Abstract: Measuring Library Broadband Networks for the National Digital Platform

Investigators at Simmons College led by Dr. Colin Rhinesmith along with partners New America's Open Technology Institute (OTI) and Internet2 request $568,672 for the 24-month research project, "Measuring Library Broadband Networks for the National Digital Platform." The project will examine how public libraries can utilize broadband measurement tools and training materials to develop a better understanding of the relationship between library network infrastructure and digital services. The project team will draw upon their expertise in digital equity research, broadband measurement, and network management to investigate how advanced broadband measurement capabilities can inform the capacity of the nation's public libraries to support the online software applications and social and technical infrastructure needed to promote the National Digital Platform (NDP) in U.S. public libraries.

The project team will collaborate with a research panel of 10-15 public librarians and network administrators from not-for-profit Research and Education (R&E) Network partners in rural, suburban, and urban communities across the U.S. over the two-year grant period to gather quantitative and qualitative data using participatory design approaches. The data will be used by the library community to: (1) understand broadband speeds and quality of service that public libraries receive; (2) assess how well the broadband service and infrastructure are supporting their communities' digital needs; (3) understand broadband network usage and capacity, along with additional data that would be useful to public libraries in providing their communities with online software applications and social and technical infrastructure; and (4) increase their knowledge of networked services and connectivity needs.

Findings from the research will be used to create the project's three deliverables: an open-source and replicable broadband measurement platform; a broadband measurement platform training manual for public librarians; and a final report on the project. The team will deploy the measurement platform and training manual to scale the project with 50-60 public libraries in collaboration with Internet2 and their state and regional Research and Education Network partners across the U.S. OTI will help develop the measurement platform, device management, and data visualization tools with the research panel, and Internet2 will provide assistance with the training manual, which will build on the technical broadband assessment toolkit developed as part of their current IMLS-funded "Toward Gigabit Libraries" project. The team will work together to deliver the final report. The project will have the capability to fundamentally change how broadband is measured in public libraries of various sizes across the nation. The research should appeal to academics, practitioners, and policymakers interested in responding to the challenges of developing a more integrated, equitable, and dynamic set of interconnected infrastructures for delivering digital library services.

Measuring Library Broadband Networks for the National Digital Platform

Investigators at Simmons College led by Dr. Colin Rhinesmith along with partners New America's Open Technology Institute (OTI) and Internet2 request $568,672 for the 24-month research project, "Measuring Library Broadband Networks for the National Digital Platform." The project team will draw upon their expertise in digital equity research, broadband measurement, and network management to investigate how advanced broadband measurement capabilities can inform the capacity of the nation's public libraries to support the online software applications and social and technical infrastructure needed to promote the National Digital Platform (NDP). In this project, we will collaborate with public librarians and network administrators from not-for-profit Research and Education (R&E) Network partners in rural, suburban, and urban communities across the U.S. to gather quantitative and qualitative data using participatory design approaches. Findings from our research will be used by the library community to: (1) understand the broadband speeds and quality of service that public libraries receive; (2) assess how well broadband service and infrastructure are supporting their communities' digital needs; (3) understand broadband network usage and capacity, along with additional data that would be useful to public libraries in providing their communities with online software applications and social and technical infrastructure; and (4) increase their knowledge of networked services and connectivity needs. Findings from the research will be used to create the project's three deliverables: an open-source and replicable broadband measurement platform; a broadband measurement platform training manual for public librarians; and a final report on the project.

1. Statement of National Need

A foundational element of the National Digital Platform (NDP) is a public library's broadband internet capability, which includes knowledge of networked services and connectivity needs. Libraries were among the first public institutions to provide free internet access in the 1990s and have remained one of the only locations in a community to provide the public access to computers, internet, and digital literacy training (Bertot, Real, & Jaeger, 2013; Bertot, McClure, & Jaeger, 2008; Jaeger, Bertot, McClure, & Langa, 2005). But since the economic recession in the late 2000's, public libraries have faced immense challenges in sustaining such free access along with traditional library services. Cuts to public funding and increased pressure on library network infrastructure from the public's demand for digital content and services are common challenges facing most public libraries, but are even more pressing in rural and tribal libraries (Real, Bertot, & Jaeger, 2014; Jorgensen, Morris, & Feller, 2014).

For over a decade, broadband scholars and policy experts have argued that as broadband infrastructure continues to support a range of applications and services the problems of measurement become even more complex and difficult (Flamm, Friedlander, Horrigan, & Lehr, 2006). As such, having access to such data on broadband speeds and quality of service at a local, more granular level is core to understanding both the relationship between public library infrastructure and services, as well as local, state, and national broadband planning efforts. In addition, having access to reliable indicators is key to understanding nationwide challenges to broadband access, adoption, and use (Flamm et al., 2006; Bertot & McClure, 2007). Others have argued that having more precise data on quality of service issues is also critical to understanding factors shaping our national digital divide (Prieger & Hu 2008).

Public libraries play a critical role in connecting individuals and families, particularly in low-income and rural areas across the U.S., to the public access technology and digital literacy skills needed to successfully participate in our digital economy and information society. As such, public libraries can serve as key partners in national efforts to develop broadband measurement tools and training materials to increase knowledge of networked services and connectivity needs among community anchor institutions. Having access to such data in public libraries can assist stakeholders not only in understanding the contours of the information society but also to learn how such data can inform practical and policy solutions to promote social and economic productivity across the U.S.

Since 1994, the *Public Libraries and the Internet* and *Public Library Funding and Technology Access* studies, and later the *Digital Inclusion Survey*, have tracked the growth of internet connectivity in public libraries and have been used to frame federal level, public library internet policies. They have successfully accomplished this task over time by providing useful data on internet connectivity and technology services in public libraries and have provided summary national-level estimates of internet connectivity in our nation's public libraries (Bertot, Jaeger, Wahl, & Sigler, 2011; Bertot, Real, Lee, McDermott, & Jaeger, 2015; Mandel, Bishop, McClure, Bertot, & Jaeger, 2010). These foundational studies have not only helped to identify the ongoing broadband challenges and needs of the public library community nationwide, but also the increasing digital expectations of their patrons. In sum, this important research helped to paint a picture of our national library broadband infrastructure to support emerging digital library services and capabilities.

However, there are currently no large scale efforts to collect automated, longitudinal measurement data on broadband speeds and quality of service issues at a local, granular level inside public libraries over time, including when buildings are closed yet wireless connectivity often remains available. This research project would address this gap.

