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

Preface

We are at a crossroads.

China and the nations of the European Union are making historical investments in research and education (R&E) infrastructure, along with investments in talent, so that the ideas and innovations that can change the world flourish. These are investments in innovation and competitiveness.

We can choose to do nothing and be overtaken as the world leader in innovation. Or we can make the choice that we have made at other crossroads in our history: we can invest in our talent, through our system of higher education, and provide all Americans with opportunities, regardless of where they live or their economic status to participate fully in our research enterprise, which has been an engine for innovation in the US economy and a global leader.

We know that talent is everywhere, but opportunity is not. We know that R&E infrastructure is essential for our scientific and engineering talent to flourish. We propose that we invest in our R&E infrastructure, ensuring that it reaches every community through our diverse system of 3,900 accredited, degree-granting higher education institutions, and ensuring that there is a bridge to opportunity wherever there is talent. These are investments in inclusion, innovation, and competitiveness.

We cannot know where the next Edison, Carver, Curie, McClintock, Einstein, or Katherine Johnson will come from.

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

- **Connect every community college, every minority serving institution, and every college and university to** a world-class and secure R&E infrastructure, with particular attention to institutions that have been chronically underserved;
- **Engage and empower every student and researcher** everywhere with the opportunity to join collaborative environments of the future, recognizing that the “last mind connected may be the mind we need;”[1] and
- **Ensure American competitiveness and leadership** by investing holistically in national R&E infrastructure as a sustainable system.

R&E infrastructure is a critical component of a national broadband plan. It complements the focus on universal access by providing a foundation for innovation, discovery, and national competitiveness. Our national story is incomplete when diverse human potential is untapped, and competitive threats unmet. Federal investment in R&E infrastructure and technology is a national imperative. Connecting every institution, empowering untapped potential, and rising to competitive challenges is possible by funding a national program of coherent, comprehensive, and highly integrated research infrastructure initiatives.

[1] Matt Rantanen, Director of Technology for the Southern California Tribal Chairmen's Association (SCTCA) and Director of the Tribal Digital Village (TDVNet) Network/Initiative

Building on a Foundation of Universal Access

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 are making 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 in their homes and businesses, we may finally bridge the 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 R&E infrastructure, which must be connected to all community colleges, minority serving institutions, and colleges and universities.*** As the precursor and leading edge of next-generation broadband deployments, R&E 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.*
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> ***– Vint Cerf, Vice President and Chief Internet Evangelist, Google***

R&E infrastructure is more than just broadband networks. It also includes software, tools, and security resources, and it provides access to computational resources and data, along with the necessary human expertise to integrate and use these resources for innovation, discovery, and national competitiveness.

We know that the broadest, forward-thinking national broadband strategy should also take advantage of the transformative power of the most advanced broadband R&E infrastructure in the world to unleash new waves of innovation, jobs, economic growth, and national competitiveness. R&E 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 R&E 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 community college, minority serving institution, college and university, and science facility, with the goal of reaching every community.

R&E 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.

Inclusion

The future we imagine is one where we acknowledge that research talent is potentially anywhere in the country – a future where we remove barriers to access for those inclined and capable of carrying out our research initiatives and provide them with the necessary access to R&E networks, scientific instruments, data, storage, and computational resources.

Because we cannot know where the next Edison, Carver, Curie, McClintock, Einstein, or Katherine Johnson will come from, and if we are to 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 need to enable R&E infrastructure broadly. And it would accelerate the cycles of innovation that will allow us to meet these and other future looming challenges with a speed that could vastly lessen their impact.

Moreover, an economy enriched by the contemporary tools of science, technology, engineering and mathematics (STEM) includes more than graduate and post-graduate researchers. Also needed are technicians, trained laboratory assistants, facility managers, engineers, and other technically trained workers. We can increase the STEM workforce by bringing high quality networking to community colleges and other institutions where training can be affordably offered. These individuals, too, need access to a R&E infrastructure. We must connect schools and libraries who partner with our higher education institutions in areas of STEM, and concurrently look for ways to leverage the FCC's investments in those schools and libraries through the E-Rate program.

