The Minds We Need: Research Infrastructure - Inclusion, Innovation, and Competitiveness

A National Research Infrastructure for Everyone, Everywhere

Universal broadband access is the foundation on which to build a more prosperous future for all Americans. If we have learned anything during this pandemic, it is that access to broadband is now a social determinant of health, education, work, and economic security. Our homes became our schools, our workplaces, and our clinics via remote education, work, and telehealth.

We have made great strides as a nation in committing resources to connect every classroom and library to broadband networks, and now with new federal programs to ensure that every American has access to a computer and the Internet, we may finally bridge the residential digital divide.

Yet ubiquitous and high-speed residential broadband isn't enough for this nation to fully realize the potential of all of its citizens and communities, and thus to remain the world leader in economic growth, development, and competition. There is an additional piece of the puzzle, another part of our national strategy. Just as we need broadband everywhere for everyone, ***we need to invest in the ongoing development of the world's most advanced research infrastructure, which must be available everywhere for everyone***. As the precursor and leading edge of next-generation broadband deployments, research infrastructure has paved the way towards the future.

> *The national infrastructure today is not uniform and does not reach all states, nor does it reach community colleges, which are feeders into four-year programs. We must enable institutions in all 50 states to have high-speed capacity. The emphasis in any national plan must be on spreading capacity to the most underserved communities. This should include strategies to make the cloud-based data storage systems usable and affordable.*
>
> ***– Vint Cerf, Vice President and Chief Internet Evangelist, Google***

"Research infrastructure is more than just broadband networks, it is an ecosystem comprising computational, data, software, networking, and security resources; tools and services; along with individuals with the requisite computational and data skills and expertise that can be seamlessly integrated and used, and collectively enable new, transformative discoveries and applications." [1]

We know that the broadest, forward-thinking national broadband strategy should also take advantage of the transformative power of the most advanced broadband research infrastructure

[1] *Transforming Science Through Cyberinfrastructure. NSF's Blueprint for a National Cyberinfrastructure Ecosystem* 2019/20

in the world to unleash new waves of innovation, jobs, economic growth, and national competitiveness. Research infrastructure which is designed for data-intensive science is a vital component of our scientific endeavor and should be a national resource. We know that such a forward-thinking national broadband strategy that includes research infrastructure should seek to connect talent and imagination wherever it is, engaging and empowering individuals from all walks of life, and providing them the sorts of opportunities that ensure American competitiveness and leadership for the rising generation by connecting every high school, every community college, and every college, university, and science facility with the goal of reaching every community.

Research infrastructure has historically been both an enabler for our science, education, and medical communities to engage today's grand challenges and it is also a platform that incubates technologies of the future. It is both a tool for today and the seedbed for American economic leadership and global competitiveness.

Research Infrastructure: Inclusion and Innovation

The future we imagine goes far beyond merely making email or web browsing faster, or creating new ways to watch television. It is a future in which telehealth 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 research infrastructure, eScience, provide high-quality education to the underserved and allow all citizens to access scientific instruments, data, storage, and computational resources; 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. It is a future where *all* Americans can access the nation's research and education infrastructure through their local schools, colleges, and universities.

Major research universities have for decades benefited from world-class broadband; in fact they are in many ways first-generation Internet citizens, having helped create the Internet itself as it spread from defense department labs to supercomputing centers to campuses and to residence halls long before first-generation broadband reached the home. With their leading broadband infrastructure, these institutions have led a generation of discovery and change.

> *While we're seeing a national progression toward incorporating artificial intelligence, machine learning, and quantum computing, every research and scientific discipline relies on cyberinfrastructure. We need to lower the barrier to entry and commit to sustaining this cyberinfrastructure.*
>
> ***– Tripti Sinha, Assistant Vice President & Chief Technology Officer, University of Maryland & Executive Director of Mid-Atlantic Crossroads (MAX)***

Almost 30 years later, there are still thousands of educational institutions, from K12 schools to smaller colleges to minority serving institutions that still lack the type of high-quality connectivity that would include them in the digital research collaboration platform. We must not find ourselves in the position that the technology leader and tribal broadband accessibility advocate, Matt Rantanen, poses: “What if the mind we need is the last mind connected?”

