NATIONAL
ENDOWMENT
FOR THE
HUMANITIES

DIVISION OF PRESERVATION AND ACCESS

Narrative Section of a Successful Application

The attached document contains the grant narrative of a previously funded grant application. It is not intended to serve as a model, but to give you a sense of how a successful application may be crafted. Every successful application is different, and each applicant is urged to prepare a proposal that reflects its unique project and aspirations. Prospective applicants should consult the NEH Division of Preservation and Access application guidelines at http://www.neh.gov/divisions/preservation for instructions. Applicants are also strongly encouraged to consult with the NEH Division of Preservation and Access staff well before a grant deadline.

Note: The attachment only contains the grant narrative, not the entire funded application. In addition, certain portions may have been redacted to protect the privacy interests of an individual and/or to protect confidential commercial and financial information and/or to protect copyrighted materials.

Project Title: Digital Preservation and Access to Aural Heritage Via A Scalable, Extensible Method

Institution: Rochester Institute of Technology

Project Director: Sungyoung Kim

Grant Program: Research and Development

3. NARRATIVE

Digital Preservation and Access to Aural Heritage Via A Scalable, Extensible Method
A Tier II NEH Research and Development Proposal, Division of Preservation and Access

3.1. SIGNIFICANCE

Aural heritage preservation is a form of cultural heritage conservation that documents and recreates the auditory experience of culturally important places, enabling virtual interaction through physics-based reconstructions of acoustical dynamics. These preserved acoustics can be reproduced virtually through a process called ***auralization*** (Kleiner et al., 1993), which provides access to the reconstructed aural heritage through digital technologies.

The 1972 UNESCO Convention defined immovable cultural heritage as "monuments, groups of buildings, and sites (of outstanding universal value)" (Samuels, 2015:5); not until 2003 did UNESCO introduce the idea of *intangible heritage* "to include 'practices, representations, expressions, knowledge, skills,' e.g., spiritual practices, folklore, song, dance, cuisine, etc., 'as well as the instruments, objects, artifacts, and cultural spaces associated therewith' (Article II.i)" (Samuels, 2015:6). **Aural heritage preservation** interconnects cultural heritage and intangible heritage by preserving the experiential features of (immovable) buildings and sites that relate to the (intangible) expressions of culture. Our project seeks to provide cultural heritage researchers and heritage constituencies with tools and processes to engage this novel and overlooked area of preservation and access that has direct implications for human experience and social interaction.

Aural heritage preservation is a two-step process: 1) capture and document extant spatial acoustics; and 2) create virtual acoustics ("auralizations") using captured data via digital audio technologies. A functional significance, of aural heritage preservation is that it enables the reconstruction of any sonic event now as if it had occurred in the preserved aural environment. Such tools allow both demonstrations of "how it sounded" as well as physics-based hypothesis testing to probe specific research questions about the sonic experience of historical and archaeological places.

Our project will codify a methodology for the capture, auralization, verification, and preservation of aural heritage, with specific attention to extensibility pathways and best practice recommendations so that the method can be broadly adopted**. We seek to enable many new forms of scholarly and public interaction with aural heritage,** serving a target audience of Humanities researchers, cultural heritage practitioners, and diverse audiences across fields for whom aural heritage matters, including architecture and urban planning, history and musicology, engineering and communication studies. Our case-study applications of the methodology will serve as models for those concerned with heritage preservation, and also for the constituencies.

3.1.1. Introduction

Throughout human time, the acoustics of the built environment have influenced human experience, especially in religious and performance spaces, and other public gathering places. Both speech and music created and heard in such spaces is profoundly shaped by the acoustical experience of the venue, unseen but influential dynamics referred to as "aural heritage". Although all buildings have aural significance for human experience, the most obvious examples in recent history are music venues such as concert halls and recording studios. Those with exceptional acoustic qualities have been regarded by performing artists and audiences as "temples of sound". For centuries, across music history, composers and performers have viewed performance rooms as musical instruments, with distinct tonal, spatial, and dynamic character. Composers have sought to include the interaction of players and rooms within their music, and instrument makers consider a room response to sound (Forsyth, 1985; Meyer & Hansen, 2009).

A form of "intangible" cultural heritage, *aural heritage* in the United States can be partially understood through its influence in recorded music, which serves to document some of the effects of historically important acoustical environments. **However, audio and music recordings cannot be considered true preservation of aural heritage: recordings do not isolate the spatial acoustics necessary for comprehensive characterization or reconstruction of auditory environments.** Systematically documenting the acoustics of spaces where historically significant event happened is essential to researchers' and public audiences' understanding of how aural heritage both informed past social and cultural interactions, and continues to influence current human experience. When architectural heritage is demolished or reconfigured, its associated auditory information vanishes. Even when a building or room is reconstructed through historically informed restoration, new materials change spatial acoustics and can create completely distinct auditory environments. Therefore, preservation of architectural and cultural heritage must also include documenting and preserving acoustical features. The following two examples show how auditory environments can be preserved and accessed even after the architecture has been destroyed.

Figure 1. [left] Teatro La Fenice, 1837; [right] The Spectrum, just after 2007 demolition. (Wikipedia).

First, one of the most renowned opera houses in history, *Teatro La Fenice in Venice* (where Rossini and Verdi performed), burned down at night on January 29, 1996. However, since its acoustical characteristics were captured two months earlier by Italian researchers who made *binaural* acoustic measurements, the auditory environment of this opera house can now be experienced and studied by the public (Tronchin & Farina, 1997). The second example is an iconic rock concert venue in Montreal, *The Spectrum*, where numerous contemporary artists played since 1952, including Miles Davis, The Police, U2, and Radiohead. Laurent Saulnier, Montreal International Jazz Festival vice-president and Director of Programming, once mentioned "It's as important as CBGB in New York, the Olympia in Paris or the Fillmore in San Francisco. C'est la salle a Montreal" (Dunlevy, 2007). The venue was closed and demolished on August 5, 2007 in favor of a high-rise condominium, yet the acoustical heritage of the room was safely preserved by Dr. Doyuen Ko (Co-PI) during its final night of operation.