2. Project Design

Research Question: Our project will address a gap in the scholarship by addressing challenges that findings from previous studies have identified, including by responding to the following:

- **Core Research Question**: *How can public libraries utilize broadband measurement tools and training materials to develop a better understanding of the relationship between library network infrastructure and digital services?*

Answers to this question can help strengthen public libraries as essential anchor institutions and partners in providing data to address the digital needs of their communities. The findings from our study will also assist the nation's public libraries in responding to the challenges of developing a more integrated, equitable, and dynamic set of interconnected infrastructures for delivering public computing access and digital library services.

The project team will respond to the research question by using participatory research methods (Schuler, & Namioka, 1993) to collaboratively design, implement, and evaluate a broadband measurement platform and training manual for public libraries and their communities, and will leverage M-Lab's deep roots in the academic internet measurement community to select relevant measurement tests (see Supportingdoc1.pdf) and apply analysis techniques used by those researchers (M-Lab, 2018). To accomplish this goal the team will work with a research panel of 10-15 individuals, including library staff/managers, network administrators, and other stakeholders, representing public libraries across the U.S. over the two-year grant period to provide their institutions with a means of gathering automated measurements of their broadband connection speed and quality of service. The project team will continue to work with the partnering libraries beyond the grant period to continue to assist them in continuing to monitor and maintain the broadband measurement platform and to revise and update the training manual.

Broadband Measurement Platform

The broadband measurement system that will be developed in our project using participatory design research methods will build on OTI's previous work in Alexandria, Virginia city public schools, where connection speeds and latency of classroom connections were measured using the Network Diagnostic Tool provided by Measurement Lab (M-Lab) (Ritzo, 2017A). Measurements were run automatically over the course of two months from small computers which were placed in up to three classrooms per school. By conducting automated measurement tests on a randomize basis over time, from different vantage points within the school network, researchers were able to look at connection quality trends over time, for example during peak and non-peak time periods. The system used for measurement in Alexandria was an early prototype, and was an opportunity to uncover the challenges of automated measurement within highly managed networks. In this project, the measurement system will be refined and expanded based on the needs expressed by the library community.

The project team will also consider new techniques which now exist to measure both speed and quality of service (QoS) characteristics of library broadband networks. Passive networked devices the size of a pack of cards running open-source broadband measurement platforms, such as Project BisMark, Network Diagnostic Tool, or PerfSonar, can be installed at library broadband ingress sites to monitor and measure broadband speeds and QoS, i.e., latency and jitter, as well as identify the broadband service provider. As such, public libraries need access to accurate broadband data and reliable networks to inform their ability to support emerging software applications and other networked services to meet the digital demands of their communities.

The measurement system is envisioned to consist of three main components:

1. One or more small computers, connected to the library's network, will be configured to run a range of internet measurement tests. Placement of these computers will measure internet connection from different vantage points, providing a diversity of measurements that align with the access provided to library facility as a whole, to patrons on public access computers or using WiFi, and to staff using wired or wireless connections.

2. A cloud-based service where test data collected by the small computers will be sent, analyzed, and visualized for research staff and library partners. This service will provide library partners and research staff access to the collected data, and provide a visualization and analysis of the data collected.
3. A second cloud-based service used to administer, provision, and update all of the measurement computers to be used on the project. This will allow easy setup of new devices, and to access and troubleshoot them remotely during the course of the first and second stages of this research pilot.

A prototype version of the system described above has been developed following on OTI's previous research (Ritzo, 2017B) and will be used as a demonstration tool with the research panel of representatives from the 10-15 libraries. This group will be brought together for an in-person participatory design workshop in the fall 2018, where the project team will work to identify both the technical specifications for the pilot measurement system, as well as some of the initial content to be included in the broadband measurement platform training manual, which will build on Internet2's current IMLS-funded technical broadband assessment toolkit (Spellman, Werle, Block, 2017). In the interest of producing an end product that is scalable and openly licensed, the project team will focus on using open source tools wherever possible. However, given the past use of the Ookla speed test in the *Digital Inclusion Survey* (Bertot, Real, Lee, McDermott, & Jaeger, 2015), the project may also include non-open source tests such as Ookla at the discretion and advice of our advisory board and stakeholder panelists.

At the conclusion of the initial stakeholder participatory design workshop in the fall, our goal will be to have identified the following: the specific network measurement tests (see Supportingdoc1.pdf) that will be available in the measurement system; the types of additional data that would be helpful to collect from existing library IT systems; and a sense of how visualizations of this data might be displayed in order to provide meaningful and actionable analysis. After the initial workshop while development is beginning, project staff will visit the 10-15 libraries in the initial research panel and conduct three additional interview protocols: one with librarians, one IT staff, and one or more focus groups with patrons.

This data gathered during both the initial participatory design workshop and fieldwork visits during the first two phases of the project in Year 1 will provide the information needed to finalize the broadband measurement platform and training manual needed to scale the project to 50-60 public libraries in rural, suburban, and urban libraries across the U.S in Year 2 (see "Schedule of Completion" docs). By the end of the grant period, OTI will help to develop an open-source and replicable broadband measurement platform, which includes a testing platform, device management, and data visualization system, as well as a final report on the research.

Broadband Measurement Training Manual

Working with the librarians from the pilot libraries and the project team, Internet2 will provide assistance with the broadband measurement training manual, which will build on the technical broadband assessment toolkit developed as part of their current IMLS-funded "Toward Gigabit Libraries" (#RE-00-15-0110-15) project and leverage the key lessons learned on how to effectively engage rural librarians

with minimal technical expertise. The manual will include complete documentation of setup, system implementation, ongoing use, as well as a range of easy to understand educational materials about broadband measurement written for library staff with little to no networking background.

The research conducted to inform both the broadband measurement platform and training manual, as well as to build on findings from existing research in the field, will benefit the intended audience by helping public libraries and their communities better understand the relationship between infrastructure and services, as well as helping libraries to develop the capabilities needed to work toward setting service quality benchmarks. These issues and considerations have been recommended by scholars as key areas for future research (Bertot, Jaeger, Wahl, & Sigler, 2011). In addition to investigating these key areas, our project will gather quantitative and qualitative data to examine the following related topics (T):

T1. Understand broadband speeds and quality of service that public libraries receive;

T2. Assess how well the broadband service and infrastructure are supporting their communities' digital needs;

T3. Understand broadband network usage and capacity, along with additional data that would be useful to public libraries in providing their communities with online software applications and social and technical infrastructure; and

T4. Increase their knowledge of networked services and connectivity needs.