We know that there is talent, imagination, and the capacity for innovation in every community. What is missing in far too many communities – urban, rural, and tribal – is opportunity. Broadband is now a stepping stone on a path towards a future of quality education, healthcare, and prosperity for all.

An Investment in Research Infrastructure[2]

With leadership from our research universities, and with seed money from the National Science Foundation in the 1980s and 1990s, 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 community, through the development of a state, regional, and national ecology of research infrastructures, 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 -- through “Research and Education Networks (RENs).”

In some parts of the US, these RENs have worked assiduously to connect schools and libraries, as well as the rest of higher education, health care, science and cultural organizations, and other vital public-serving institutions. But this work is uneven and incomplete. In many states, RENS are either poorly funded or financially out of reach for numerous institutions or they are unable to provide equitable services to the hardest-to-reach communities.

> *In many of our colleges, libraries, museums, and K12 schools, especially in underserved geographic areas and organizations, there are simply not enough people and not enough people with the right expertise to ensure equitable access.*
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> ***– Marla Meehl, Head of Network Engineering and Telecommunications Section (NETS) in the Computational and Information Systems Laboratory (CISL) at the National Center for Atmospheric Research (NCAR)***

[2] The critical role that the National Science Foundation has played in recent years through the Campus Cyberinfrastructure Program (CC*) cannot be understated, just as the role of the NSF was foundational in the evolution of the Internet. *The Campus Cyberinfrastructure (CC*) program invests in coordinated campus-level networking and cyberinfrastructure improvements, innovation, integration, and engineering for science applications and distributed research projects.*

Fundamental scientific research and technology development from research universities, via public-private partnerships, has led the way to unprecedented transformations. It is not hard to draw a line for the development of digital electronics and the Internet to the use of AI, automation, and cloud computing in the development of mRNA vaccines for COVID-19.

The path from digital technology to science is now a virtuous circle. A key enabler for the digitalization of science has its roots in cyberinfrastructure developed more than three decades ago via funding from the NSF, along with the creation of our national supercomputer centers.

Today, we must boldly reinvest in the next generation of research infrastructure at scale, finally extending its leading capabilities to every institution and enabling the collaborations that assure every American mind is connected into an advanced digital fabric that will unleash our knowledge-based competitive edge into the future.

To retain and build upon our role as the leading economy in the world, our actions should be to:

- **Connect** every high school and higher education institution with a world-class, future-proof, and secure infrastructure with attention to institutions that have been chronically underserved,
- **Engage and empower** every student and researcher, everywhere with the collaborative environments of the future, recognizing that the "last mind connected may be the mind we need," and
- **Ensure American competitiveness and leadership** by investing holistically in national research infrastructure as a sustainable system.

Research Infrastructure: US Competitiveness and Global Grand Challenges

Our research infrastructure, with its genesis in our colleges and universities, along with their government and private sector partners, led to the ARPANET in the 1970s; the Internet in the 1980s; the graphical World Wide Web browser in the 1990s; Google and Facebook in the 2000s; and advances in genomics and precision medicine, precision agriculture and manufacturing, artificial intelligence, and the Internet of Things over the past 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.***

Imagine the future if this infrastructure were accessible not just at our leading research universities and colleges, but extended in every secondary school and community college, in every college and university (especially every minority serving institution), and within all of the communities

where these institutions reside. If we roll out transformative applications and dramatically improve research infrastructure to model and lead innovation for society at large, we will be able to revolutionize health care, energy efficiency, education, transportation, public safety, and civic engagement, while improving sustainability, accelerating our economy, and creating the jobs of tomorrow – today.

> *Infrastructure support needs to be ongoing and steady, and aligned with research goals. The scale of science that we want to be able to do requires sustainable infrastructure. We also need to ensure that this infrastructure benefits institutions that have not always been designated as producing very high research activity.*
>
> ***– Anke Kamrath, Director of Computational and Information Systems Laboratory (CISL) of the National Center for Atmospheric Research (NCAR)***

If we could harness the creativity and innovation inherent in every community by providing access to our most advanced research infrastructure, it would lead to ground-breaking new applications and jobs. It would help us address the many global existential threats we face, including the decline of natural resources; the collapse of ecosystems and loss of biodiversity; global warming and human-induced climate change; chemical pollution of the Earth system, including the atmosphere and oceans; rising food insecurity; and pandemics and untreatable diseases.

