AAAS Research Competitiveness Program Office for formal external reviews of this project (see AAAS commitment letter). This review process will be coordinated through the Utah EPSCoR Office. In addition, we will carry out annual reviews with external reviewers and the Utah EPSCoR State Committee, in conjunction with the annual statewide meeting. External keynote speakers/reviewers will be given honoraria to stay two full days to review ongoing project components. To optimize time and expense, RII C2 review activities will be held in conjunction with the corresponding Track 1 and Track 2 efforts (if those proposals are successful).

We have assembled a RII C2 Project Management Team (PMT) with extensive experience in advanced networking and CI, including working with large research projects and operating open-access infrastructure facilities. The PD for the project is Dr. Steve Corbató (UU). Corbató previously led the national R&E network (Abilene) for Internet2 and later served as its technology lead. In this capacity, he developed a non-profit holding company (FiberCo) for acquiring dark fiber assets from telecommunications companies on behalf of U.S. research and education [8]. While at the University of Washington prior to Internet2, he helped develop the Washington State K-20 Network and the Pacific Northwest Gigapop regional network based in Seattle. The RII C2 PD will have primary responsibility for representing the project to the State EPSCoR Committee and Office.

The network-focused co-PIs on the PMT are Kelly McDonald (BYU) and Dr. Michael Petersen (UEN). Petersen will be joined by UEN's director of technical services, Jim Stewart. Senior personnel Nate Benson will represent USU in the HPC/advanced network area. Two other co-PIs, Prof. Jim Ehleringer (UU, Track 1 PI) and Prof. Larry Baxter (BYU, Track 1 co-PI) and will provide linkage to the Track 1 objectives and projects. Senior personnel Prof. Julio Facelli (UU CHPC director and Track 2 state PI) and Prof. Alex Boldyrev (USU) will complete the PMT. The state EPSCoR director (currently, Prof. Ron Pugmire of UU) will be an *ex officio* member of this committee.

The Utah Education Network (UEN) has over 25 years of experience and the reputation for the planning and implementation of large, complex, multiphase projects that have stringent timelines as their primary constraint. UEN currently manages a statewide broadband network that connects over 1900 higher education, public education, libraries and other education and government entities throughout Utah. UEN's base budget is expected to be $41.3 million for FY2011. Notably, in contrast to most organizations where personnel make up the largest recurring cost, 47% of UEN's budget is committed to multiyear circuit contracts and just 30% for personnel.

UEN has assigned Kevin Dutt as the project manager for the *Research@UEN* project. Kevin has been with UEN and the University of Utah for over 19 years and managed many of UEN's and the University of Utah's key network implementation projects. In his current role as a Project Manager for UEN, Kevin manages diverse projects throughout Utah to include fiber builds and network improvements with service providers and contractors, multiphase licensed carrier class

microwave radio installs and all infrastructure improvements for new and existing buildings. In addition, Kevin manages the installation of UEN designed and implemented distance education classrooms. We estimate that the Provo extension piece of this project will require up to 10% of Kevin's time during the first year of this award.

UEN management and technical staff have been collaborating with UU, USU, and BYU researchers, network architects and cable plant operations staff over the past year developing requirements and initial designs for the research network. Research faculty members, technical staff, and management meet regularly for purposes of planning the conceptual and functional requirements of the research network. Additional collaboration takes place through a very active list server that includes this same group of constituents.

5. References Cited

1. The Carnegie Classification of Institutions of Higher Education, <http://classifications.carnegiefoundation.org/>, Carnegie Foundation for the Advancement of Teaching, New York, 2005.
2. USTAR Initiative, <http://www.innovationutah.com/>.
3. Perlich, P. 2006. Long term demographic trends impacting higher education in Utah. 2006; <http://www.bebr.utah.edu/Documents/Studies/HighEdTrends.pdf>.
4. Large-scale Virtualization in the Emulab Network Testbed. Mike Hibler, Robert Ricci, Leigh Stoller, Jonathon Duerig, Shashi Guruprasad, Tim Stack, Kirk Webb, and Jay Lepreau. In Proceedings of the 2008 USENIX Annual Technical Conference, pages 113-128, Boston, MA, June 2008.
5. R. Ricci and Flux Research Group, ProtoGENI framework <http://www.protogeni.net/trac/protogeni>
6. U.S. Department of Commerce, Census Bureau, State and County Quick Facts, <http://quickfacts.census.gov/qfd/states/49000.html>
7. perfSONAR network performance measurement framework and infrastructure: <http://www.perfsonar.net/>.
8. S. Corbató and S. Cotter, 2005. Dark Fiber: Shining a New Light. *EDUCAUSE Review,* vol. 40, no. 3: 68-69.