The research findings will assist public librarians as their institutions continue to evolve in providing a robust broadband foundation for the NDP. The research will also help inform libraries' capacity to support new, QoS sensitive applications, including: 4K streaming, HD video conferencing, online testing, virtual reality, and telemedicine. Further, the public library community will use the data to help navigate key policy issues, including the use of Universal Service Funds/E-Rate and the capabilities of our nation's public libraries to support current and evolving patron needs across diverse communities.

The project team along with our research panel and experts on our Advisory Board will help us respond to our data gathering, analysis, and final reporting in order to answer our research question and address the additional topics stated above. Our Advisory Board members include broadband research and policy experts with experience working in or with public libraries related to their network infrastructure and digital service needs. The findings from the research, which will be used to develop the broadband measurement platform and training manual, will also help build on findings from the IMLS-funded research project, "At the Edges of the National Digital Platform: Rural Library Hotspot Lending Programs" (#RE-00-15-0110-15) that looked at how rural libraries are addressing the challenges of Internet connectivity with hotspot lending programs (Strover, Whitacre, Rhinesmith, & Schrubbe, 2017).

Theoretical Framework: The conceptual framing for the research is focused at the intersection of Library and Information Science (LIS) and Science and Technology Studies (STS). This focus on the interplay

between public library services (LIS) and infrastructure studies (STS) will guide the project's overall research to help public libraries develop a better understanding of the relationship between library network infrastructure and digital services.

Existing research on digital inclusion and broadband adoption within LIS provides this project with both theoretical and practical knowledge on the role of public libraries in providing diverse populations with access to computers and networked services to support social and economic outcomes. This research has not only looked at the role of libraries in providing individuals and families with a sense of comfort as a precursor to their technology use (Rhinesmith, 2012), but it has also looked at the potential of public libraries to promote broadband adoption (Whitacre & Rhinesmith, 2015). This literature has also recognized the importance of investigating public library services within an ecological model (Dailey, Bryne, Powell, Karaganis, & Chung, 2010; Rhinesmith, 2016) that recognizes other important local actors that have a stake in digital equity.

The second scholarly approach that contributes to this study's theoretical framework is drawn from infrastructure studies within STS. This approach provides a foundation upon which to consider the social and technical forces shaping the design, implementation, and evaluation of network infrastructure both inside and beyond local organizational contexts (Edwards, Bowker, Jackson, & Williams, 2009; Sandvig, 2013; Star & Ruhleder, 1996). This conceptual framing offers our project with an opportunity to investigate how the social and technical aspects of library broadband networks and digital needs influence the knowledge, attitudes, and behaviors of public librarians, networked administrators, and library patrons. It also provides a lens through which to analyze the impacts of internet service providers and other networked actors in shaping broadband measurement results. In this way, infrastructure studies contributes an analytical framework for understanding the tension between multiple actors to learn how these factors come together to shape both library broadband networks and digital services.

This theoretical framework has several benefits for the intended audience, because of its focus on both the interconnected social and technical aspects of the project. The theoretical framework should be of interest to multiple audiences, including scholars, practitioners, and policymakers concerned with the challenges and opportunities in understanding the relationship between library network infrastructure and digital services and its impacts on librarians, networked administrators, and library patrons in diverse communities across the U.S.

Sample: As mentioned above, the participants in our study will focus primarily on a panel of 10-15 individuals in rural, suburban, and urban communities across the U.S. over the two-year grant period. These individuals will include library staff/managers and network administrators who will help us to design the broadband measurement platform and create the training manual in the first two phases of the project. The findings will help us to finalize the measurement platform and training manual which we will use to scale the pilot to up to 50 libraries across the U.S. Internet2 will assist us in identifying participants for both the research panel and the wider group of participating libraries in collaboration with their Research and Education (R&E) Network members and State Library agencies from across the U.S. In order to gain a better understanding of the relationship between library network infrastructure and digital

services, we will recruit library patrons to participate in our focus groups at the 10-15 libraries that will serve as the research sites for our panel of participants during the grant period.

Data Collection: The project team will collaborate with the research panel to gather quantitative and qualitative data. The quantitative data will be collected primarily through the broadband measurement devices after they have been implemented in each of the 10-15 partnering public libraries. In Year 2 of the project, a survey will be designed and implemented with the group of initial libraries and the broader group of 50 libraries that will seek to gather data to answer the research question, while continuing to build on the findings from Year 1. The researchers will gather qualitative data using participatory design methods (Schuler, & Namioka, 1993) during the fall 2018 workshop to assist the project team in determining the needs of the community to inform the design and implementation of the measurement platform and training manual. The qualitative data will also include interviews with our research panel over the two-year grant period. We also plan to conduct focus groups with library patrons on their digital experiences inside libraries to help us gather data to understand the relationship between library network infrastructure and digital services. These focus groups will take place at least half of the partnering libraries participating in our research panel.

IMLS Agency-Level Goal 2: Community

The research will also gather data to ensure that the project team can effectively respond to the IMLS agency level performance goals. Our survey protocol for community partners will include required questions for IMLS Agency-level goals in the *Community* category, the results of which will be included in our final reporting. Additionally, we will collect and submit Grantee reported responses for the *Community* Performance Measure goal that will reflect a measurable change or outcome that our project intends to achieve.

Analysis: Quantitative data gathered through the broadband measurement platform will be analyzed through data analysis tools for time-series data such as Prometheus (Prometheus Authors, 2018) and Grafana (Grafana Labs, 2017), using statistical analysis tools such as RStudio (RStudio, 2016), and through custom designed visualizations based on input from the research panel of librarians and IT staff. The research team will also have the ability to export the data for statistical analysis in an outside software platform, such as SPSS. The qualitative data gathered from the participatory design workshop, interviews, and focus groups, as well as from the fieldwork visits with the 10-15 libraries in our research panel during the first year of the project, will be transcribed and uploaded as files into Dedoose for analysis. The researchers will use this software platform to code the data and develop themes for our analysis. The goal for our analysis will be to use our theoretical framework to guide how we look at both the quantitative and qualitative data, including being able to "triangulate" (Stake, 1995) multiple perspectives from library staff, network administrators, and patrons.

Findings from our data collection and analysis will be used to create the project's three deliverables: an open-source and replicable broadband measurement platform; a broadband measurement platform training manual for public librarians; and a final research report on the project. The research should appeal to

academics, practitioners, and policymakers interested in responding to the challenges of developing a more integrated, equitable, and dynamic set of interconnected infrastructures for delivering digital library services. The research will also build on current findings from over twenty years of research on public library internet services.