From a methodological standpoint, it is important to emphasize that historical illustrations and photographs, such as those above, merely provide incomplete visual preservation of architecture, silent memorials to the dynamic, aural culture driven by architectural acoustics. Researchers and audiences new to aural heritage often do know that the musically and culturally valuable sonic features of buildings cannot be reliably recovered from visual data alone (although some visual indications can guide reconstructive estimates). Therefore, where architecture remains intact, there is a unique opportunity for accurate and detailed aural heritage preservation, for which no specific preservation and access protocol yet exists. Through the systematic application of the aural heritage protocol proposed by this project, a diversity of researchers will be able to preserve the culturally influential acoustical dynamics of heritage sites, and transform preserved aural heritage data into research tools, virtual experiences, and public interfaces.

3.1.2. Objectives

This project will develop, test, and share aural heritage preservation, translation, and access technologies via three detailed case study applications and associated outreach projects to raise awareness in the cultural heritage community of the importance and feasibility of preserving and reconstruction aural heritage. Project activities include 1) **development of a translatable aural heritage capture protocol** for long-term preservation and virtual representations of this intangible form of cultural heritage; 2) **establishment of a standardized method of processing captured acoustical data into scalable auralizations (reconstructions for listening)** that translate across audio reproduction platforms; and 3) **creation of tutorials and extensibility pathways for other researchers to implement these methodologies** via instructed workshop events, web-based tutorials, and other publicly accessible project products and resources.

3.1.3. Case-Study Applications: Endangered Aural Heritage from Cultural Heritage Architecture

In order to demonstrate to local and global constituencies of historical and archaeological spaces the value of preserving aural heritage, we have carefully selected three contrasting cultural heritage sites recognized by preservation associations. They are colloquially known as "temples": "a temple of sound", "a temple of commerce" and "an ancient Andean temple". In order to develop the proposed protocol and ensure its adaptability by other researchers across contexts, we have chosen case studies with contrasting features and social significance**.**

Our case-studies are culturally, architecturally, and temporally distinct examples of endangered aural heritage. For a small-room venue with recent historical context, we will apply the method to the preservation of aural heritage from American recording studios in Nashville's Historic Music Row that have shaped the history of recorded music (Case-Study 1). In January 2015, the National Trust for Historic Preservation designated Music Row as a "National Treasure," a highly significant yet threatened historic place. As an example of large and public space acoustics, we will apply the method to spaces inside the Rochester Savings Bank located in downtown of Rochester. This building is listed on the National Register of Historic Places (NRHP), and has historical significance for art, architecture and commerce (Case-Study 2). We intersect with the archaeological community and address an example from ancient American prehistory by focusing on the interior architecture at the 3,000-year-old UNESCO World Heritage Site at Chavín de Huántar, Peru, one of the best-preserved examples of pre-Columbian architecture in the Americas (Case-Study 3). These culturally distinct and diverse spaces provide distinct types of aural environments that demonstrate the extensibility of our method, and present unique fieldwork contexts that we will address with best-practice recommendations in **adoption guidelines**.

*Please refer to Appendix **B** (p. 32) for an expanded discussion of these three case-study sites*.

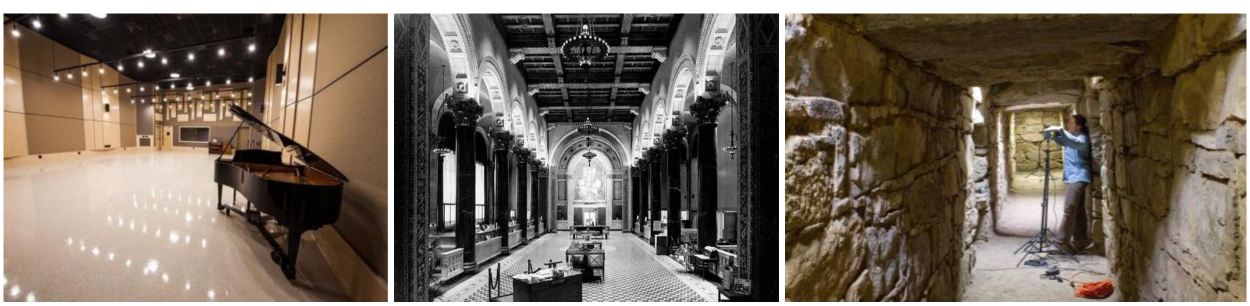

Figure 2. [left] Case Study 1: one of the Columbia Studios on Music Row (Belmont University); [center] Case Study 2: the historic decorated interior of the Rochester Community Savings Bank (now RIT-owned), on the National Register of Historic Places (NRHP); [right] Case Study 3: interior architecture at the UNESCO World Heritage site at Chavín de Huántar, Peru, an ancient religious center.

3.2. INSTITUTIONAL BACKGROUND

The Rochester Institute of Technology (RIT), a unique institution of higher education, provides its 18,000 students with state-of-the-art technology-based education through a pragmatic curriculum, rich in laboratory experiences. A total of 11 colleges deliver diverse and cutting-edge curricula in technology, science, and culture. Among these programs is an academic option focused in audio engineering, led by Dr. Sungyoung Kim. The program currently utilizes dedicated laboratories. Among them, the Multichannel Audio Laboratory will be solely dedicated to the proposed research project. Dr. Kim received and RIT internal grant with the title of "Developing an Electro-acoustic System Assisting Performance of Players in a Medium-size Rehearsal Room (Grant Writer's Boot Camp Seed Funding Award, $5000)." Through this initial grant and following external grants, Dr. Kim successfully established the RIT Virtual Acoustics System and demonstrated how the system could support musicians (Kim et al., 2014b). In addition, Dr. Kim included the topic of acoustic capture and recreation in a course, EEET 451 *3D Audio*, so that students can learn and practice the topic using the RIT Virtual Acoustics System. Recently, students virtually recreated acoustics of the RIT Allen Chapel (where religious activities take place) in the laboratory, and made public demonstrations (Kim, 2018). The main purpose of this laboratory is to teach immersive audio reproduction and to mix multichannel sound sources into new three-dimensional (3D) audio formats. The laboratory is equipped with 22 active loudspeakers plus two subwoofers, shown in figure 3 (below), as well as a head-and-torso simulator (HATS, Brüel & Kjær 4128D). For the research proposed to the NEH, Dr. Kim will design a *scalable auralization process* (explained in Section 3.4, Methodology and Standards) to translate and test aural heritage translation through any configuration of loudspeakers or headphones, using these facilities.

