

# **Unleashing Waves of Innovation Transformative Broadband for America's Future**

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## **Executive Summary**

A forward-thinking National Broadband Strategy should focus on the transformative power of advanced networks to unleash new waves of innovation, jobs, economic growth, and national competitiveness – and to create new tools to deliver health care, education, and a low carbon economy. ARRA broadband decisions should target high-impact investments with those criteria in mind. They should seek to rebuild U.S. global leadership in networking – and the economic innovations that networking can create. Broadband investments should “pull from the future.”

A proven track record of innovating in networking and its applications, of deploying and continually upgrading advanced networks, and of extending those networks to the unserved and underserved across our nation, lies not with telephone or cable companies, nor with most state governments, but with our nation's colleges and universities and the state, regional and national research and education networks that this community has built, in many instances forged through partnerships with telecommunications providers and state agencies to achieve these goals. A National Broadband Strategy should begin with America's colleges and universities and the state, regional and national research and education networks that connect them and extend to reach schools, libraries, hospitals, clinics, government agencies, agricultural extension sites, and community centers across the nation.

Stimulus broadband investments should be a strategic down-payment on positioning our nation to continue to be the world leader in economic growth and development, by implementing a more comprehensive and cohesive broadband strategy. That strategy should put innovation first and foremost, including the education of the next generation of innovators, workers, and consumers. Funds should be invested in a way that leads to innovations in how we design, build, and use networks. We must be able to look back on BTOP investments as having been the stimulus for the next wave of great innovations in the networking world.

To “pull from the future,” we advocate investing \$930 million in our colleges and universities and their partners to launch next-generation infrastructure for research, education and health. We advocate that the balance of BTOP and RUS funds (nearly \$6 billion) be invested in state broadband plans that build on, and take leadership from, existing state and regional networks that already connect colleges and universities, community colleges, K-12 schools, libraries, hospitals, clinics, government agencies, agricultural extension sites, and community centers – advancing and extending those network connections to truly 21<sup>st</sup> century standards. Investments in these state plans should be done in a way that private sector companies can build upon them to extend connectivity to households in the future.

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<sup>1</sup> For the most current version of this essay, as well as related essays, visit <http://www.cra.org/ccc/initiatives>

## **America's Broadband Future and Higher Education**

America's broadband future is to lead internationally in the invention and widespread adoption of transformative applications that can exist only in a world of dramatically improved broadband infrastructure. This is a future that goes dramatically beyond merely making email or web browsing faster or creating new ways to watch television. It is a future in which telemedicine delivers efficient and personalized healthcare to citizens across the land; telepresence saves energy costs in travel and sparks new forms of collaboration and social interaction; eLearning and eScience provide high-quality education to the underserved and allow all citizens to access scientific instruments and data; eGovernment creates a truly engaged and participatory democracy for one and all; and e-commerce allows all communities to participate more fully in the global economy.

We propose an aggressive national broadband strategy that tightly couples innovation in our colleges and universities to a rapid upgrading of our commercial broadband infrastructure. This investment will enable a new generation of innovators and innovations on our campuses, emanating outward to the communities and regions surrounding those campuses, to unserved and underserved populations and regions, and to our nation at large.

The university community brought us ARPANET in the 1970's, the Internet in the 1980's, the graphical World Wide Web browser in the 1990's, and Google and Facebook in the current decade. These and other transformative innovations from America's colleges and universities have generated countless millions of jobs and countless billions of dollars in economic growth, making America the world leader in information technology. Our colleges and universities continually educate new generations of innovators, workers, and consumers. They also have a proven track record, working in concert with state, regional, and national research and education networks that they created, of reaching unserved and underserved communities with connectivity *and* content. The potential for America's future is limitless if we support the unique innovative strengths of our colleges and universities, working with other public and private sector partners to expand access to and breadth of broadband services for all of America.