The researchers will publish the findings from this project widely in a broad range of venues, including scholarly journals and academic conferences, as well as in more public venues of interest to library practitioners, public policymakers, and other key stakeholder groups. The project team will work with our Advisory Board members to help disseminate the research findings widely. The team will also reach out to national associations, such as the American Library Association, to help us connect the deliverables with those who can act upon the results.

3. Diversity Plan

The research project plans to engage with underserved communities and their shared experiences, worldviews, and ways of learning by partnering with a diverse group of public libraries in rural, suburban, and urban libraries. Our project team has existing partnerships with small, rural, and tribal libraries, as well as larger urban libraries that serve diverse populations, including low-income, older adult, and homeless populations, as well as patrons with disabilities. Because poor communities and communities of color are often disproportionately impacted by the digital divide, we plan to partner with public libraries in these communities in order to build upon findings from previous studies research that have examined the relationship between broadband speeds and quality of service to issues of race and class (Prieger & Hu, 2008). The proposed project will engage with marginalized communities by inviting representatives from the communities to participate as either part of the research panel of initial 10-15 libraries, or as part of our broader network of 50-60 public libraries in diverse communities across the U.S.

4. National Impact

The overall goals of this research project are: (1) to extend and expand upon research and measurement initiatives seeking to understand and contextualize the broadband service and infrastructure needs of E-rate funded institutions; (2) build an easy-to-use broadband measurement system, using open source tools and infrastructure, with built in data analysis and visualization components, in collaboration with stakeholders from a broad range of libraries and communities; and (3) to develop a toolkit of instructional materials to accompany this broadband measurement system. The project will have the capability to fundamentally change how broadband is measured in public libraries of various sizes across the nation, as well as understanding whether E-Rate funded services are meeting the needs of libraries and their communities. In order to scale, the project will provide hands-on guidance on how to build the low-cost device measurement platform and install it in a library. The research will document the technical processes and software requirements needed to scale the device installations in public libraries across the nation. It will also report on the design processes used with library staff to develop useful and effective interfaces driven by user input from key stakeholders.

The project will help to strengthen public libraries as essential anchor institutions and partners in providing data to address the digital needs of their communities. By serving as partners in developing a

broadband measurement platform and training materials to better understand the relationship between infrastructure and digital services the project will help to increase knowledge of public library networked services and connectivity needs. The findings will also assist the nation's public libraries in responding to the challenges of developing a more integrated, equitable, and dynamic set of interconnected infrastructures for delivering public computing access and digital library services. We plan to sustain the project outputs and resources by continuing to provide participating libraries with updates to the broadband measurement platform as well as occasionally revisiting and updating the content in the training manual to help ensure that both the measurement devices and training materials stay current. This work will be sustained beyond the grant period through a continued partnership between Simmons College, OTI, and Internet2.

References

Bertot, J. C., & McClure, C. R. (2007). Assessing sufficiency and quality of bandwidth for public libraries. *Information Technology & Libraries*, *26*(1), 14-22.

Bertot, J. C., & McClure, C. R., & Jaeger, P. T. (2008). The impacts of free public internet Access on public library patrons and communities. *The Library Quarterly: Information, Community, Policy*, (3), 285-301.

Bertot, J. C., Jaeger, P. T., Wahl, E. E., & Sigler, K. I. (2011). Public libraries and the Internet: an evolutionary perspective. *Library Technology Reports*, (6), 7-18.

Bertot, J. C., Real, C. Lee, J., McDermott, A. J., & Jaeger, P. T. (2015). *2014 digital inclusion survey: Survey findings and results*. College Park, MD: Information Policy and Access Center. Retrieved from http://digitalinclusion.umd.edu/sites/default/files/uploads/2014DigitalInclusionSurveyFinalRelease.pdf

Bertot, J. C., Real, B., & Jaeger, P. T. (2016). Public libraries building digital inclusive communities: Data and findings from the 2013 digital inclusion survey. *Library Quarterly*, *86*(3), 270-289.

Dailey, D., Bryne, A., Powell, A., Karaganis, J., & Chung, J. (U.S.). (2010). *Broadband adoption in low-income communities*. Brooklyn, NY: Social Science Research Council. Retrieved from http://webarchive.ssrc.org/pdfs/Broadband_Adoption_v1.1.pdf

Edwards, P. N., Jackson, S. J., Bowker, G. C., & Williams, R. (2009). Introduction: An agenda for infrastructure studies. *Journal Of The Association For Information Systems*, *10*(5), 364-374.

Flamm, K., Friedlander, A., Horrigan, J., & Lehr, W. (2007). *Measuring broadband: Improving communications policymaking through better data collection*. Washington, DC: Pew Internet and American Life Project. Retrieved from http://people.csail.mit.edu/wlehr/Lehr-Papers_files/PIP_Measuring%20Broadband.pdf

Grafana Labs (2017). Grafana - The open platform for analytics and monitoring. Retrieved from: https://grafana.com/

Jaeger, P. T., Bertot, J. C., McClure, C. R., & Langa, L. A. (2006). The policy implications of internet connectivity in public libraries. *Government Information Quarterly*, *23*, 123-141.

Jorgensen, M., Morris, T., & Feller, S. (2014). *Digital inclusion in native communities: The role of tribal libraries*. Retrieved from http://www.atalm.org/sites/default/files/Report.pdf

Mandel, L. H., Bishop, B. W., McClure, C. R., Bertot, J. C., & Jaeger, P. T. (2010). Broadband for public libraries: Importance, issues, and research needs. *Government Information Quarterly*, *27*280-291.

M-Lab (2018). M-Lab Papers, Publications, and Regulator Filings. Retrieved from: https://www.measurementlab.net/publications/

Prieger, J. E., & Hu, W. (2008). The broadband digital divide and the nexus of race, competition, and quality. *Information Economics And Policy*, *20*, 150-167.

Prometheus Authors (2018). Prometheus - Monitoring system & time series database. Retrieved from: https://prometheus.io/

RStudio (2016). RStudio - Open source and enterprise-ready professional software for R. Retrieved from: https://www.rstudio.com/

Real, B., McDermott, A. J., Bertot, J. C., & Jaeger, P. T. (2015). Digital inclusion and the affordable care act: Public libraries, politics, policy, and enrollment in "Obamacare". *Public Library Quarterly*, *34*(1), 1-22.

Rhinesmith, C. (2012). Free library hot spots: Supporting broadband adoption in Philadelphia's low-income communities. *International Journal of Communication*, *6*, 2529- 2554.