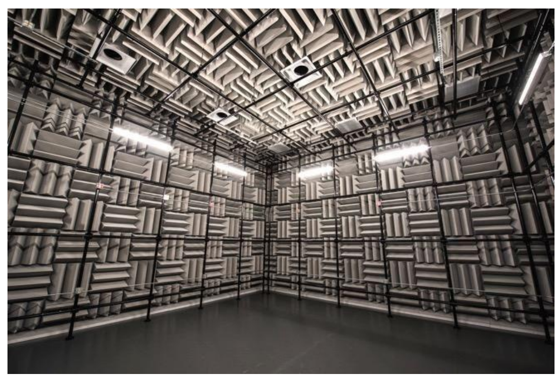

Figure 3. [left] The Multichannel Audio Laboratory at RIT, and [right] the anechoic chamber at Belmont University; both facilities enable aural heritage reconstruction research.

Belmont University, located in the heart of Nashville's Music Row, is a world leader in music business and audio engineering education. The Mike Curb College of Entertainment & Music Business is the only college of its kind accredited for both business (Association to Advance Collegiate Schools of Business) and technology (Accreditation Board for Engineering and Technology). It is housed in a new 134,000-square-foot building featuring the state-of-the-art audio research labs, music studios, and media production suites. The key facilities include a hemi-anechoic chamber (left photo, Fig. 3, above), and a 250-seat film sound mixing stage with a DOLBY ATMOS immersive audio system, the first university-based installation in the world (Kenny, 2015). In addition to the main campus complex, the college operates three other historic recording studios on Music Row: *Columbia Studio A, Columbia Studio B, and Ocean Way Studio*.

From their opening in the mid-1950s, Belmont-owned and operated ***Columbia Studio A and B*** (the case-study recording studios to be preserved and auralized in the proposed project) **provided the**

sonic landscape for many of that generation's biggest hits and greatest artists, including Bob Dylan, Johnny Cash, Patti Page, Elvis Costello, Simon & Garfunkel. Having access to these legacy recording studios provides a unique research and learning environment in which faculty and students have the opportunity to study and contribute to the history of music recording in a functioning technical and business setting. **Belmont's commitment to preserving musical heritage of America** is also demonstrated in the newly opened "Gallery of Iconic Guitars," a dedicated museum for nearly 500 historically significant instruments and supporting endowment, a total value of approximately $10.5 million (The GIG at Belmont, n.d.). Steven Kern Shaw, the grandson of Jerome Kern, one of America's foremost composers, specified his desire that these instruments be donated to an institution capable of properly exhibiting and caring for them. Beyond conveying the important history and design of these instruments, the *Gallery of Iconic Guitars* will foster future opportunities for many of the instruments in the collection to be played by both well-known and student musicians, an interactive way of bringing alive this musical cultural heritage for a new generation.

3.3. HISTORY, SCOPE, AND DURATION

3.3.1. Research Background of Senior Personnel

Dr. Kim will serve as the Project Manager. He is an expert on audio digital signal processing for multichannel reproduced sound fields. In his Ph.D. dissertation, Dr. Kim investigated which perceptual attributes are important for listeners when they listen to multichannel reproduced music. The study revealed that listeners preferred a sound field associated with "wider" and "tighter-bass" impression (Kim, 2009). He joined Yamaha Corporation's Spatial Acoustics team in 2007, where he leveraged his spatial signal processing skills. He developed a tool that converts various reproduction formats to the ITU-R BS.775 5-channel format (ITU, 2006), which allows sound designers to work in studios without visiting actual venues. For example, Dr. Kim developed a method to render a virtually elevated sound image (Kim, 2014a) through the 5-channel format. His research expanded to developing a processing tool for homogeneous spaciousness across multiple reproduction formats from a pair of headphones (for electronic piano players) to five-channel loudspeakers (for audiences using a home theater audio/visual (AV) amplifier). Dr. Kim's pioneering experience in spatial hearing signal processing will support our development of new research methods for the "scalable reproduction" of captured aural heritage proposed to the NEH. In 2010, Dr. Kim joined a project that aimed to **preserve the acoustics of Casals Hall in Tokyo**, an important cultural heritage of Japan, before its closing. He was in charge of signal processing to reconstruct the captured acoustics for long-term preservation. Dr. Kim has also worked to develop technologies related to a large array of loudspeakers that enhances concert hall experience, the Yamaha Active Field Control system (AFC). He led a case study that recreates a virtual Renaissance church (Watanabe et al., 2013) in a modern concert hall, an application closely related to the current proposal. In collaboration with co-PI, Dr. Ko and Prof. Wieslaw Woszczyk at McGill University, Dr. Kim organized a special session on Virtual Concert Hall Acoustics at the International Congress on Acoustics (ICA) 2013 with an associated event, the Virtual Salon Concert (Virtual Salon. 2013.).