We are falling significantly behind other nations, particularly China and the nations of the European Union, in our investment in research infrastructure. In the research infrastructure arena, China recently announced an academy-led $260 Billion USD *Internet of the Future* deployment.[3] In addition, China leads the US with 228 of the world's 500 fastest supercomputers (to the US's 113).[4] Similarly the European Union continues to invest in infrastructure for research both across the EU and globally.[5]

A national broadband strategy that includes a comprehensive, coordinated, and aggressive investment in research infrastructure offers the greatest imaginable leverage to increase America's competitiveness, which is presently at risk. It is exactly the kind of strategic investment imagined in the COVID-19 pandemic relief bills and anticipated in the president's national infrastructure proposal as well as the national broadband bills being considered by Congress. We will achieve this competitiveness only through investment in increased connection and inclusion.

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[3] www.globaltimes.cn/page/202104/1221584.shtml

[4] www.statista.com/statistics/264445/number-of-supercomputers-worldwide-by-country/

[5] www.nordu.net/content/arctic-connect-re-position-paper
digital-strategy.ec.europa.eu/en/policies/open-science-cloud
www.geant.org/News_and_Events/Pages/BELLA-EllaLink-cable-gets-go-ahead.aspx

Building Blocks for Our Connected, Collaborative, Competitive Future

To finally connect every institution that hosts our bright minds with future-proof capacity for research and education, it is essential that we invest in completing and upgrading our national research infrastructure platform. However, to learn from the past, we must also learn to structure new infrastructure investments holistically.

Development of a phased, multi-year plan that first establishes solid cohesive inventories of gaps at the local, regional, and national levels for the connectivity, collaboration environments, and community building is a starting point.

In the past, programs like the American Recovery and Reinvestment Act-era Broadband Technology Opportunities Plan (BTOP) showed that when nonprofit partners were eligible for leadership roles in proposals, and when opportunities for long-term investments were enabled through prudent rulemaking by the funding agency, significant progress could be made in reaching underserved and unserved community anchor institutions.[6] Several research infrastructure programs were funded and successful, but they were also uneven, as not all states were successful, due to the competitive structure and per-state application process that often prioritized broadband goals other than research infrastructure, indeed pitting various broadband goals that are potentially synergistic against one another. Further, requirements for sustainability tended to focus funding in denser, potentially more economically viable, areas.

To assure more comprehensive outcomes -- a national research infrastructure that reaches every community through their education institutions -- in the next infrastructure program, a first step in this next investment must be a systematic planning phase that identifies all secondary school, community college, university, and university-related research facilities that are underserved or unserved, and develops clear strategies for each institution, each state, each tribal nation, and each territory. An effort must be made to integrate those locally tuned plans into a cohesive end-to-end strategy. Such a plan should leverage the nonprofit and institutionally-based research network collaborations that exist in most states and nationally, allow for new ones to emerge where they are needed, and allow for both local innovation and common national goals.

> *We can't create a national cyberinfrastructure without engaging community-based organizations. People trust them because they are the faces they know. There needs to be outreach to identify those organizations and give them the tools and funding to participate in the digital world. Small organizations see larger organizations access resources and leave community-based organizations behind. We have an opportunity to change this with a national cyberinfrastructure plan that addresses these inequities.*
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> ***– Lisa Wilson, Associate Vice President for Research and Sponsored Programs, Clarke Atlanta University***

[6] The NTIA's BTOP program funded several successful advanced research infrastructure programs in 2010, but the work to achieve universal inclusion of every institution and assuredly designed to reach every mind is incomplete.