This "pull from the future" strategy will, in a small number of years, generate huge economic stimulus and result in waves of transformative innovation emanating from Gbps-enabled university faculty, staff, and student innovators, interacting with researchers at corporate and national laboratories, impacting businesses and consumers nationwide.

### **Our Recommendation**

We recommend that under the American Recovery and Reinvestment Act, a strong partnership, possibly supported by an inter-agency agreement, be formed between the National Telecommunications and Information Administration (NTIA) and the National Science Foundation (NSF).

NSF's \$200 million "Academic Research Infrastructure" competition and NSF's \$300 million "Major Research Instrumentation" competition will provide half a billion dollars for the university community to propose "point of the spear" projects to deploy next-generation science infrastructure that will drive innovation, while NSF's core programs will provide expanded

support for research into new network designs, capabilities, and applications – the same sorts of investments that gave us the life-changing computing and communications innovations that we enjoy today.

Complementing these NSF investments, NTIA would provide \$930 million to launch next-generation network infrastructure for research and education that will be a catalyst for innovation in our colleges and universities, with a particular focus on enabling minority-serving colleges and universities, NSF EPSCoR (Experimental Program to Stimulate Competitive Research) universities, and the communities served by these institutions to participate in this new era of innovation, and to prosper in the new global economy.

Our colleges and universities – along with the state, regional, and national network partners that extend their reach and the reach of the Internet to the unserved and underserved across this nation – are the right core engine to launch the ARRA broadband strategy. The partnership between NSF and NTIA will use the power of broadband to enable a new generation of innovators and innovations, setting the stage to roll out transformative applications and dramatically improved broadband infrastructure to society at large, revolutionizing health care, energy efficiency, education, transportation, public safety, and civic engagement, while improving sustainability, accelerating our economy, and creating the jobs of tomorrow – today!

Jump-starting the national broadband strategy with a comprehensive, coordinated and aggressive investment in our colleges and universities to advance broadband at the high end offers the greatest imaginable leverage – accompanied by a proven track record of utilizing that leverage to increase America’s competitiveness. It is exactly the kind of strategic investment imagined in the American Recovery and Reinvestment Act.

### **Why Use Colleges and Universities to Power the ARRA Broadband Strategy?**

- *Colleges and universities are innovation incubators.* They brought us ARPANET in the 1970’s, the Internet in the 1980’s, the graphical World Wide Web browser in the 1990’s, and Google and Facebook in the current decade. These and other transformative innovations from America’s colleges and universities have generated countless millions of jobs and countless billions of dollars in economic growth, making America the world leader in information technology. We would not be here today, were it not for these engines of innovation.
- *College and university applications drive advances in networking.* These institutions are the heart of demanding, advanced scientific applications. The data-driven experiments, simulations, and analyses of science today require high-speed broadband to move data from remote instruments to the lab and to share massive data sets among scientists globally. Why does this matter? Because these scientists will help us model climate change, discover genetic markers for inherited diseases, and explore the potential of low carbon and renewable energy sources. Colleges and universities are also the source of innovation in America’s health care system, providing cutting-edge health research, medical education, clinical care, and rural telemedicine. The bandwidth demands of today’s advanced scientific applications – tens of gigabits per second – foreshadow similar bandwidth needs in homes and businesses in the future.