Dr. Ko has dedicated his research efforts over the last 10 years to the study of architectural acoustic measurement and virtual acoustic creation (see Fig.4, below, for acoustical measurement work). As a part of the team at Virtual Acoustic Technology (VAT) Lab at McGill University, he has measured acoustic responses of over 100 historically significant concert halls, churches, and recording studios in North America, Europe and Asia. Since 2005, through research supported by The Fonds de recherche du Québec – Société et culture (FRQSC) in Canada, Dr. Ko has measured over 40 Quebec churches and constructed a comprehensive library of acoustic responses, thus preserving Quebec's aural heritage by capturing these acoustic properties. This aural heritage library is becoming a powerful research tool for disciplines ranging from music performance to architectural acoustics

(Woszczyk et al., 2008). “The Virtual Haydn” project shows the value of applying real acoustic responses in music production (Beghin, 2009). Released worldwide by the classical music label Naxos, the complete works of Joseph Haydn for solo keyboard have been recorded in nine virtually reconstructed rooms replicating the spaces in which these pieces would have been performed during Haydn’s lifetime. Using the library of acoustic responses captured in Europe and Canada, Dr. Ko applied these virtual rooms both in the recording process and in post-production. The keyboardist and musicologist Dr. Tom Beghin summarized his experience performing and recording in virtual acoustics as follows (Woszczyk et al, 2009): ***“The virtual room had unmistakably become an essential part of my musicianship and my interpretations.”*** In his Ph.D. dissertation, Dr. Ko investigated the effects of virtually-recreated acoustics on a musician’s perception of room acoustics and musical performance. The research deepened our understanding of how virtual acoustics benefit musicians and audiences in music performance and studio recording (Ko, 2015).

Figure 4. Aural Heritage Capture: setup examples proposed by Co-PI Ko (photos by Co-PI Ko).

Dr. Kolar, recently a Weatherhead Fellow (2016-17) at the School for Advanced Research (SAR) in Santa Fe, NM, is a pioneer of interdisciplinary *cultural acoustics* research that applies acoustical and auditory science to the study of human culture (Kolar. n.d.a). Previously the Five College Mellon Postdoctoral Fellow in Digital Humanities, Kolar has worked in aural heritage research and preservation for over a decade. During her interdisciplinary doctoral studies in music, acoustics, audio engineering and auditory perception at Stanford University’s Center for Computer Research in Music and Acoustics (CCRMA), she co-organized two continuing interdisciplinary research projects on human sonic experience in cultural contexts (Kolar. n.d.b; Abel, J. n.d). Her Ph.D. dissertation applied ecologically valid human auditory perceptual experiments in-situ at the 3,000-year-old UNESCO World Heritage site at Chavín de Huántar, Peru (Kolar, 2013b), one of the case-study locations for the proposed project. An active invited speaker and conference organizer, Dr. Kolar has presented aural heritage research at meetings of professional organizations spanning the Humanities and sciences, including meetings of the American Association for the Advancement of Science (AAAS), the XII Congress of the Study Group for Music Archaeology of the International Council for Traditional Music (ICTM), the Society for Ethnomusicology (SEM), Computer Applications and Quantitative Methods in Archaeology (CAA), and the Society for American Archaeology (SAA), among other conferences. In 2010, Kolar was awarded *First Place, Best Student Paper Award in Architectural Acoustics* for "A Modular Computational Acoustic Model of Ancient Chavín de Huántar, Perú” (Kolar et al. 2010). Recently, she co-chaired two days of special sessions on archaeoacoustics at *Acoustics’17 Boston,* where she presented on auralization in archaeological contexts (Kolar, 2017a). Her recent theoretical article on archaeological sonics was published in the peer-reviewed interdisciplinary journal *Time & Mind* in February (Kolar, 2017b), and with a new paper under review for a case-study application of her new method for archaeological acoustical field survey (Kolar et al., 2018). To reach a broad public audience online Kolar has written for general audiences (Kolar, 2013a, 2013c), with two new social science and Humanities articles in press. For audiences in anthropology, archaeology, and cultural heritage, Kolar is developing a book about the study of sound in archaeology.

3.3.2. Scope & Duration

The interrelated project research areas—aural heritage capture, reconstruction, verification and preservation—will be iteratively investigated, across three contrasting case-study venues, to provide a documented model for applying the proposed aural heritage capture and reconstruction protocol. **For each of these research areas, we will produce a processual toolkit accompanied by adoption guidelines that include best practice recommendations.** In order to provide application guidance and training, we will create web tutorials and workshop events for cultural heritage practitioners to apply these methods to preserve and provide access to aural heritage in diverse contexts worldwide.

For example, if a researcher wishes to capture aural heritage, our guidelines and tutorials (given as an instructed workshop event and also on the project website) will provide instructions for how to plan aural heritage research, and then engage the technical process. Our documentation will include the selection, use, and site-contextual application of audio capture tools (microphones, preamplifiers, audio interfaces, recording devices, etc.), including high-quality "consumer" audio devices that are widely available to non-specialist researchers. We will provide information about evaluating and selecting appropriate tools, to fit a range of budgets and documentation goals. These instructions will explain how to use, calibrate, and position audio equipment in the context of aural heritage capture, and then detail the data handling and reconstruction process for which we provide software and additional guidelines for audio playback/virtual reconstruction through both professional and consumer audio reproduction systems.

The proposed research activities follow the Work Plan detailed in Section 3.5: 1) specification of *an aural heritage capture protocol*; 2) standardization of digital processing of this acoustical data into virtual reconstructions of aural heritage "auralizations"; 3) testing and verification of reconstructions; and 4) *dissemination of these new and extensible methods for aural heritage preservation and access*, through scholarly publications, workshops, and web-based tutorials. These activities build on knowledge and research experience of the key personnel, and will utilize facilities and resources of the supporting institutions as discussed above. Details of project outreach are discussed in the subsequent sections: 3.7, Evaluation and Sustainability, and 3.8, Intended Audience. The applicants anticipate completing the stated goals of the project within three years. The details of research methods and work plans are explained in the following sections.

3.4. METHODOLOGY AND STANDARDS

3.4.1. Methodological Contributions

The proposed interdisciplinary Humanities research advances understanding of auditory culture and its digital intersections. Our three methodological contributions are:

[MC1] **Development of a translatable aural heritage capture protocol** for long-term preservation and virtual representations of this intangible form of cultural heritage;

[MC2] **Standardization of a method for processing captured acoustical data into scalable auralizations** (reconstructions for listening) that translate across audio reproduction platforms;

[MC3] **Dissemination, including instructed tutorials** about the aural heritage capture, preservation, and access protocol for cultural heritage professionals, and implementation of free public access to case study data and demonstrations through both a digital repository and interactive website.