Rhinesmith, C. (2016). *Digital inclusion and meaningful broadband adoption initiatives*. Evanston, IL: Benton Foundation. Retrieved from https://www.benton.org/inclusion-adoption-report

Ritzo, C. (2017A). *Measuring broadband in schools: A technical case study on applied internet measurement in preK-12 schools*. Washington, D.C.: New America Open Technology Institute. Retrieved from https://na-production.s3.amazonaws.com/documents/MBINS_Final.pdf

Ritzo, C. (2017B). *Deploying and Managing a Fleet of Measurement Kit Devices.* Washington, D.C.: New America Open Technology Institute. Retrieved from https://opentechinstitute.github.io/2017/10/deploying-and-managing-a-fleet-of-measurement-kit-devices/

Sandvig, C. (2013). The internet as an infrastructure. In W. H. Dutton (ed.), *The Oxford handbook of internet studies* (pp. 86–108). Oxford, UK: Oxford University Press.

Schuler, D., & Namioka, A. (1993). *Participatory design: Principles and practices*. Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc.

Spellman, S., Werle, J., & Block, C. (2017). Toward gigabit libraries. *D-Lib Magazine*, *23*(5/6). Retrieved from http://www.dlib.org/dlib/may17/spellman/05spellman.html

Stake, R. (1995). *The art of case study research*. Thousand Oaks, CA: SAGE Publications.

Star, S. L., & Ruhleder, K. (1996). Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information Systems Research*, *7*(1), 111–134.

Strover, S., Whitacre, B., Rhinesmith, C., & Schrubbe, A. (2017). At the edges of the national digital platform. *D-Lib Magazine*, *23*(5/6). Retrieved from http://www.dlib.org/dlib/may17/strover/05strover.html

Whitacre, B., & Rhinesmith, C. (2015). Public libraries and residential broadband adoption: Do more computers lead to higher rates? *Government Information Quarterly*, *32*(2), 164-177.

Schedule of Completion

	Phase 1 - 2018						**Phase 2 - 2018-2019**						**Phase 3 - 2019**						**Phase 4 - 2020**				
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Dec	Jan	Feb	Mar	Apr	May
Task 1: Identify participants for research panel	σ																						
Task 2: Develop interview and focus group protocols																							
Task 3: Host participatory design workshop					σ																		
Task 4: Confirm libraries for initial pilot																							
Task 5: Decide on best broadband measurement test platforms																							
Task 6: Finalize list of Advisory Committee members																							
Task 7: Analyze qualitative data from participatory design workshop																							
Task 8: Develop library patron focus group and interview protocols																							
Task 9: Design broadband usage survey instruments																							
Task 10: Build the broadband measurement device																							
Task 11: Leverage existing measurement platforms to measure and test																							
Task 12: Build cloud service where devices are managed																							
Task 13: Launch small scale, prototype deployment for library feedback												σ											
Task 14: Collect quantitative data on broadband speeds and QoS																							
Task 15: Develop outreach and training materials																							
Task 16: Conduct focus group and interviews w/stakeholder groups																							
Task 17: Finalize measurement tool and training manual to scale project												Δ											
Task 18: Continue to iterate on broadband measurement tools																							
Task 19: Work with R&E network to scale the project																							
Task 20: Deploy tool & manual to 50-60 libraries targeting multiple types																		Δ					
Task 21: Conference call with Advisory Board members	σ						σ						σ					σ					
Task 22: Complete analysis of quantitative and qualitative data																							
Task 23: Write up final report draft for feedback																							
Task 24: Revise final report draft based on feedback																							
Task 25: Submit final report to IMLS																							Δ
Task 26: Announce availability of raw data from research																							
Task 27: Publish research findings in journals, conferences, etc.																							Δ

σ = milestone Δ = deliverable

DIGITAL PRODUCT FORM

Introduction

The Institute of Museum and Library Services (IMLS) is committed to expanding public access to federally funded digital products (i.e., digital content, resources, assets, software, and datasets). The products you create with IMLS funding require careful stewardship to protect and enhance their value, and they should be freely and readily available for use and re-use by libraries, archives, museums, and the public. However, applying these principles to the development and management of digital products can be challenging. Because technology is dynamic and because we do not want to inhibit innovation, we do not want to prescribe set standards and practices that could become quickly outdated. Instead, we ask that you answer questions that address specific aspects of creating and managing digital products. Like all components of your IMLS application, your answers will be used by IMLS staff and by expert peer reviewers to evaluate your application, and they will be important in determining whether your project will be funded.

Instructions

You must provide answers to the questions in Part I. In addition, you must also complete at least one of the subsequent sections. If you intend to create or collect digital content, resources, or assets, complete Part II. If you intend to develop software, complete Part III. If you intend to create a dataset, complete Part IV.

PART I: Intellectual Property Rights and Permissions

A. Creating or Collecting New Digital Content, Resources, or Assets

A.1 What will be the intellectual property status of the digital products (content, resources, assets, software, or datasets) you intend to create? Who will hold the copyright(s)? How will you explain property rights and permissions to potential users (for example, by assigning a non-restrictive license such as BSD, GNU, MIT, or Creative Commons to the product)?
Explain and justify your licensing selections.

Software produced under this program will be assigned an MIT license, as is consistent with other software produced by New America’s Open Technology Institute (OTI) for use with the M-Lab platform. The MIT licence is a permissive license that places only limited restriction on reuse. Data produced using M-Lab tools integrated into the software will be licensed using the Creative Commons Zero license, consistent with M-Lab's licensing practice for data produced by tests running on the M-Lab platform. Content and other digital products produced by the program will be licensed using the Creative Commons Attribution-Noncommercial-Share-Alike 4.0 license which allows reuse with attribution for noncommercial use. Copyrights for software produced will be held by New America.

A.2 What ownership rights will your organization assert over the new digital products and what conditions will you impose on access and use? Explain and justify any terms of access and conditions of use and detail how you will notify potential users about relevant terms or conditions.

New America will not assert ownership rights or impose conditions on access and use of software products produced in this program, other than the attribution requirement for reuse of content or resources licensed under the Creative Commons 4.0 license.

A.3 If you will create any products that may involve privacy concerns, require obtaining permissions or rights, or raise any cultural sensitivities, describe the issues and how you plan to address them.

The software products produced will not involve the collection of personally identifiable information (PII) or data that would require permission or rights, or which would raise cultural sensitivities. However, there is the possibility of library staff or patrons involved in this work to inquire about user privacy, permissions, and cultural sensitivities, concerning the data collected by tests being run from measurement devices. For example, someone might ask if internet measurement tests monitor the browsing behavior or content of users on the network, or guess that an upload or download test means that one's personal files were uploaded to the internet somewhere, or that some unknown file was downloaded. These concerns will be addressed by including specific descriptions of each test the measurement device will employ, how it functions, and what data is involved when the test is run. For example, the primary speed test used by M-Lab, NDT, generates random data specifically for the purpose of the test rather than relying on uploading or downloading specific files. Additionally, documentation concerning user privacy, PII, etc. will be included in the toolkit documentation.

