The University of Washington Information School proposes a *Laura Bush 21st Century Librarian Early-Career Development* project titled "Open-Source Hardware Assembly, Repair, and Sustainability" that addresses IMLS Goal 3, and Objective 3.5 (per section A.2 of the 2022 NOFO). This $294,387 grant will support Dr. Nicholas Weber's investigation of how open-source hardware is being used to meet an increased demand for economic and environmentally responsible computing. The results of this research will positively impact the success of open-source hardware adoption in public institutions, and increase the ability of LIS professionals to support open-source hardware assembly and repair.

Project Justification: Increased access to open-source software and open data have proven to be a positive force for advancing equity - lowering a barrier to educational and research opportunities [1] and providing greater transparency into government actions [2]. LIS practitioners have been pivotal to the success of both open data and software by creating programming, service models, and documentation that make otherwise complex technologies publicly accessible.

This project seeks to understand how LIS professionals can play a similarly important role in the success of **open-source hardware.** Equitable access to proprietary hardware has been, and I argue will continue to be a significant dilemma given current political, economic and environmental conditions, including: 1. Strains on a global supply chain that have made computing devices significantly more expensive and difficult to obtain; 2. Shortages in medical equipment and instrumentation that have deepened inequalities in health care; 3. Extreme effects of climate change that are being worsened by environmentally destructive practices in mining, shipping, and manufacturing of hardware; and, 4. 'Right to Repair' legislation that has failed to force device manufacturers away from unsustainable business models like planned obsolescence. Open-source hardware can offer a modest, but viable way to overcome these dilemmas. For example, open-source instrumentation can reduce the costs of basic scientific research by up to 99% [3,4]; open-source hardware can improve repair time and effectively reduce the cost of education technology [6]; and civic technologists using open-source sensing devices can significantly improve personal data privacy [5].

Despite the important economic and inclusive potential of open-source hardware (OSH), there are three major *barriers* to the adoption and widespread success of most open-source hardware projects: 1. ***Assembly***: OSH projects are often difficult to produce because of missing instructions, necessary part lists, or lack of specificity in documentation [5] that describes the assembly of a hardware component; 2. ***Repair***: The exchange and discovery of relevant OSH is often hurt by a lack of archiving and publishing of OSH specifications [6]. This prohibits non-experts from easily finding and reusing OSH plans as an alternative to proprietary instruments or in repairing existing hardware; 3. ***Sustainability***: Many OSH projects require not only timely documentation, but ongoing work to refresh supply-chain lists and provide support to user communities that engage in the sustainable repair of OSH [7]. **Library and information professionals can play an important role in helping open-source hardware practitioners overcome each of these challenges**. In doing so, LIS professionals can also improve the assembly, repair, and actively engage in the long-term sustainability of OSH as equitable access to computing.

Project Work Plan: This *three-year* project will ask the following research questions: 1. *What contextual information is required to reproduce and assemble OSH?*; 2. *How do OSH practitioners evaluate and judge quality documentation*?; 3. *How are successful OSH projects documented to ensure their long-term accessibility?*; and, 4. *What maintenance tasks are required to improve the accessibility of OSH projects over time?* These questions will be answered through a comparative case-study approach that uses both quantitative and qualitative research methods.

In **Year 1**, our research team will collect and analyze survey data from a collaboration with the *Open Source Hardware and Association (OSHA)*. Over the last four years, OSHA has conducted surveys of 2,500 different OSH projects (including scientists, civic technologists, and educators). This data has never been systematically analyzed and presents an opportunity to understand perceptions of successful OSH development, and the role that documentation plays for sustainable OSH projects. Our new collection and analysis of the existing survey data will include descriptive statistics and a regression model that will help identify variables that correlate with success of OSH projects. The results of this analysis will be used to understand the documentary practices of successful OSH projects, and create a systematic method of sampling cases for a comparative qualitative study.