3.4.2. [MC1] An *aural heritage capture protocol* for preservation and access

Through the application of highly technical acoustical and auditory scientific techniques, aural heritage can be captured and translated across audio reproduction platforms. Our aural heritage capture process builds on a standard technique from architectural acoustics for capturing room acoustics, called Impulse Response Measurement (i.e., a method refined by Farina, 2000 & 2007). This "room sampling" process documents acoustical features using an audio test signal reproduced through precision loudspeakers, captured via microphones, and recorded as digital audio data, that can be "auralized" for listeners in a different space, when it is combined with a virtual sound source and played over loudspeakers [MC2]. These methods [MC1 & MC2] are summarized in Figure 5.

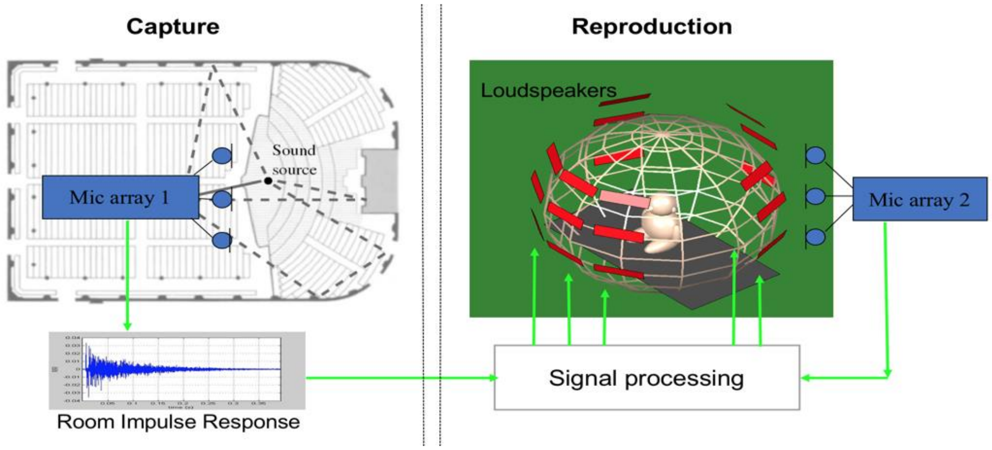

Figure 5. Conceptualized schematic of the aural heritage capture [MC1] & reproduction process [MC2].

The specificity of our proposed capture method ensures a detailed record of the acoustical dynamics of the aural heritage target, enabling a broadly extensible aural heritage capture, presentation, and preservation protocol. Although anyone can preserve a basic "aural impression" of a space by recording acoustic events in it with a microphone, such an audio recording is merely an "overview" that does not provide information about the *complex interactions* between the room and whatever acoustic events took place. Thus, a standard audio recording cannot be used to comprehensively identify room-related acoustical features; **the aural heritage present in an audio recording cannot be separated from the recorded event**. In contrast, systematic impulse response measurements as applied in the proposed method allow the separation and storage of dynamical aural heritage data for future usage, in a format extensible across analytical and demonstration applications. We adapt a well-established room acoustics method that excites target architecture using a time-stretched pulse (TSP) (Farina, 2000; 2007) that captures the aural heritage as room impulse responses (RIRs), which is based on the international standard on room acoustic measurement, **ISO3382-2** (ISO, 2008). Our method thus captures and preserves the RIRs of a target space following acoustical standards. After IR capture and digital preservation, in order to reconstruct the room acoustics—to hear a sound as if it had been made within the preserved aural heritage, and thus "virtually access" the aural heritage—we use computational and digital audio techniques to *auralize* sound in virtual performance.

Best practice recommendations are an important point of addressing Humanities and cultural heritage audiences. When capturing spatial acoustics, it is important to use locations for sound sources and microphones that are culturally representative of historical or inferred human usages of the space. Thus, the contextually and acoustically appropriate selection of a sound source and microphone positions is one of the best practice recommendations that we will produce to aid our target audience of cultural heritage practitioners. These recommendations will also address the following practical considerations: 1) awareness of pre-procedures for aural heritage capture, preservation, and reconstruction—including a checklist of logistics considerations including securing permissions, and identifying and appropriately addressing local/global constituencies; 2) specification/selection/adaptation of audio equipment and other logistics; 3) determination of culturally relevant and acoustically representative positions for microphones and sound sources to capture acoustics representative of aural heritage; 4) procedural considerations such as audio device/measurement signal calibration, and techniques for avoiding errors such as equipment noise, background noise, and signal distortion.

3.4.3. [MC2] Translating captured aural heritage data into scalable auralizations

Scalability of the aural heritage capture and translation protocol ensures that the method will be useful to cultural heritage professionals working in diverse contexts, and not assuming their access to specialized audio facilities. Our protocol specifically supports the reconstruction needs of common cultural heritage applications, especially for those who wish to provide internet or individual access to aural heritage demonstrations (e.g., over headphones in a museum exhibit or guided tour/tablet context). The auralization process is based on *convolution*, which allows virtual interaction between any new sound source and the captured aural heritage data. The right panel of Figure 5, above, illustrates convolution as "Signal Processing", and the left panel shows how the convolved aural heritage data and new signals are delivered to a listener through a specified array of loudspeakers (or earphones, not shown), thus creating the *auralization* or sonic reconstruction.

Because our proposed method targets broad audiences, with various reproduction scenarios, it must provide scalability of the aural heritage data through different audio reproduction platforms, from multichannel loudspeaker arrays, as shown above, to 2-channel headphones. To enable broad and customizable dissemination, we will establish this "scalable auralization" of captured aural heritage through two steps:

1) Applying the captured acoustics to sound/music (either live or pre-recorded) using custom digital signal processing techniques to virtually transport the source into space;
2) Reproducing this virtual acoustical heritage for listeners: (a) over different configurations of loudspeakers, or (b) for earphones, "binaurally", for individualized/web listening.

There are a number of technical challenges that we will address in the process of translating aural heritage from measured room acoustics to their reconstructions as auralizations. To cover a wide range of reproduction formats, we will first transport the preserved acoustics to a standard high definition array of 24 loudspeakers shown in Figure 6, right.