Part II: Projects Creating or Collecting Digital Content, Resources, or Assets

A. Creating or Collecting New Digital Content, Resources, or Assets

A.1 Describe the digital content, resources, or assets you will create or collect, the quantities of each type, and format you will use.

OTI will deliver a replicable internet measurement and data visualization platform, consisting of open source software running on recommended measurement devices, which leverages the Measurement Lab platform and tools. The system may also make use of non-M-Lab and non-open source tests such as Ookla, as well as incorporate local network utilization data from switches, WiFi controllers, or other network infrastructure. OTI will also contribute to documentation of this platform, such that it could be replicated by individuals, libraries, etc.; and to generally broaden understanding of internet/broadband measurement in the library community.

Data produced by M-Lab measurement tests from devices placed in libraries will be submitted to M-Lab, but also will be maintained as a separate dataset in the data collection and visualization system mentioned above. The specific tests employed on the measurement devices as well as the resulting data the tests produce, will be determined iteratively with input from our stakeholders, but is likely to include the Network Diagnostic Tool (NDT), Neubot, and other tests supported by M-Lab. The amount of data gathered by each test in the measurement system will be variable according to the number of tests, devices, the frequency each test is scheduled to run, and the length of time in which data is collected. Test data will be stored in perpetuity by M-Lab. Data produced by non-M-Lab tests will be submitted to the test provider, per their policies, and will be retained by our measurement system.

Digital content in the form of documentation will be available in standard formats, but will also be adapted as relevant to the community of interest. The first stage of the project will involve a meeting of community stakeholders, where we will identify the formats or documentation platforms to use for digital assets. For example, we are considering the Software/Library Carpentry model for documentation about the technical components of the measurement platform, and a variety of formats for general documentation such as PDF, Word, LibreOffice, Google Docs, etc. However, these options will be adjusted based on the input of our stakeholder group.

A.2 List the equipment, software, and supplies that you will use to create the content, resources, or assets, or the name of the service provider that will perform the work.

OTI will use internal computing resources to create content, resources, or assets. Measurement test devices available in OTI's inventory include approximately 20 Odroid C1+ computers, which will be used to test pre-deployment versions of measurement software that will be deployed in stages 2-4 of the project, along with additional computers of similar form factor and/or system specifications purchased specifically for latter stages of the research. Additionally, OTI will leverage services provided by Resin.io, a platform as a service company which provides remote management and administration of these types of computing devices. Hosting of server side components of this system will provided for the grant term by virtual machines in the Google Cloud Platform, Linode, or on-premise as may be required for some monitoring and measurement services such as perfSONAR. Server side components will be developed such that they can be re-deployed via standard virtualization tools such as Docker, and hosted on the cloud or local infrastructure of choice to future users.

A.3 List all the digital file formats (e.g., XML, TIFF, MPEG) you plan to use, along with the relevant information about the appropriate quality standards (e.g., resolution, sampling rate, or pixel dimensions).

We will use digital file formats and specifications based on the needs identified by our stakeholders in stage 1 of the project.

B. Workflow and Asset Maintenance/Preservation

B.1 Describe your quality control plan (i.e., how you will monitor and evaluate your workflow and products).

OTI's standard practice with all M-Lab related code follows a rigorous quality control protocol during development. A new project typically begins as an idea, which is discussed by the team. If a decision is made to move forward, a design document is produced and discussed. Once a project is approved for development, all coding is done in a developer's fork or in a feature branch, and submitted to at least one other team member for code review. Reviewers must provide approval before any code is merged into a master or production branch. We also build quality control into the development process itself by using integration tests and commit hooks, which test the code for stylistic compliance. OTI also leverages continuous integration testing from Travis-ci.org/com on each commit and/or pull request. Lastly, software releases are tested on a testbed of hardware devices prior to any production roll out. OTI maintains a full hardware testbed of M-Lab servers and sample clients, as well as an inventory of measurement devices that will be used in this research, so any part of the measurement system can be tested independently or concurrently, in a separate, offline environment. For example, this testbed is used to benchmark and qualify new releases of M-Lab's server side code for NDT, and to perform automated testing from computers with a range of operating systems typically used by end users.

B.2 Describe your plan for preserving and maintaining digital assets during and after the award period of performance. Your plan may address storage systems, shared repositories, technical documentation, migration planning, and commitment of organizational funding for these purposes. Please note: You may charge the federal award before closeout for the costs of publication or sharing of research results if the costs are not incurred during the period of performance of the federal award (see 2 C.F.R. § 200.461).

All code will be hosted in shared Github repositories. Any other relevant digital assets will also be saved in a Github repository, such as technical documentation, toolkit resources, images, and final published documents. OTI is committed to using its organizational capacity to host these resources through our Github account. We are also open to hosting these resources elsewhere should project partners desire alternative or additional platforms or storage locations. OTI will utilize cloud computing resources, such as virtual servers on Google Cloud Services, to host data and visualization components specific to this project. Measurement test data will be stored on this cloud computing platform at least for the duration of this research project. All data collected by the project and the measurement system will be archived as a function of our final report, provided to participating libraries, and made available in perpetuity on an archiving platform to

be recommended by our advisory group and/or principal investigator. At the discretion and direction of stakeholders from the libraries that will be a part of this project, we can maintain these cloud resources after the completion of research or assist with migrating these resources. In any case, when these resources are spun down during the final phases of the research, summary resources, data exports, etc. can be made of the systems in their final state, and hosted statically alongside our documentation for reinstantiating them if needed.

C. Metadata

C.1 Describe how you will produce any and all technical, descriptive, administrative, or preservation metadata. Specify which standards you will use for the metadata structure (e.g., MARC, Dublin Core, Encoded Archival Description, PBCore, PREMIS) and metadata content (e.g., thesauri).

We will engage our advisory group and initial pilot workshop participants to determine what preservation standards, metadata structures, and metadata content are most useful to consider using. Simmons College is currently working to launch their institutional repository, which could also be used to host our project assets, and help define which metadata is needed for archival storage.

C.2 Explain your strategy for preserving and maintaining metadata created or collected during and after the award period of performance.

C.3 Explain what metadata sharing and/or other strategies you will use to facilitate widespread discovery and use of the digital content, resources, or assets created during your project (e.g., an API [Application Programming Interface], contributions to a digital platform, or other ways you might enable batch queries and retrieval of metadata).