Major research universities have for decades benefited from world-class broadband infrastructure; in fact they are in many ways first-generation Internet citizens, having helped create the Internet itself, and the concepts and systems that have made it so ubiquitous and increasingly capable in many ways, 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.*
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> ***– Tripti Sinha, Assistant Vice President & Chief Technology Officer, University of Maryland & Executive Director of Mid-Atlantic Crossroads (MAX)***

Almost 30 years later, the preponderance of community colleges, minority serving institutions, and colleges and universities still lack the type of high-quality connectivity that would allow them to participate in the digital R&E universe. 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. Access to R&E infrastructure is now a stepping stone on a path toward a future of quality education and prosperity for all.

Innovation[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 R&E 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 state and regional research and education networks (RENs) and through our national research and education network (NREN), Internet2.

In some parts of the US, these RENs have connected the rest of higher education, health care, science, and worked assiduously to connect schools, libraries, 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.*
>
> ***– 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)***

Fundamental scientific research and technology developments from research universities, including many public-private partnerships, have led the way to unprecedented transformations. It is not hard to draw a line between the development of digital electronics and the Internet to the use of artificial intelligence (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 with funding from the NSF, along with the creation of our national supercomputer centers.

Today, we must boldly reinvest in the next generation of R&E infrastructure at every community college, minority serving institution, college and university, finally extending leading capabilities to every institution and enabling the collaborations that assure every college student can be connected into an advanced

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[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.*

digital fabric that will unleash our knowledge-based competitive edge into the future. Indeed, this reinvigorated investment will be vital for the leadership of our nation, including driving the development of state-of-the-art cyberinfrastructure through deeper and broader engagements among and with the scientific community.

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

- **Connect every community college, every minority serving institution, and every college and university, including all urban, rural, and tribal institutions** to a world-class and secure R&E infrastructure, with particular attention to institutions that have been chronically underserved;
- **Engage and empower every student and researcher** everywhere with the opportunity to join 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 R&E infrastructure as a sustainable system.

Competitiveness

Our R&E 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 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 millions of jobs and 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 to every community college, to every college and university, especially every minority serving institution, and thereby present in all of the communities where these institutions reside. If we roll out transformative applications and dramatically improve R&E 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.*
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> ***– Anke Kamrath, Director of Computational and Information Systems Laboratory (CISL) of the National Center for Atmospheric Research (NCAR)***

We are falling significantly behind other nations, particularly China and the nations of the European Union, in our investment in R&E infrastructure. In the R&E infrastructure arena, China recently announced an

academy-led $260 Billion USD *Internet of the Future* deployment.[3] Similarly, the European Union continues to invest in infrastructure for research both across the EU and globally.[4]

A national broadband strategy that includes a comprehensive, coordinated, and aggressive investment in R&E infrastructure offers great 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 Biden-Harris 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.

Building Blocks for Our Connected, Collaborative, Competitive Future

To finally connect every institution that hosts our bright minds with world class capacity for research and education, it is essential that we invest in completing and upgrading our national R&E infrastructure.

Development of a phased, multi-stage 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.[5] Several R&E 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 R&E 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 ensure more comprehensive outcomes — a national R&E 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 community colleges, minority serving institutions, all colleges and universities, and university-related research facilities that are underserved or unserved, and develops clear strategies for each institution, each state, region, 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 R&E network collaborations that exist in most states, regionally, and nationally, while allowing for new ones to emerge where they are needed, and allowing for both local innovation and common national goals.

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[3] www.globaltimes.cn/page/202104/1221584.shtml
[4] 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
[5] 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.

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.

– Lisa Wilson, Associate Vice President for Research and Sponsored Programs, Clarke Atlanta University

The final outcome must be to complete fiber optic-based connectivity to each and every community college, minority serving institution, college and university campus, and research center[6] 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 encourage 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.[7] To build this country's universities, the Morrill Act of 1862 gave 30,000 acres per member of Congress from every state and territory to be used in establishing a "land grant university." Today we need "fiber grant colleges and universities" in order to begin to address the complex issues we face nationally and globally.