In **Year 1 and 2**, our project team will execute a comparative qualitative case study of OSH projects based on survey analysis completed in Year 1, as well as a sample of education specific hardware projects that we have previously engaged in interview studies [7]. Semi-structured interviews will be conducted with participants of 30 OSH projects in science, civic technology and secondary education in order to understand documentation practices, judgements, and evaluation of open-source hardware documentation. Interview data, as well as additional archival material gathered from each project's team, will be analyzed thematically. Case studies of each project will then be compared to understand differences and similarities in the documentation practices that lead to successful long-term OSH development.

In **Year 3**, the team will work with OSHA to develop a documentation protocol for OSH. This will be a machine-readable document providing metadata fields, as well as assembly instructions for developers, to fill out and maintain while producing OSH. With 10 projects from Year 2's case study, we will then pilot and evaluate the documentation protocol. A revised protocol will be published and promoted by OSHA as a best practice.

Diversity Plan: This project focuses on understanding structural and institutional barriers to Open Source Hardware assembly, maintenance and repair. As a result, participant diversity is central to understanding how and in what ways OSH increases access, lowers costs, and levels educational barriers. This project therefore seeks to address diversity in two specific ways: 1. ***Stakeholders***: Access to hardware necessary for advanced computing and research is a significant barrier to participation [7]. By investigating, documenting, and easing the development of open-source hardware this project has the potential to significantly improve the diversity of basic research practitioners, educators, and civic technologists; 2. ***Project team***: Students educated and paid to participate in this research project will be recruited from inclusive initiatives at the University of Washington such as the McNair Scholars program.

Project Results: This project will produce three important outcomes: 1. ***Research findings***: Empirical research from this project will demonstrate the economic, societal, and environmental benefits of open-source hardware and instrumentation. These findings will be shared broadly in both research and practitioner venues including ASIS&T, ARL, and JCDL.; 2. ***Documentation***: In collaboration with project partners (OSHA) and students, this project will design, evaluate, and publish a machine-readable documentation protocol which will improve the ability of open-source hardware to be assembled, repaired, and sustained; 3. ***Curriculum***: An open-access textbook and video tutorials will be developed, focusing on the LIS skills needed to use, produce, and preserve open-source hardware. The textbook will be published by OpenStax. Collectively, these outcomes will increase the propensity of open-source hardware succeeding as a viable alternative to proprietary hardware, and as a way of overcoming barriers to hardware access.

Budget: The estimated total request from IMLS for this 3-year project is $294,387 with no cost share. This includes $21,893 for 0.50 month of PI summer support (plus $5,080 fringe) per year; $50,423 for 4.50 academic months (Y2) and 1.50 summer months (Y1-2) of PhD RA support (plus $10,891fringe) and $53,029 for 3 summer months (Y1-3) of Master's RA support (plus $11,455 fringe); $4,000 for travel to present research findings; $8,000 for materials/supplies; $12,500 for participant incentives and advisory board stipends; $18,730 for Graduate student operating fees; and $98,386 for indirects. Indirects are charged at 55.5% on MTDC per the UW's negotiated rate for Early Career Research Development.

References:

[1] Chassanoff, A., et al (2018). Software curation in research libraries: Practice and promise. *JLSC*, *6*. **[2]** Weber, N. and Yan, A (2018). Open Data Mining. *iConference 2018 Proceedings*. **[3]** Pearce, J. M. (2020). Distributed Manufacturing of Open Source Medical Hardware for Pandemics. *JMMP*, *4*(2), 49. **[4]** Garmendia, O., et al (2020). Low-cost, easy-to-build noninvasive pressure support ventilator for under-resourced regions *European Respiratory Journal*, *55*(6). **[5]** Oberloier, S., & Pearce, J. M. (2018). General design procedure for free and open-source hardware for scientific equipment. *Designs*, *2*(1), 2. **[6]** Hausberg, J. P., & Spaeth, S. (2020). Why makers make what they make: motivations to contribute to open-source hardware development. *R&D Management*, *50*(1), 75-95. **[7]** Pearce, J. M. (2017). Emerging business models for open-source hardware. *Journal of Open Hardware*, *1*(1), 2.