- *Colleges and universities have a four-decade proven track record in deploying, managing, operating, and continually upgrading advanced networks.* With seed money from NSF in the 1980's and 1990's, CSNET, NSFNET, and Internet2 provided a critically important stimulus to the early growth of the Internet by bringing academic researchers and students online across the United States, at first in their labs, then in their dorm rooms. The research and education community has experience in deploying, managing, operating, and continually upgrading broadband networks on campuses; advanced optical networks through state and regional consortia; and the highest-performance optical nationwide backbone capabilities.
- *Colleges and universities also have a proven track record, working in concert with state, regional, and national research and education networks that they created, of reaching unserved and underserved communities with connectivity and content.* These state, regional, and national research and education networks – typically built in partnership with telecommunications providers and state agencies – today exist in 37 states and reach more than 55,000 community institutions such as community colleges, K-12 schools, libraries, hospitals, clinics, government agencies, agricultural extension sites, and community centers, as well as Tribal Colleges and Universities, Hispanic Serving Institutions, Historically Black Colleges and Universities, Alaska Native Serving Institutions, and Native Hawaiian Serving Institutions.
- *Colleges and universities today are preparing tomorrow's innovators, workers, and consumers – tomorrow's doctors, nurses, police, firefighters, managers, government leaders, and technologists.* Students' experiences with high bandwidth connectivity on their campuses are driving their expectations and the domestic demand for new high-bandwidth applications that will advance America and be exportable to the rest of the advanced world. These experiences also prepare tomorrow's workforce, which must design, deploy, manage, and use a new generation of broadband networks based on 21<sup>st</sup> century architectures infrastructure and technology, as well as invent new waves of technology and applications. Today's students are tomorrow's innovators, workers, and consumers. Students must “live in the future” in order to bring this future to our communities across the nation.
- *Colleges and universities serve as neutral territory for open, non-proprietary, unclassified advances, fostering close partnerships with and among industry and government and across all sectors ranging from education to health care.* America crucially needs this level of open non-proprietary synergy as it strives to rapidly unleash and support next-generation networking to achieve transformations in economic competitiveness, environmental sustainability and cost-effective health care. Universities have a track record of building systems software that lowers the barrier-to-entry for creating new applications that leverage the available bandwidth – systems software that includes the network-capable operating systems of the 1980's, the middleware and grid technologies of the 1990's, and the wide-area network services of the most recent decade. Universities also have a track record of partnership with industry and with corporate research organizations, driving new discoveries from concepts to products and services.
- *Colleges and universities are catalysts for local, regional, and national economic growth.* They are the hubs for local communities: culture, information, training, medical care,

employment, and social interaction. This is especially true for rural and underserved areas. Outreach from colleges and universities to surrounding communities, counties, and states extends their reach and impact.

In short, America's colleges and universities and their partners have the knowledge, the experience, the foundation network infrastructure, and the track record to jump-start a national broadband vision and strategy, leveraging federal ARRA investments in ways that will spread broadband, create jobs, improve health, push the frontiers of science, and educate young people. Achieving this vision requires revolutionary advances in America's networking capability, and rapid but comprehensive and cohesive deployment of broadband capabilities into every geographic part of our nation to serve research and education, healthcare, energy efficiency, education, transportation, public safety, civic engagement, and broad economic development.

### **Needed: Joint NTIA-NSF Leadership**

The Internet is a globe-altering technology resulting from a decades-long collective effort by the federal government, the higher education community, and the corporate sector, rapidly joined by international partners as its importance emerged. ARRA recognizes the value of the Internet to every American by including \$7.2 billion for universal broadband, with \$2.5 billion to be administered by Agriculture's Rural Utility Service (RUS) program, and \$4.7 billion by the National Telecommunication and Information Administration (NTIA) within the Department of Commerce.

We recommend that under the ARRA BTOP, a strong partnership, possibly supported by an inter-agency agreement, be formed between the NTIA and the National Science Foundation (NSF). The NSF has played and will continue to play the role of supporting the development, deployment, and utilization of the most advanced networking capabilities and network applications. NSF's constituency is America's colleges and universities, supported by their regional, state, and national networking partners. NTIA can leverage NSF's direct reach into academia and its experience and the successes it has enabled for American higher education.

Universities are small cities, and therefore advances in university environments where the future will be rapidly prototyped are naturally stress-tested and can be rapidly transitioned. A set of coordinated investments that begin with research universities can expand to engage thousands of additional college and university campuses across the nation as anchor partners in restoring the nation's leadership in broadband deployment, utilization, and innovation for all Americans.