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 operate infrastructure, but more importantly, can also share best practices, provide training in areas such as data science and cyber-system R&D, infrastructure security, identity management and technology; and negotiate group commercial arrangements.[8]

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.[9] In some states, connectivity to all institutions is incomplete while in other states and parts of the US territories and tribal lands, adequate connectivity for all research and education institutions is highly uneven and incomplete.

To fully realize a competitive advantage in R&E infrastructure, new funding and programs must go beyond just connectivity improvements, which are critical, but must also provide the software and systems that secure R&E from threat actors and that enable collaboration in a trusted open environment. The tools for

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

[7] 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.

[8] "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

[9] "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

this activity, like the network components, will need to be realized at local, state, and national levels and funding must be allocated accordingly.

Systems and approaches need to be enabled nationally, including those activities that no institution can do alone, like identity federation software, security analytics, data movement, and storage. The much larger task of implementing those solutions must be supported locally – with local funding where appropriate, and through other support mechanisms in areas of low economic capacity, with the appropriate staff development, training, facilities, and workforce aspects fully addressed.

Human Capacity Building[10]

R&E 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, maintain, and continue to develop new concepts in R&E infrastructure and its applications 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, Historically Black Colleges and Universities, Hispanic Serving Institutions, Alaska Native and Native Hawaiian Serving Institutions, Asian American and Pacific Islander Serving Institutions, and community colleges, 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 R&E 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.

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*[11]:

"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.**

[10] 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."
[11] *Lewis Latimer Plan for Digital Equity and Inclusion*, a collaboration commissioned by the National Urban League, March 30, 2021.

- **Using the networks to improve how we deliver essential services, in particular in workforce development, health care, and education."[12]**

To which we would add: connect, engage, and empower all community colleges, minority serving institutions, and all colleges and universities to R&E infrastructure in order to ensure opportunities are commensurate with the immense talent and imagination we find in every community, so that American leadership and competitiveness can flourish, and can thereby enable science and network communities to develop the groundbreaking concepts and systems that drive our progress and leadership in the community of nations and improve our quality of life.

Action Plan:

These aspirations 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 in phases. 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 college student 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, trust and identity tools, 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.

There are several federal agencies that have the expertise and leadership to ably lead this effort, including the Networking and Information Technology Research and Development program, 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 bottom-up assessment and 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-phased process that focuses on the equitable outcomes as measured through results and also measured against the comprehensive and integrated plan.

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[12] Ibid

It is with this recognition of current structural deficiencies that we recommend a plan in three phases 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 agencies selected to lead this program, along with a coordinating body — similar to the way that NITRD served in the development and spread of the Internet — the authority to receive comments from stakeholders and to set new rules and processes that assure the outcomes described here.

To be fully successful, we must also strive for deeper engagement with and training of the community that supports this infrastructure, developing an action plan to drive and sustain our cyberinfrastructure at the leading edge. Such state-of-the-art (intelligent) infrastructures, and the services and applications they support, will define whether we lead or trail competing nations: in education, economic strength, innovation, and enduring leadership on the world stage.

Outline: Action Plan and Funding Timeline

Our plans call for a $4.989 Billion one-time investment, to be completed in three phases, extending the nation's research and education infrastructure and R&E leading-edge capabilities to every community college, minority serving institution, and college and university, enabling innovation while ensuring every college student is connected into an advanced digital fabric.

Awards in all categories should be prioritized to nonprofit R&E networks, tribal, and/or across all community colleges, minority serving institutions, colleges and universities, and university research-affiliated organizations that can then form partnerships, as appropriate, with private sector companies to implement the programs, with a goal of engaging our nation's diverse system of 3,900 accredited, degree-granting higher education institutions.

Phase 1: Focus on Needs Assessment, Training, Planning, Local Organizational Development, Federal Agency Coordination, and Tools Development ($363.75 Million)

- $5M per state and territory planning grant resulting in a needs analysis for each
- Up to $1.25M to each state and territory for consortia building and training
- $10M national coordinating strategy planning grant
- $7.5M for up to 5 multi-state consortia building and training
- $500K/year for 5 years to support inter-agency federal government coordination

Phase 2: Transition from Planning to Initial Implementation ($1.425 Billion)

- Up to $25M per state and territory to begin implementation identified in plan
- $50M for development of collaboration tools, security, and infrastructure at the national level
- Develop and release program rules for Phase 3 program, based on Phase 1 needs analysis and Phase 2 implementation