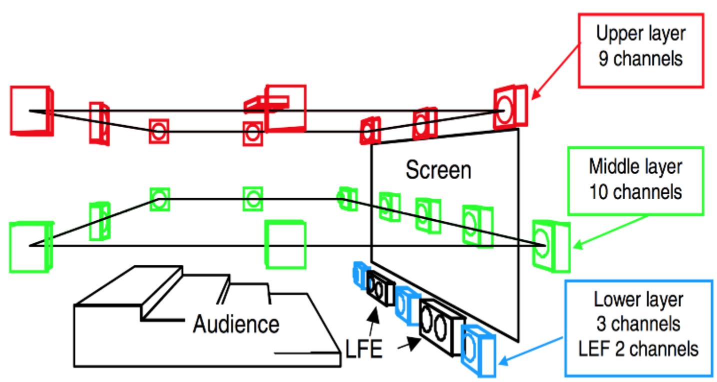

Figure 6. 22.2 channel immersive surround system by NHK (diagram from Hamasaki et al., 2005).

This loudspeaker array, the NHK 22.2 sound system, was developed by Japan Broadcasting Corporation (NHK) for an Ultra High Definition (UHD) TV for fully immersive auditory experience over extended listening area (Hamasaki et al., 2005, 2007).

Next, we will implement scalable reproduction processing that converts the 24-channel sound to any standard format specified by **the International Telecommunication Union Recommendation** (ITU, 2016). This scalable processing will generate subsets of the 24 channels for other configurations, by considering technical details such as the inter-channel level, time, and spectral differences. For instance, if the desired auralization platform is a five-channel surround home theater system, the method will render a five-channel signal from a weighted sum of 24 channels.

In addition to loudspeaker installations that reproduce aural heritage in specific locations, we will also render *binaural* auralization optimized for earphone/headphone delivery via web interfaces to provide the broadest public access opportunities for individual listeners to virtually experience acoustic spaces. Binaural technology replicates what a person would hear if they were listening in an actual space. Previously, Dr. Kim conducted several research projects to optimize the binaural technology for electrical piano players, and recreating virtually elevated sound image (Kim et al., 2012, 2014a). By making acoustical documentation of the historical places using the technology of a binaural mannequin-head/torso with microphones in its ears (as illustrated in the right panel of figure 4 above), the captured aural heritage can be played back over earphones/headphones to precisely translate the spatial acoustical experience. While there are several limitations (Wallach, 1940), this method can enable multiple listeners to experience the target acoustics with a relatively simple device. In particular, with web-based distribution, global access to the preserved aural heritage will be possible; a listener will only need a pair of ear/headphones to experience the binaural stimuli made accessible through the project's website.

3.4.4. [MC3] Instructed tutorials for aural heritage capture, preservation, and access

The third methodological area of our project is to provide tutorials for the adoption of the proposed protocol by other researchers. We will translate the technical aspects of the culturally contextualized acoustical and audio research practices for diverse audiences. Our target audiences are cultural heritage practitioners, musicians and audio engineers, and a wide public that includes local constituencies of our case study venues. We wish to both provide access to the method, and to demonstrate the preserved aural heritage via auralized reconstructions, both in live events at our host institutions, and also via our project website (hosted by RIT; discussed below). Because our project seeks to encourage cultural heritage professionals to include aural heritage in their preservation and access projects, we plan to propose and host tutorials at professional meetings. To reach the widest audience, we will also provide aural heritage preservation tutorials on our project website, to be supervised and developed by Dr. Kolar (who worked as a web developer prior to her doctoral studies, and currently maintains aural heritage websites such as her professional site, *www.culturalacoustics.org*). In addition to case-study demonstrations and resources about implementing the method, the project website will provide public interfacing about project activities and events. To sustain public visibility and free and open access, RIT will host the project website, and archive project data in its digital repository system (*Please refer to Letter of Support from RIT Library, p. 58)*. Dissemination details are provided in Sections 3.7 and 3.8.

3.5. WORK PLAN

We propose five interrelated areas of research (A1-A5), each led by one of the project's Co-PI's and its cultural acoustics consultant: [A1] developing a protocol of aural heritage capture and audio processing in preparation for auralization (Dr. Ko); [A2] establishing a standardized method of processing captured acoustical data into multiple reproduction formats (Dr. Kim); [A3] constructing a public and educational web interface for virtual reproduction of aural heritage (Dr. Kolar); [A4] evaluating the proposed aural heritage capture and reproduction protocol in (all researchers); and [A5] providing tutorials and documents of the proposed protocol for wide range of applications (all researchers). Additional work [A6] includes the programming of site-based events (all researchers), organizing dedicated workshops on the adaptation of these methods for cultural heritage researchers, and disseminating research results at professional conferences that address cultural heritage professionals. The proposed work is planned over three years, as detailed here:

PROPOSED SCHEDULE:

Jan. - Dec. 2019 (12 months): Establishing the aural heritage preservation method

- [A1] Design aural heritage capture and determine testing positions in three case-study venues.
- [A1] Capture & document Case-Study 1, the historical Music Row studios, *Columbia A & B.*
- [A2] Design and test an algorithm for scalable auralizations (via loudspeakers).
- [A3] Specify and begin development of project dissemination website, posting project information and introductory tutorial about aural heritage preservation.
- [A5] Draft best practices workflow for aural heritage capture protocol.
- [A6] Host 1st Advisory Board Meeting (ABM) to review project goals and methods.