The final outcome must be to complete fiber optic-based connectivity to each and every high school, college campus, and research center[7] that currently does not have fiber-optic connectivity. The plan needs to include all states, territories, and tribal lands that are part of this nation. In exchange for the federal government's assistance in making the investment to extend fiber-optic networks to these facilities, rules should be crafted to incent contract and ownership structures with public and private sector partners that place maximum control of long-term bandwidth growth cost structures in the hands of the connected institutions, thus maximizing sustainability. Dark fiber Indefeasible Rights of Use (IRU's) owned by the institution or nonprofit collaborative partners and extended to carrier neutral facilities in both last-mile and middle-mile applications, should be prioritized over short-term recurring fee approaches.[8]

Beyond the cabling, startup activities that enable the development and sustainability of people networks, including consortia at local, regional, and national levels should be considered part of infrastructure development and sustainability. Such consortia can not only operate infrastructure, but more importantly, can also share best practices, train in areas like data science, infrastructure security, identity management and technology, and can negotiate group commercial arrangements.[9]

Nearly 40 of 50 states already have a state or regional research and education network organization that can support these functions; however, not all of these organizations have a mission that fully supports training, data science, security, and other activities.[10] In some states, connectivity to all institutions is incomplete and in other states and parts of the US territories and tribal lands, adequate connectivity for research and education is highly uneven and incomplete.

> *Infrastructure support needs to be ongoing and steady, and aligned with research goals. The scale of science that we want to be able to do requires sustainable infrastructure. We also need to ensure that this infrastructure benefits institutions that have not always been designated as producing very high research activity.*
>
> ***– Anke Kamrath, Director of Computational and Information Systems Laboratory (CISL) of the National Center for Atmospheric Research (NCAR)***

To fully realize a competitive advantage in research infrastructure, new funding and programs must go beyond just connectivity improvements (which are critical), but must also provide the software and systems that secure research from threat actors and that enable collaboration in a trusted open environment. The tools for this activity, like the network components, will need to be realized at local, state, and national levels and funding must be allocated accordingly.

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[7] Research centers should be defined to include remote telescopes and science instruments, academic medical centers, and direct collaborators with research institutions.

[8] Allowing underserved and unserved institutions to enter into long-term IRU's is similar to helping a renter purchase a home; with an IRU contract, the owner controls the upkeep and ongoing value, not the landlord.

[9] "The federal government and state governments should develop an institutional framework that will help America's anchor institutions obtain broadband connectivity, training, applications and services." National Broadband Plan, Section 8.22

[10] "Federal and state policies should facilitate demand aggregation and use of state, regional, and local networks when that is the most cost-efficient solution for anchor institutions to meet their connectivity needs." National Broadband Plan, Section 8.20

Systems and approaches need to be enabled nationally, including those activities that no institution should do alone, like identity federation software, security analytics, data movement, and storage. The much larger task of implementing those solutions must be funded locally with the appropriate staff development, training, facilities, and workforce aspects fully addressed.

Research Infrastructure Includes Human Capacity Building[11]

Research infrastructure is more than just access to high-speed networking and data repositories. There is a human infrastructure of technologists, scientists, and citizens who create and maintain research infrastructure to discover and share knowledge. Fundamentally, the purpose of research and education networks is to foster collaboration which results in discovery and dissemination of knowledge.

But not every institution has the human resources necessary to participate in these collaborations, and not every individual has the skills to do so. Institutions critical to society such as tribal colleges and universities, minority serving institutions, Historically Black Colleges and Universities, Hispanic Serving Institutions, Alaska Native and Native Hawaiian Serving Institutions, Asian American and Pacific Islander Serving Institutions, community colleges, public libraries, and rural school districts often lack the resources necessary to hire and train network engineers, data scientists, technology support professionals, and other individuals necessary to participate in these knowledge networks.

By providing access to research infrastructure *and* focusing on building the necessary human capacity to make most meaningful use of this infrastructure, every community will have an opportunity to lead, to thrive, and to prosper.

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[11] The National Urban League's *Lewis Latimer Plan for Digital Equity and Inclusion* embraces this notion with far-reaching recommendations for a new federal office of digital equity, a national digital literacy program, and a workforce of "digital navigators."