Phase 3: Full Implementation Programs ($3.25 Billion)

- $3.25B in needs-based grants, linked to the prior years planning activities, to address local, state, regional, national, tribal and territorial needs and gaps
- Up to $150M of the total for undersea cable R&E capacity to connect territories, Alaska, and Hawaii

Phase 1 Activities

Phase 1 of the program focuses on needs assessment, training, planning, local organizational development, federal agency coordination, and tools development. This approach fully recognizes that a multi-phased 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, Phase 1 of the program should provide planning funding across the R&E infrastructure ecosystem to develop data, identify program needs, and begin training and staff development activities. Phase 1 should also allow national and federal resources to establish the framework for subsequent collaboration with the R&E 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. These planning grants will also allow these organizations to augment their efforts with outside expertise, including training and support so local institutions can get up to speed faster.
    - Additionally, a $10 Million planning grant should be awarded to an existing national nonprofit organization or organizations 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 levels, and investments in training related to data science, identity management, infrastructure operations, security, and cloud computing will be critical.
    - A total of $55 Million should be allocated for consortia building, participation and training grants of up to $1M per year each of the 50 states and territories should be provided. The

purpose of such grants is to offer training and participation in community building activities across research and education consortia.

- 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 participation 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 agencies 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 $1.5 Million per year during the program performance period for staffing and other support of the program.

- **Coordinate R&E 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 R&E infrastructure programs coordination should be established, perhaps within the National Science Foundation, to assure that programs are coordinated across agencies and to assure R&E 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 R&E 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.

Phase 2 Activities

The Phase 2 program transitions from planning to implementation. An initial investment of up to $25 Million per state and territory, predicated on needs identified in the planning inventory from Phase 1, across every state and territory, should be granted to the organizations that submitted accepted needs analysis 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 tribal broadband funds should provide support for R&E institutions located within tribal lands. Through Phase 2 funds, every state and territory should be able to begin security, identity management, collaboration tools, infrastructure, and additional planning or development activities necessary to advance their state or territory's plan. Awards should be prioritized to nonprofit R&E networks, tribal, and/or university-affiliated organizations that can then form partnerships as appropriate with private sector companies to implement the programs.

A $50 Million award should be granted to a nonprofit national research and education network for national R&E infrastructure, training, and coordination activities, including middle-mile infrastructure development; trust, identity, wireless management, and other collaboration tools; 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.

Phase 3 Activities

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

- $3.2 Billion would support a connection program with the goal of connecting every institution, every college student, 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 the needs identified in planning activities. In addition to state, territory, and tribal R&E infrastructure needs, this funding should also be available for national interstate R&E 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 $150 Million should be made available from the total $3.2 Billion to secure long-term R&E capacity to underserved R&E entities in Guam, American Samoa, Northern Mariana, Puerto Rico, Hawaii, Alaska, and US Virgin Islands, including the undersea submarine cable capacity for R&E networks.
- Awards in all categories should be prioritized to nonprofit R&E networks, tribal, and/or university-affiliated organizations that 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:

- **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 such programs as VISTA, Peace Corps, Teach for America, and/or 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])* Such an organization would address qualifications of its volunteers, training of volunteers, and complexities such as liability protections.

- **Teach digital literacy.** 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(s). 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.*
>
> ***– Matthew Rantanen, Director of Technology, Southern California Tribal Chairmen's Association***

- **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. Experts would need to be vetted by their institutions to ensure quality control. 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 to contribute to research and unable to further their own learning. We should do all we can to include them.*
>
> ***– Inder Monga, Executive Director, Energy Sciences Network (ESnet)***

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[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

Examples: How R&E 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 R&E networks, and major commercial R&E cloud services.
https://cenic.org/news/indigenous-tribes-in-southern-california-are-now-participants-in-pacific-wa

Education

R&E infrastructure and services could be further extended to the K12 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, museum, 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 K12 schools, libraries, and higher education locations are all connected to common research and education networks – a critical activity during the pandemic and 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 R&E networks like MAX and Internet2.
https://www.maxgigapop.net/

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' 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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