Similarly, community colleges, Tribal Colleges, and other minority-serving institutions are often centers of community cultural life, engines of economic innovation and entrepreneurship, and sources of the next generation of talented employees, employers, leaders and entrepreneurs. Providing these centers of community life with leading-edge networks, tools, and the connections to higher education research and education throughout the nation will accelerate economic growth and job creation in rural and underserved communities throughout the United States.

As part of the initiative, colleges, universities and their partners will be expected to reach out to their surrounding communities, partnering with local governments or private sector carriers, to

expand high-speed connectivity into the neighborhoods and community surrounding campuses where their faculty, staff, and half their students live. These “concentrations of advanced broadband and innovation” will serve as the catalyst for driving demand and leading to the next step in a national broadband strategy – expanding advanced high-speed broadband to every home, school, and business in the nation.

There is a long and highly successful tradition of major research universities partnering with smaller institutions in unserved and underserved regions of the nation to provide advanced connectivity, making these smaller institutions and regions more competitive. These efforts will continue, through the GigaPoPs (Gigabit-per-second Points of Presence) and RONS (Regional Optical Networks) and state and regional networks that are the heart of these regional initiatives embracing NSF’s EPSCoR institutions. Universities will require their regional and national networks to partner with efforts (federal and state) to reach out and connect their medical facilities with rural and underserved populations. They will be expected to partner with their states to connect, upgrade and extend networks connecting K-12 schools, libraries, public safety institutions, agriculture extension sites, government buildings, elder-care centers and the like.

Marrying NSF’s higher education leadership with NTIA’s telecommunications and policy leadership is precisely what is necessary to ensure that this generation of Americans, and future generations, will continue to compete and to lead in the global economy.

### **What Investments are Needed from NSF and NTIA through ARRA?**

Executing a comprehensive and cohesive long range networking infrastructure plan for the research and education community will take several billion dollars over the next decade. As part of the ARRA it is proposed that NSF and NTIA team on the initial stages of this effort.

NSF’s \$200 million “Academic Research Infrastructure” competition and NSF’s \$300 million “Major Research Instrumentation” competition provide half a billion dollars for the community to propose “point of the spear” projects to deploy next-generation “research enabled” science infrastructure that will enable next-generation eScience and eLearning applications. NSF’s regular core programs will also continue to fund advanced research into new network designs and capabilities – for example, programs to improve the production and quality of the software in networks and at their endpoints, to enhance the security of these components, to improve the attribution and resolution of network-based misbehavior, and to encourage the collaboration of computing and non-computing specialists to address issues of how best to use the increased capacity appropriately and to the benefit of society.

Complementing the NSF leading-edge applications, NTIA would provide \$930 million to launch next-generation network infrastructure for research and education. While the program needs to be shaped through the NTIA’s planning process, we would suggest the following general approach:

- **Institutional Infrastructure – \$600 Million\***

**\$600 million** would be used to provide high-speed campus wired and wireless network upgrades for approximately 400 colleges and universities, allowing students and faculty

across disciplines and across the broad spectrum of higher education institutions to “live in the future” with ubiquitous high-speed connectivity, access to cloud computing facilities, the opportunity to inject new functionality and capabilities into the network, widespread adoption of high-definition teleconferencing to support multi-institutional teams, etc. Universities, colleges, and underserved institutions would benefit from these resources and from the research and education partnerships that improved campus infrastructure and broadband connectivity will enable.

\* Note that this represents only a portion of the investment that would be required to upgrade the campus networking infrastructure of all U.S. colleges and universities.

- **Gigabit Points of Presence (GigaPoPs), Regional Optical Networks (RONs), and State Networks (StateNets) – \$290 Million\***

**\$170 million** would be used to capitalize 1 Gbps connections from 250-300 colleges and universities, through a program that connects them to the existing state and regional networks. Networking is a geographic activity; this component would be structured similarly to the extremely well conceived NSF Connections program, with proposals expected from geographical clusters of institutions and the GigaPoPs, RONs, and state networks that serve them. As part of this, NTIA will invest in upgrades to the broad range of underserved campuses, including Tribal Colleges and Universities, Hispanic Serving Institutions, Historically Black Colleges and Universities (HBCUs), Alaska Native Serving Institutions, Native Hawaiian Serving Institutions, minority-serving institutions, EPSCoR institutions, community colleges and the like, to increase their links to the rest of the world.