As a part of our communications and outreach, we will inform target libraries, at a national level, about the availability of the tool, as well as include information about partners involved and process used to develop, pilot, and the Toolkit. Further, we will also allow the broader library, broadband, and digital inclusion community aware of these tools and our willingness to allow these other parties to augment or evolve the Toolkit to meet other library community needs or to assimilate into other, complementary digital library initiatives, tools, and projects.

D. Access and Use

D.1 Describe how you will make the digital content, resources, or assets available to the public. Include details such as the delivery strategy (e.g., openly available online, available to specified audiences) and underlying hardware/software platforms and infrastructure (e.g., specific digital

repository software or leased services, accessibility via standard web browsers, requirements for special software tools in order to use the content).

The central deliverable for the proposed project is a Toolkit that will be refined through a series of hands-on pilots and available for use or download by any interested party. As such, the sustainability of the project, and its central deliverable, the Toolkit, is critical. Internet2 will make available, via its website, the final Toolkit, and also ask its partners and supporters to make the Toolkit available for digital download as well. Internet2 will also create a collaboration space on
its social network site called Muse (https://www.internet2.edu/vision-initiatives/initiatives/us-ucan/projects) to facilitate best practices and knowledge sharing among the libraries and other stakeholders around the use of the Toolkit.

Software, analysis code, and other technical resources will be stored in a central repository on Github through project partner, OTI, where it will remain available after program completion.

D.2 Provide the name(s) and URL(s) (Uniform Resource Locator) for any examples of previous digital content, resources, or assets your organization has created.

IMLS-Funded "Toward Gigabit Libraries" Broadband Toolkit (draft version)
https://docs.google.com/document/d/1y-EBhVd8CAuTFqJLj6HAR5mQtjYzANhe6dL7bO0eh_o/edit?usp=sharing

IMLS-Funded "Toward Gigabit Libraries" Broadband Improvement Plan (draft version)
https://drive.google.com/open?id=1HE2Za1J-gPIHxzrq2TAHSLxHyuRKBsxkeKa2JrFIzZ4

Part III. Projects Developing Software

A. General Information

A.1 Describe the software you intend to create, including a summary of the major functions it will perform and the intended primary audience(s) it will serve.

The software that will be developed for this project will have three primary components described below. The requirements for each of these components will be developed using participatory methods with our stakeholder pilot group. As such, the components and functions described below are generalized to some degree, knowing that additional needs or changes may be required once we have completed the initial project workshop with participants from 10-15 libraries.

1. ***Client Test Runner*** - Software running on each network measurement device will run automated network measurement tests and sending the resulting data to the cloud service described in #2 below. This software will be installed on each measurement device, which will receive its configuration from the cloud service described below. This

software will be used by the project team, but will also be of interest to IT staff or library staff with technical backgrounds.

2. ***Data Receiver, Visualizer, and Archiver Cloud Service*** - Cloud service software will be developed to receive test from data each measurement device (client), archive it, and provide visualization of the data for analysis. This cloud service will also provide authentication and authorization functions, to provide program staff and designated library or IT staff from partner libraries the ability to login, manage device configurations, and explore visualizations of collected network measurement data. This service will also provide a plugin architecture to allow for integration of data from external IT systems such as switches or WiFi controllers. For external systems that cannot be integrated directly, an upload feature will be provided. Wherever possible, the software used for components of the client coordinating cloud service will use existing open source software frameworks and services. This software component will run on a server, virtual machine, or cloud hosting provider, and will be developed with portability in mind, such that the component could be installed in a variety of environments.
3. ***Client Provisioning and Management Cloud Service*** - We will subscribe to a second cloud-based service called *Resin.io* to administer, provision, and update all of the measurement computers to be used on the project. This will allow easy setup of new devices, and to access and troubleshoot them remotely during the course of the first and second stages of this research pilot. *Resin.io* is committed to open source release of their entire codebase, and their commercial offerings help sustain this development path. Their paid service tiers provide a turnkey service which we will use on this project, but we also expect that all components of their service will be open sourced, and available for technical implementers to replicate in the not distant future.

A.2 List other existing software that wholly or partially performs the same functions, and explain how the software you intend to create is different, and justify why those differences are significant and necessary.

While many network measurement projects have developed a similar system for single measurement tests, i.e. code runs test from a computing device and sends data elsewhere, to our knowledge a single open source system that implements multiple network measurement tests and provides a central server for data storage and analysis has not been implemented.

In cases where an existing open source software could be used to meet the requirements for any one system component, the team will leverage that software. The monitoring and time-series database software, Prometheus, is one example. Prometheus is likely to be used as a component of the Data Receiver, Visualizer, and Archiver Cloud Service, since our team knows it well and Prometheus has a strong user base and support community. Additionally, web application frameworks such as Flask will likely be selected for user interface and systems integration components.

B. Technical Information

B.1 List the programming languages, platforms, software, or other applications you will use to create your software and explain why you chose them.

Our team is well-versed in programming languages for such as Python, JavaScript, and HTML. We also have in-depth experience with many open source software which will be used for some components of the measurement system. In general, we will select programming languages based on input from our advisory group and pilot stakeholders and our team's expertise with the language. For third party open source or proprietary software we will ensure that the product has a strong user base and support community.

B.2 Describe how the software you intend to create will extend or interoperate with relevant existing software.

The measurement device software we intend to create will use multiple network measurement software products, and will send data to a central service. As such we are designing a client software that will enable the interoperability of these tests to be scheduled and run from a single computer, instead of installing and running each measurement test separately.

Similarly, most existing open source network measurement software tests submit their results to a central storage location provided by the developers of that service. In the case of M-Lab tests, the resulting data from multiple tests are stored centrally and made available by M-Lab, but in a general format that is specific to the M-Lab community alone. Thus the *Data Receiver, Visualizer, and Archiver Cloud Service* will provide a central storage and analysis service for specific communities to use, rather than the general use case described above for M-Lab, or similar services provided by individual measurement test developers.

B.3 Describe any underlying additional software or system dependencies necessary to run the software you intend to create.

All software to be developed for the measurement devices and servers will require the Linux operating system.

B.4 Describe the processes you will use for development, documentation, and for maintaining and updating documentation for users of the software.