Jan. - Sep. 2020 (9 months): Methodological work on aural heritage reconstruction

- [A1] Capture & document Case-Study 2: Rochester Community Savings Bank (NRHP).
- [A1] Capture & document Case-Study 3: UNESCO World Heritage at Chavín de Huántar, Peru.
- [A2] Design and test an algorithm for scalable auralizations (via headphones).
- [A2] Host public demonstration event at Belmont University, with digital reconstructions of the first aural heritage case-study through a multichannel array of loudspeakers.
- [A2] Host public demonstration event at *ImagineRIT 2020*, RIT's annual technical exhibition, which is attended by more than 30,000 local people, with digital reconstructions of the second aural heritage case-study through a multichannel array of loudspeakers.
- [A3] Continue development of project website: activities updates, event info/registrations, external links, and first public auralization interface for exploring aural heritage (headphones).
- [A4] Evaluate recreated acoustics of case-study aural heritage (objectively and subjectively).
- [A5] Draft best practices workflow for scalable auralizations.
- [A5] Prepare workshop and tutorial materials for instructing capture & reproduction processes.
- [A6] Host a recording studio acoustic preservation workshop at Belmont University.
- [A6] Host 2nd ABM to review progress and discuss constituency communication.

Oct. 2020 - Sep. 2021 (12 months): Public interfacing and dissemination

- [A1] Capture & document additional aural heritage to test extensibility using ubiquitous audio tools.
- [A2] Digitally reconstruct case-study the third case-study aural heritage through a loudspeaker array for demonstration at *ImagineRIT 2021*.
- [A2] Digitally reconstruct all case-study aural heritage examples for headphone auralizations.
- [A3] Debut website public interfaces that auralize the preserved aural heritage case studies.
- [A5] Document, store, and provide access to the preserved aural heritage case studies.
- [A5] Produce a web-based tutorial of the reconstruction/auralization method.
- [A5] Produce and host a workshop event for cultural heritage practitioners that provides an instructed tutorial of the entire aural heritage preservation and access method.
- [A6] Test/evaluate usability and accessibility of the project website.
- [A6] Host 3rd ABM to review progress, discuss public dissemination strategies and future.

Oct. - Dec. 2021 (3 months): Concluding events, documentation, & sustainability measures

- [A2] Host a public "concert" in virtually reconstructed studios at Belmont University.
- [A3/A5] Complete the website, with links to digital repositories of code and methodological documentation, and other project resources.
- [A4] Evaluate (objectively and subjectively) the case-study headphone auralizations.
- [A5] Verification study: record binaural responses of the case-study studios and in their reconstructions using a Head-And-Torso Simulator (HATS), for psychophysical comparison.
- [A6] Publish about technical achievements in relevant journals.
- [A6] Host RIT aural heritage preservation workshop for a cultural heritage audience.

3.6. STAFF

Dr. Sungyoung Kim, Project Manager (PM) and Co-Principal Investigator (Co-PI), is an Associate Professor in the Electrical, Computer and Telecommunication Engineering Technology Department of Rochester Institute of Technology (RIT). Dr. Kim will oversee the overall progress of the proposed research, and will have responsibility for all aspects of the project. He will design the scalable auralization method. In addition, he will be responsible for the project evaluation and reporting to NEH. Dr. Kim will devote 15'% of his time to this project (5% cost sharing).

Dr. Doyuen Ko, Co-Principal Investigator (Co-PI), is an assistant professor in Audio Engineering Technology department at The Mike Curb College of Entertainment & Music Business of Belmont University. Dr. Ko will supervise and assess the quality of all capture, preservation, and recreation procedures, and oversee the development of aural heritage capture protocol. Dr. Ko will devote 15% of his time to this project.

Dr. Miriam Kolar, Aural Heritage Consultant, is a Five College Associate based in Amherst, MA. Dr. Kolar will be in charge of 1) developing and applying the method in the case-study application at Chavín de Húantar, Peru, and 2) establishing an interactive website, to be hosted at Belmont University, for dissemination and public interfacing of research methodologies and case-study aural heritage examples. She will devote 25-50% of her time to this project, depending on season and project stage.

Research Assistants: 1) TBA, audio software engineer (ASE) is a research assistant from the Master's program of Telecommunication Engineering Technology at RIT. The ASE will be hired to work with Dr. Kim and Dr. Kolar in implementing scalable auralizations, assisting Dr. Kim in setting technical standards, and conducting subjective and objective evaluation. The ASE will work 800 hours per year for the proposed research. **2) TBA, acoustic capturing engineer (ACE)** is a research assistant from the master's program of Audio Engineering Technology at Belmont University. The RE will support the project work at Belmont University. ACE will work 600 hours per year for the proposed research. *Please refer to Appendix **E** (p. 50) for the job descriptions of two research assistants.*

Advisory board

To facilitate productive communications with the broader audience of Humanities and cultural heritage professionals we hope to serve, we have assembled an advisory board of respected historic preservation and archaeological experts, acoustics and music industry professionals. Our board will meet annually to ensure a balanced decision-making process, helping advise us in anticipating and addressing the needs of the various local/global constituencies for each of the three case-study venues for aural heritage preservation. Each year, this group will assess our project work plans and provide the research team informed guidance.

Carolyn Brackett (*Senior Field Officer for the National Trust for Historic Preservation, Director of the Music Row National Treasures Project*) works on preservation and heritage tourism projects across the country as part of the National Trust's National Treasures program. She currently directs the Music Row National Treasures project in Nashville, which includes working with local partners to document Music Row's history, preparing a preservation-oriented design plan, and developing plans to for creating a narrative about Music Row's for residents and visitors.

George Massenburg (*Member of National Recording Preservation Board, Advisor of the Committee for Library Information Resources, Library of Congress*) has produced and engineered over four hundred records over the past 45 years. He is a member of the National Recording Preservation Board of the Library of Congress and an advisor to the Committee for Library Information Resources. George serves as the Chief Technical Officer of META (the Music Engineering Technical Alliance), a strategic union of music producers and engineers dedicated to the highest standards for audio and delivery of music.

Patrick A. McMakin (*Director of Operations, Ocean Way Studio, Nashville, founding board member of the Music Row Neighborhood Association*) has worked successfully as a recording engineer, record producer, songwriter, GM of Sony Tree Studios, and GM Tree Productions (Sony/ATV's music production/ artist development company). After he worked at Sony/ATV for over 25 years, McMakin took the leadership of Belmont University's Ocean Way Nashville Recording Studios where he currently serves as Director of Operations. He is also a founding board member of the Music Industry Coalition and the Music Row Neighborhood Association.