In Conclusion

A compelling and eloquent statement of both the urgency of our current situation and the potential for an inclusive national broadband plan can be found in the National Urban League's *Lewis Latimer Plan for Digital Equity and Inclusion*[12]:

"How can the tools of the information economy be employed to create a more equitable and inclusive society? The answer lies in accomplishing four big, but achievable, goals:

- **Deploying networks everywhere.**
- **Getting everyone connected.**
- **Creating new economic opportunities to participate in the growth of the digital economy.**
- **Using the networks to improve how we deliver essential services, in particular in workforce development, health care, and education."**

To which we would add: Connect, engage, and empower research and education institutions with research infrastructure to ensure opportunities are commensurate with the immense talent and imagination we find in every community so that American leadership and competitiveness can flourish.

Action Plan:

This bold and decisive plan to extend and elevate the nation's research and education infrastructure can not be accomplished piecemeal, competitively, or overnight. We strongly advocate a deliberate approach to a new program, using new structures, to be implemented over a six-year period. Incremental and coordinated actions at the local, state, regional, and national levels are essential. The structural issues that have led us to the current digital divide can not be changed by using the same structures and competitive funding approaches that have been used to date. Our plans for full inclusion of every mind and to achieve an irrefutable competitive leadership position demand that we take the time to inventory implementation needs, build the people networks and directional consensus where it does not exist, and that we complete a holistic plan before significant investment is allocated.

A successful approach that integrates local, state, and national needs across network, security, identity, collaboration, and training needs is within our reach and can be accomplished if the funding systems and approaches used by the federal government are adapted to the national imperative laid out in this paper. It is essential we do not simply force this program into existing competitive structures and programs.

[12] *Lewis Latimer Plan for Digital Equity and Inclusion*, a collaboration commissioned by the National Urban League, March 30, 2021.

There are several federal agencies who have the expertise and leadership to ably lead this effort including the National Science Foundation, the Department of Commerce's National Telecommunications and Information Administration, and the Office of Science and Technology Policy, among others. What is critical is to recognize that this plan only works if it is developed both through both a bottom-up assessment/analysis and top-down coordination, prioritization, and end-to-end expectation setting. A comprehensive process that results in equity and national leadership is anathema to the typical competitive processes found in many grant programs. Our goal is not to quickly and evenly spread funding, nor is our goal to reward the most accomplished proposal writers. Our goal is to enable new approaches that set aside certain traditional structures in favor of a coordinated multi-year process that focuses on the equitable outcomes as measured through results and also measured against the comprehensive and integrated plan.

It is with this recognition of current structural deficiencies that we recommend a six-year plan to achieve our goals, managed with specific recommendations at the state and national layers that contribute to a functional and coherent whole. Legislation must give the agency selected to lead this program the authority to receive comments from stakeholders and to set new rules and processes to assure the outcomes described here.

First-Year Activities:

The First Year of the program focuses on needs assessment, training, planning, local organizational development, federal agency coordination, and tools development. This approach fully recognizes that the six-year goal of equity, inclusion, and national competitiveness will require allocation of implementation funds to areas of need where expertise, plans, and advocacy resources may not fully exist today. Therefore, the First Year of the program should provide planning funding across the research infrastructure ecosystem to develop data, identify program needs, and begin training and staff development activities. The First Year should also allow national and federal resources to establish the framework for subsequent collaboration with the research infrastructure ecosystem.

- **Fund planning grants for new or expanded infrastructure to serve underserved and unserved areas.** A quick-start program should be funded within 90 days of enactment to award planning grants that can help comprehensively inventory unserved and underserved community anchor institution needs including connectivity, security, identity management, staffing, and training needs to determine options for establishing long-term infrastructure solutions for the underserved institutions. All awards should be prioritized to nonprofit research networks, tribal, and/or university-affiliated organizations.

- We recommend a minimum of $5 Million per state and territory in planning grants to be awarded to an existing research and education nonprofit or institutional consortium such as an existing research and education network in each state or territory. In those states or territories that do not have an organized existing effort, a nonprofit, tribal, and/or university-affiliated organization should be allowed to apply for funding with the intent of forming such an organization. Planning grants will allow these entities to do engineering studies, understand permitting requirements where infrastructure development will be needed, and will allow them to onboard the resources to manage and develop their plans.