**\$120 million** would be used to capitalize both shared and dedicated 10 Gbps connections from existing regional networks from 100-150 research-oriented colleges and universities (Carnegie Doctoral/STEM and Doctoral/Professional institutions) to the existing regional networks. Networking is a geographic activity; this program would be structured similarly to the extremely well conceived NSF Connections program, with proposals expected from geographical clusters of institutions on behalf of the GigaPoPs and RONs that serve them.

\* Note that this represents only a portion of the investment that would be required in GigaPoPs, RONs, and State Networks. We advocate that the balance of BTOP and RUS funds be invested in state broadband plans that build on, and take leadership from, existing state and regional networks that already connect colleges and universities, community colleges, K-12 schools, libraries, hospitals, clinics, agricultural extension sites, government agencies, and community centers – advancing and extending those network connections to truly 21<sup>st</sup> century standards. Investments in these state plans should be done in a way that private sector companies can build upon them to extend connectivity to households in the future.

- **National Backbones and International Connectivity – \$40 million**

**\$40 million** would be used to greatly expand the national and international cyberinfrastructure backbone by enabling the national backbone network to advance to

world-leading 100 Gbps capability and to “light up” dozens of dedicated data intensive lightpaths. This can be enabled by building on prior investments by National LambdaRail and Internet2.

### **Operational Recommendations**

There are two potentially complementary streams of funding: funding flowing through NSF to support network and applications research, creating the next generation of life-changing computing and communications innovations for all Americans; and funding flowing through NTIA that will extend today’s – and tomorrow’s – innovations broadly across our nation to colleges, universities, minority-serving institutions and the communities that these institutions serve. We propose to coordinate these streams, thereby commingling innovation and access, accelerating the pace of change, and creating new jobs and economic prosperity within reach of any motivated young student or adult through our remarkable system of higher education. To do this will require coordination between NSF research programs and the NTIA ARRA broadband initiative. We recommend the following:

- Creation of a joint network advisory group – possibly supported by a formal inter-agency agreement – to give coherent direction to efforts at NTIA and NSF, drawing on experts recommended by both agencies.
- NTIA grants in this portfolio, and recommend in this white paper, should be selected through a peer-reviewed process, judged by experts in networking and advanced applications.
- State-led grants should build on, and take leadership from, existing state and regional networks that already connect colleges and universities, community colleges, K-12 schools, libraries, hospitals, clinics, agricultural extension sites, government agencies, and community centers – advancing and extending those network connections to truly 21<sup>st</sup> century standards. Investments in these state plans should be done in a way that private sector companies can build upon them to extend connectivity to households in the future.
- Proposals with close linkage and collaboration with national labs and corporate labs should be encouraged.
- Similarly, proposals involving multiple universities, as well as one or more regional networks and national networks, will be viewed favorably. These multilateral efforts will create network tools and applications that are interoperable and scalable.

### **The Bigger Picture and the Payoff**

The revolution in broadband telecommunications networks and the accelerated rate of this growth internationally, along with the global explosion in knowledge and ready access to powerful research and communications tools, are creating unprecedented changes in the research and education community, along with profound changes in business, commerce, agriculture, government, and health care. New jobs, new industries, an explosion in entrepreneurship, access to quality health care, new modes of community building, increased access to timely information and global markets, and the ability of an extended community to interact closely across space

and time: all are dividends of this revolution in broadband networks and information technology.

Throughout the United States, those colleges and universities – and the communities they serve – that have access to this global fabric of interconnected and interoperable broadband networks have created new forms of education and research, good jobs, medical and health information and care, communication, and the chance to participate in the affairs of the broader society. This global fabric brings to many the promise of inclusion, opportunity, wealth, and better health; for others, particularly among unserved or underserved regions and populations, access to these opportunities has been, at best, limited, and more often, non-existent. Until now.