OTI's standard practice with all M-Lab related code follows a rigorous quality control protocol during development. A new project typically begins as an idea, which is discussed by the team. If a decision is made to move forward, a design document is produced and discussed. Once a

project is approved for development, all coding is done in a developer's fork or in a feature branch, and submitted to at least one other team member for code review. Reviewers must provide approval before any code is merged into a master or production branch. We also build quality control into the development process itself by using integration tests and commit hooks, which test the code for stylistic compliance. OTI also leverages continuous integration testing from Travis-ci.org/com on each commit and/or pull request. Lastly, software releases are tested on a testbed of hardware devices prior to any production roll out. OTI maintains a full hardware testbed of M-Lab servers and sample clients, as well as an inventory of measurement devices that will be used in this research, so any part of the measurement system can be tested independently or concurrently, in a separate, offline environment. For example, this testbed is used to benchmark and qualify new releases of M-Lab's server side code for NDT, and to perform automated testing from computers with a range of operating systems typically used by end users.

B.5 Provide the name(s) and URL(s) for examples of any previous software your organization has created.

Measuring Broadband in Alexandria City Public Schools

- Project page:
  - https://www.newamerica.org/in-depth/measuring-broadband-alexandrias-schools/
- Data analysis code:
  - https://github.com/opentechinstitute/bb-schools-analysis
- Prototype measurement system code:
  - https://github.com/opentechinstitute/mlab-governor-client

Piecewise - M-Lab based community engagement software

- Documentation and code:
  - https://github.com/opentechinstitute/piecewise
- Live examples in use by partners:
  - Seattle, WA - http://www.seattle.gov/broadband-speed-test
  - Stevens County, WA - https://stevenscountybroadband.net/
  - Clearwater County, ID - https://ed-broadband.clearwatercounty.org/

Measurement Kit Rpi - Automatically run M-Lab tests from a small computer

- Documentation and code: https://github.com/opentechinstitute/mk-rpi
- Blog post - Building Raspberry Pi M Lab Autotester: https://opentechinstitute.github.io/2017/10/building-raspberry-pi-m-lab-autotester/
- Blog post - Deploying and Managing a Fleet of Measurement Kit Devices: https://opentechinstitute.github.io/2017/10/deploying-and-managing-a-fleet-of-measurement-kit-devices/

C. Access and Use

C.1 We expect applicants seeking federal funds for software to develop and release these products under open-source licenses to maximize access and promote reuse. What ownership rights will your organization assert over the software you intend to create, and what conditions will you impose on its access and use? Identify and explain the license under which you will release source code for the software you develop (e.g., BSD, GNU, or MIT software licenses). Explain and justify any prohibitive terms or conditions of use or access and detail how you will notify potential users about relevant terms and conditions.

Software produced under this program will be assigned an MIT license, as is consistent with other software produced by New America's Open Technology Institute (OTI) for use with the M-Lab platform. The MIT licence is a permissive license that places only limited restriction on reuse. Data produced using M-Lab tools integrated into the software will be licensed using the Creative Commons Zero license, consistent with M-Lab's licensing practice for data produced by tests running on the M-Lab platform. Content and other digital products produced by the program will be licensed using the Creative Commons Attribution-Noncommercial-Share-Alike 4.0 license which allows reuse with attribution for noncommercial use. Copyrights for software produced will be held by New America and the Open Technology Institute.

C.2 Describe how you will make the software and source code available to the public and/or its intended users.

All software and source code will be made available publicly in a Github repository under the Open Technology Institute: https://github.com/opentechinstitute/

C.3 Identify where you will deposit the source code for the software you intend to develop:
Name of publicly accessible source code repository: To be determined
URL: To be determined

Part IV: Projects Creating Datasets

A.1 Identify the type of data you plan to collect or generate, and the purpose or intended use to which you expect it to be put. Describe the method(s) you will use and the approximate dates or intervals at which you will collect or generate it.

Quantitative data collected by measurement tests is described in the supporting document: *Available Broadband Measurement Tests.* Software running on small computers will initiate all measurement tests. The period of collection will be determined during the program itself, in collaboration with partner libraries. The data generated by each test will be sent to a cloud service developed for this program, where it will be stored, visualized, and made accessible. Additionally, tests will send their measurements to the project or platform from which the test

originated. For example, all M-Lab tests will also send their data to the public M-Lab dataset, and Ookla tests (if implemented) will also send their data to Ookla servers.

A.2 Does the proposed data collection or research activity require approval by any internal review panel or institutional review board (IRB)? If so, has the proposed research activity been approved? If not, what is your plan for securing approval?

The collection of quantitative data does not require institutional review board approval, as these tests will not involve human subjects.

A.3 Will you collect any personally identifiable information (PII), confidential information (e.g., trade secrets), or proprietary information? If so, detail the specific steps you will take to protect such information while you prepare the data files for public release (e.g., data anonymization, data suppression PII, or synthetic data).

The broadband measurement tests in this program will not collect any PII, confidential information, or proprietary information.

A.4 If you will collect additional documentation, such as consent agreements, along with the data, describe plans for preserving the documentation and ensuring that its relationship to the collected data is maintained.

A.5 What methods will you use to collect or generate the data? Provide details about any technical requirements or dependencies that would be necessary for understanding, retrieving, displaying, or processing the dataset(s).

Broadband measurement tests will run from small computers placed in each library's networks. Each device will need to have access to the Internet. Some measurement tests may require specific firewall ports to be available for use in order to run. Program staff will provide documentation in these cases, and work with R&E partner staff and library staff / IT support to communicate the required configurations. Requirements for understanding and displaying the data generated by broadband measurement tests will be gathered in the initial phases of the project, and iterated to ensure they meet end user expectations. Data will be submitted to a cloud service developed for the explicit purpose of understanding, retrieving, displaying and processing the dataset, which will use standard open source tools and code wherever possible. Once requirements are gathered for this system, dependencies will be documented, as will the setup and management of the entire system.

A.6 What documentation (e.g., data documentation, codebooks) will you capture or create along with the dataset(s)? Where will the documentation be stored and in what format(s)? How will you permanently associate and manage the documentation with the dataset(s) it describes?

All code used to generate quantitative data and the analysis of it will be documented and stored in the same Github repository. Documentation will be created in Markdown format, and will be viewable alongside code in the repository.

A.7 What is your plan for archiving, managing, and disseminating data after the completion of the award-funded project?

Data produced by M-Lab measurement tests from devices placed in libraries will be submitted to M-Lab, but also will be maintained as a separate dataset in the data collection and visualization system to be produced by the project. We will publish an archive of the project data as well, in the Github repository alongside other code assets, and on the project website.

A.8 Identify where you will deposit the dataset(s):
Name of repository: To be determined
URL: To be determined

A.9 When and how frequently will you review this data management plan? How will the implementation be monitored?