- Additionally, a $5 Million planning grant should be awarded to an existing national nonprofit organization to create a report identifying gaps and opportunities to provide equitable services across networking, security, identity management, cloud access, training, and organizational development in collaboration with the state, tribal, and territoritory efforts. This organization would have the role of harmonizing the multiple state or regional plans into a coherent national plan.

- **Invest in consortia building, participation, and training**.
  Newly connected research and education institutions will need to develop staff expertise to fully utilize their improved access. Investments to create or join consortia at the local, regional, or national level, and investments in training related to data science, identity management, infrastructure operations, security, and cloud computing will be critical.

  - A total of $75 Million should be allocated for consortia building, participation and training grants of a minimum of $250,000 per year for up to five years each of the 50 states and territories should be provided. The purpose of such grants is to offer training and participate in community building activities across research and education consortias.

  - Consortia supporting grants should also be available of up to $2.5 Million for up to five multi-state consortia applications led by a Tribal College or University, Historically Black College or University, or a nonprofit organization representing minority-serving consortia efforts. The purpose of such grants would be to offer training and to participate in consortia building activities, including development of shared centers of excellence.

Scientists can be found anywhere in the world, not just in major universities. The people that have questions often don't have the hardware, infrastructure, and the expertise to answer these questions. Imagine the difference it would have made if the residents of Flint, Michigan, had the capacity to access information about water quality. By building a cyberinfrastructure that includes everyone, we can change this.

– V. Balaji, Head, Modeling Systems Division, Cooperative Institute for Modeling the Earth System, Princeton University

- **Solicit input on how to equitably award program funds to achieve uniform deployment.** The selected federal administrative agency should be provided explicit legislative authority to solicit and receive comments from community anchor institutions, and their nonprofit collaborators about prioritization and dispersing of funds, including the ability to create new granting programs based on the national plan that is developed. The agency's activity should include a broad review of equity and sustainability and should develop funding rules for subsequent infrastructure, training, and systems developments and deployments that are both responsive to local needs and that build a coherent end-to-end strategy across access, inclusion, sustainability, and competitiveness considerations. The agency's review and planning process should specifically work with potential applicants to achieve new practices and approaches to achieve sustainable research and education connectivity to locations that previously have not been served in part due to grantee sustainability rules. The agency should be authorized to spend up to $7.5 Million per year during the program performance period for staffing and other support of the program.

- **Coordinate research infrastructure programs across federal agencies.** We advocate for much stronger interagency coordination across those agencies with research and education infrastructure responsibilities. A new office of research infrastructure programs coordination should be established, perhaps within the Office of Science and Technology Policy, similar to the Office or Internet Connectivity and Growth recently created at NTIA, to assure that programs are coordinated across agencies and to assure research infrastructure investments are maximized and sustainable, and to assure that end-to-end strategies and equity are uniform. Key responsibilities would be inventorying the current status of broadband research infrastructure at the local, regional, national, and global levels, mapping competitive threats to American research leadership, developing plans to bring underserved areas up to a new standard, and coordinating across the infrastructure investments and ongoing operating subsidy programs to assure universal access, sustainability, and competitive leadership. We recommend $500,000 per year in funding to the selected agency to support fulfillment of this critical mission.

Second-Year Activities:

The Second-Year program transitions from planning to implementation. An initial investment of $25 Million per state and territory across every state and territory should be granted to organization's that submitted accepted plans. These initial funds should be used for infrastructure installation, upgrades and expansion, and program management described as priorities in the planning grant submission. A separate pool complementing existing ACP tribal broadband funds should provide support for research institutions located within tribal lands. Through these Second-Year funds, every state and territory should be able to begin security, identity management, collaboration tools, infrastructure and other planning or development activities necessary to advance their state or territory's plan. Awards should be prioritized to nonprofit research networks, tribal, and/or university-affiliated organizations who can then form partnerships as appropriate with private sector companies to implement the programs.

A $50 Million award should be granted to nonprofit national research and education network for national research infrastructure, training, and coordination activities including (1) middle-mile infrastructure development; (2) trust, identity, wireless management, and other collaboration tools; (3) security, data movement, and training that will support and integrate with state, tribal, and territory plans.