The big payoff to the economy and society of the investments proposed here will be the societal transformations described throughout this document. But the *immediate stimulus* to the economy in the form of jobs will be significant in the next 12-18 months, and will help to stabilize the country's rapid decline in high-tech employment. Upgrades to campus connectivity could be accomplished within the first 12 months, with the bulk of the dollars going to telecommunications and cable suppliers, construction/installation companies, and network equipment manufacturers. Similar upgrades to broadband networks will occur within the next 18 months, with additional employment as a result. The Information Technology and Innovation Foundation conducted a study of the job-creating effects of new investments in broadband, using standard economic techniques for estimating direct, indirect and induced, and "network effect" job categories. Based upon the ITIF's methodology, the investment outlined in this proposal would result *in the first year* in 5,920 direct jobs, 15,421 indirect and induced jobs, and 24,783 jobs from the "network effect," for a total of 46,124 new or saved jobs, most in the private sector and many in small businesses.

Transformative innovations from America's colleges and universities have generated countless millions of jobs and countless billions of dollars in economic growth, making America the world leader in information technology. Our colleges and universities continually educate new generations of innovators, workers, and consumers. They also have a proven track record, working in concert with state, regional, and national research and education networks that they created, of reaching unserved and underserved communities with connectivity *and* content.

Over the past several decades the higher education community has accelerated many generations of networking, each a breathtaking advance that could not be deployed in the commercial sector because of the inherent risk. In building these advanced networks, higher education has always worked collaboratively with government and with the corporate community – with telecommunications companies and others with a stake in advanced technology and with significant research arms of their own – to create infrastructures that can quickly be hardened and deployed broadly. The broadband components of the American Recovery and Reinvestment Act hold the potential to bring not just today's Internet technology, but tomorrow's, to all Americans. The new investments in basic science will enable new advanced applications to ride on that next-generation infrastructure.

The potential for America's future is limitless if we support the unique innovative strengths of our colleges and universities, working with other public and private sector partners to expand access to and breadth of broadband services for all of America. The robust advanced network

infrastructure put into place by the research and education community and its partners is ready to serve as the foundation and springboard for the nation's broadband strategy under the ARRA. We have a cohesive and comprehensive plan and the engine is ready. All that is needed is the fuel to drive it. Our institutions of higher education are the right core engine to launch the ARRA broadband strategy.

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*The plan described in this white paper has been drafted by Ed Lazowska (University of Washington and the Computing Community Consortium), Larry Smarr (Calit2 and UCSD), Peter Lee (Carnegie Mellon University and the Computing Research Association), Chip Elliott (BBN Technologies and the GENI Project Office), Tom West (National LambdaRail), David Lassner (University of Hawaii), Doug Van Houweling (Internet2), Gary Bachula (Internet2), Louis Fox (WICHE), and Tim Lance (NYSERNet), in consultation with many others.*

*This plan has been formally endorsed by Internet2, National LambdaRail, the Computing Community Consortium, the Computing Research Association, EDUCAUSE, The Quilt, StateNets, the EPSCoR/IDeA Foundation, the Western Interstate Commission for Higher Education, and the Southeastern Universities Research Association. Collectively, these organizations represent all 50 states, over 2200 colleges and universities, 30 state and regional networks, 44 corporations, and international reach to networks in 90 countries. State and regional networks connect over 55,000 institutions including K-12 schools, community colleges, colleges and universities, libraries, hospitals, clinics, medical research centers, agricultural extension sites, museums, and community and performing arts centers.*



*An earlier version of this white paper, titled "Infrastructure for eScience and eLearning in Higher Education," is available at <http://www.cra.org/ccc/initiatives>, along with essays on a number of related topics, including "Information Technology R&D and U.S. Innovation," "Innovation in Networking," "Big-Data Computing," and "Security is Not a Commodity: The Road Forward for Cybersecurity Research."*