Also in this period, the federal agency operating the program should work with the national nonprofit partner and state entities to finalize the infrastructure plans, solicit necessary comments to release program rules, and receive formal proposals (where necessary) to begin the infrastructure build-out phase.

Third-Year to Sixth-Year Activities:

The final phase of the program involves the extension of the infrastructure to every state, territory, and tribal land to provide equitable research infrastructure to every underserved community anchor institution and research center.

- $6.25 Billion would support a connection program with the goal of connecting every institution, every mind, and assuring global competitiveness. This funding would be distributed according to priorities identified in the planning phases, through multiple performance-monitored funding waves over the remaining four years to address to the needs identified in planning activities. In addition to state, territory, and tribal research infrastructure needs, this funding should also be available for national interstate research infrastructure; delivery of training programs; collaboration activities including state middle-mile infrastructure; national scale collaboration tools including trust and identity; institutional wireless infrastructure; security; and data movement.

- Up to an additional $300 Million should be made available to secure long-term research capacity to underserved research entities in Guam, American Samoa, Northern Mariana, Puerto Rico, Hawaii, Alaska, and US Virgin Islands, including the undersea submarine cable capacity for research networks.
- Awards in all categories should be prioritized to nonprofit research networks, tribal, and/or university-affiliated organizations who can then form partnerships as appropriate with private sector companies to implement the programs.

Community Building:

We also recommend that programs be funded to develop the following programs:

- **Create a National Cyber Corps**. Create a structure for individuals, perhaps recent graduates, to work on-site at underserved institutions to assist them in taking the steps needed to ensure full and equitable access. This could be modeled on the Network Startup Resource Center, a nonprofit organization that offers technical training and engineering assistance to enrich the "network of networks" internationally, with more than two decades of success in over 100 countries.[13] (The Washington Post recently found the Latimer Plan's[14] similar call for a "digital literacy corps" compelling.[15])

- **Teach digital literacy and data science.** It is now more important than ever to teach digital literacy and how to access and participate in the digital world. One way to do this is to create a national digital literacy program for all K12 teachers and, as a result, for their students.

- **Create collaboration hubs**. Affinity groups will emerge around a particular focus, community, or geographic area (or areas). There should be support and encouragement of such structures.

> *We need to build an infrastructure for collaboration, community spaces for like-minded individuals to share knowledge and best practices. For example, the tribes in Southern California have created an online opportunity for a community space with the Maori and indigenous people around the world. Cyberinfrastructure can change the greater ecosystem of indigenous people and of other groups as well.*
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> ***– Matthew Rantanen, Director of Technology, Southern California Tribal Chairmen's Association***

[13] https://nsrc.org
[14] https://nul.org/sites/default/files/2021-04/NUL%20LL%20DEIA%20041421%20Latimer%20Plan_vFINAL_1136AM.pdf
[15] Washington Post Editorial Board, April 25, 2021 https://www.washingtonpost.com/opinions/the-part-of-the-broadband-debate-were-missing/2021/04/24/1872491a-9ee5-11eb-8005-bffc3a39f6d3_story.html

- **Create mentor networks.** Each state could create a network of mentors: experts who agree to conduct workshops, training sessions, and individual consultations with underserved institutions. For example, Alex Feltus, a professor at Clemson University, conducts data workshops with under-resourced institutions across the state of South Carolina, most recently with Tribal Colleges and Universities.

> *We must democratize education and a national research and education infrastructure is one of the keys to doing so. Think about the brilliant minds that lack access and so are unable contribute to research and unable to further their own learning. We should do all we can to include them.*
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> ***– Inder Monga, Executive Director, Energy Sciences Network (ESnet)***

Examples: How Research Infrastructure Can Connect, Empower, and Enable the Next Generation of American Leadership

Tribal Nations

Research and education network infrastructure is helping to connect tribal communities. Twenty tribal nations in Southern California are now directly connected to the state-of-the-art International Internet Exchange, Pacific Wave, and its peering, high-performance scientific networks and ever-expanding global connectivity. This new connection enables tribal libraries, scientific research facilities, and cultural preservation institutions to collaborate with partners across the state, the nation, and the world. Tribal Digital Village, a tribal consortium-owned Internet service provider in San Diego County, has connected to Pacific Wave's infrastructure on the West Coast. A joint project of CENIC and the Pacific Northwest Gigapop (PNWGP), Pacific Wave interconnects most international Asia-Pacific research and education networks, key US Western regional research and education networks, leading national-scale research networks, and major commercial research cloud services.
https://cenic.org/news/indigenous-tribes-in-southern-california-are-now-participants-in-pacific-wa

Education

Research infrastructure and services could be further extended to the K-12 realm. Eduroam, for example, is a service that could be extended to more educational locations. With Eduroam, users who are credentialed from an educational institution can visit any other Eduroam-enabled campus, school or library and access its network through their laptop, smartphone, or other mobile device, with minimal configuration and without the need for guest credentials. Eduroam provides an automatic guest provisioning system, secure wireless connection, and encryption and authentication using WPA2-Enterprise standards. This service provides thousands of Eduroam hotspots with world-class quality and free of data-roaming charges. Professors, students, and staff are able to freely roam their fellow campuses without the hassle of gaining Internet access. The simplicity, security, and benefit of Eduroam is an immediate ability for effective collaboration from any Eduroam-connected institution and reduced time-to-science. Utah, Nebraska, and Delaware are engaged in such efforts at present, where K-12 schools, libraries, and higher education locations are all connected to common Research and Education Networks -- a critical activity during the pandemic and on into the future.
https://incommon.org/eduroam/

Healthcare

Modern healthcare and medical research requires leading-edge technology. Research-grade connectivity for the US National Institutes of Health, the largest biomedical research agency in the world, is provided by the Mid-Atlantic Crossroads (MAX) and Internet2. The NIH has experienced increased traffic demands, not surprisingly, during the pandemic, but because the infrastructure was built to handle massive and unpredictable scientific workflows, research and operations continued to function, while COVID-related research data was also securely and

quickly accessible to research collaborators who enjoyed access to research networks like MAX and Internet2.
https://www.maxgigapop.net/
For a family living in a rural area distant from an urban center, who are expecting a child and have concerns about congenital heart disease, access to a state-of-the-art research network in their local hospital or clinic can have profound impacts. Real-time fetal echocardiograms locally transmitted over the research network accompanied by consultation with pediatric cardiologists at a distant urban medical center become possible. So, too, can support via Zoom (or other related technologies) of interdisciplinary teams of pediatric cardiologists, heart surgeons, maternal fetal medicine specialists, neonatologists, and genetic counselors — the kind of care one would get at a major university medical center. Moreover, store-and-forward technologies for high resolution images — x-ray radiography, fluoroscopy, magnetic resonance imaging (MRI) — are also enabled by capacious research networks. For rural and remote communities, access to a research network can be life-saving.

Climate

Addressing climate change requires high-tech research collaboration. Together, the National Oceanic and Atmospheric Administration (NOAA) and the National Center for Atmospheric Research (NCAR) are working with partners across the weather and climate modeling community to deliver the best products and infrastructure that enable forecasters to save lives and protect property nationwide. NCAR provides the atmospheric and related Earth system science community with state-of-the-art resources, including supercomputers, research aircraft, sophisticated computer models, and extensive data sets. Networking for NCAR is provided by the research and education network Front Range GigaPop based in Boulder, Colorado and connected to other advanced research and education infrastructures that span the globe.
https://frgp.net/frgp/

Food Supply

The future of agriculture involves equipping farms with technology. In California, several of the UC Division of Agriculture and Natural Resources's facilities now have broadband after being hooked up to the California Research and Education Network's fiber backbone. When moisture sensors are deployed in fields, agricultural economists have found that farmers can realize a 10 to 20% decrease in water use as well as a significant increase in field output. In a state like California, plagued by drought, using less water to grow more food is a major improvement. Benefits like these would have an immediate impact on farming communities and overall production. But, without broadband connectivity, such tools remain out of reach for many farmers.
https://cenic.org/blog/grow-food-grow-jobs-how-broadband-can-boost-farming-in-californias-central

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