Hideo Miyazaki (*manager of the acoustic design and consulting group of Yamaha Corporation*) actively works in room acoustics research, and has contributed to about 100 acoustical design projects as an acoustical consultant. Recent representative projects of his acoustical design include Kurume City Plaza (2016), Higashi-Hiroshima Arts & Culture Hall (2016), Shimizu Marinart (2012), and Yamaha Hall (2010). Mr. Miyazaki worked with Co-PI Kim to preserve the aural heritage of **Casals Hall** in Tokyo, a historic concert hall, before its closing in 2010.

John Rick (Associate Professor, Dept. of Anthropology at Stanford University) has directed the archaeological research and conservation project at Chavín de Huántar, Peru, for over twenty years. A world-renowned archaeologist and cultural heritage professional, Rick is known for his pioneering adaptations of digital technologies to address both archaeological investigations and conservation techniques (Rick, 2012). With consultant Dr. Kolar, Rick initiated archaeoacoustics research at the site in 2008, and *pioneered aural heritage conservation data collection there as a non-specialist researcher following a capture protocol designed by Kolar and a Stanford colleague*.

Michael E. Ruhling (Professor of Performing Arts in the College of Liberal Arts at RIT, and a Senior Associate Faculty in Musicology at the Eastman School of Music) is a renowned musicologist who wrote *Johann Peter Salomon's Scores of Four Haydn Symphonies: Edition with Commentary*. His essay on the symphonies of Michael Haydn is included in *The Symphonic Repertoire, Vol. 1: The Eighteenth Century Symphony*. Dr. Ruhling was named the 2008-2009 Christopher Hogwood Historically Informed Performance Fellow by the Boston Handel and Haydn Society, the oldest performing ensemble in the United States.

3.7. EVALUATION AND SUSTAINABILITY

3.7.1. Multi-stage evaluation and sustainability; audience identification and support

Our multi-stage work plan, with internal evaluation goals and dissemination activities at every stage, includes live events and web interfaces that provide opportunities for project researchers to interact with each other and the larger communities addressed by our project. Important to our methodological development and its dissemination are the creation and implementation of instructed tutorials as outreach events for cultural heritage practitioners; tutorial event registration and surveys will help us evaluate and track the communicative reach, success, and implementation of the aural heritage preservation method and other project products. To understand the wider impact of public access to grant products (provided in both events and through the project website), we will use optional in-person surveys, and standard web tracking statistics to understand how site visitors access information, tutorials, demonstrations, and tools provided on the website. For live events, we will have registration procedures that provide demographics and other information about engaged audiences; for tutorial events, we will implement follow-up communications based on registration and attendance data, to enable continued communication with interested researchers and support the adoption of our protocol in cultural heritage work through direct interaction with our colleagues across fields.

3.7.2 Sustainable accessibility to aural heritage data

The various forms of aural heritage data and auralization products generated by the project will provide free and open access to different targeted communities. Architectural acoustics—the essence of aural heritage data—are customarily documented and used across audio engineering applications in the form of impulse responses (IR), preserved as digital audio files. IR data is widely understood and employed throughout audio engineering, acoustical and music research fields. A single IR file size would be around 1.0 MB. ***For contextualized information attached directly to the aural heritage data files, the descriptive naming convention will serve as metadata:***

*VENUE NAME_DATE_ROOM LOCATION NUMBER_*
SOURCE RECEIVER DISTANCE_HEIGHT_MICROPHONE TYPE.wav.

Figure 7, below, visualizes an example of aural heritage Impulse Response (IR) data captured at Casals hall in Japan by Co-PI Kim in August 2009. The IR filename (shown at the top of the left graphic) follows the naming convention discussed for this proposal, providing *metadata* of measurement details: the name indicates that the IR was captured with an omni-directional microphone at location 3 (as specified in additional capture documentation) with distance of 6 m from the sound source, and at a height of 2.5 m from the venue floor. In aural heritage capture documentation, it is necessary to include a floor plan or diagram (as well as reference photos) to indicate measurement locations. Such a floor plan, annotated with capture location (red circle), can be seen in the right panel of Figure 7.

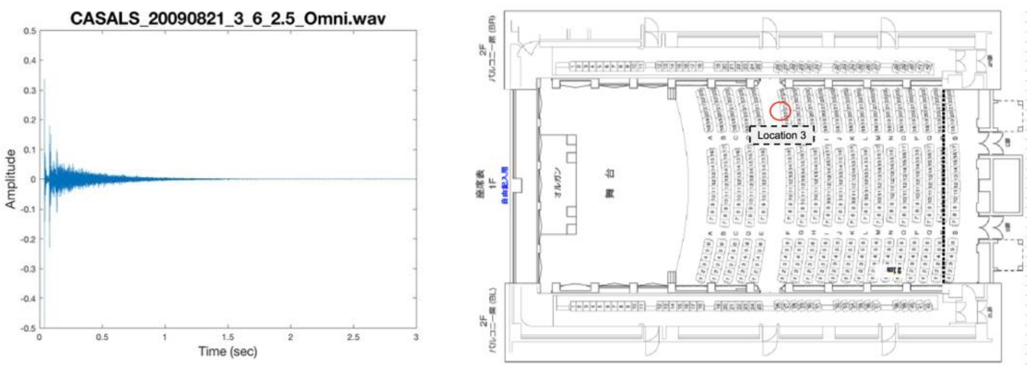

Figure 7. Aural Heritage Data: [left] an example of an impulse response (IR) shown as audio waveform; [right] floor plan of the Casals Hall, Japan, indicating the capture location of this IR.

In addition, we will create a spreadsheet file that contains detailed description of each aural heritage data file, based on the Dublin Core Metadata Element Set (http://dublincore.org/documents/dces/). We expect to capture 160-300 points for a single venue, which becomes about 1.6-3 GB accumulating to no more than 30GB for the entire research period. We will store the captured data in a subdirectory categorized by the venue type (office, lecture room, recording studio, small auditorium, large auditorium, small chamber hall, medium concert hall, large concert hall, quad, plaza, and user-defined one) and its name. Such a small amount of data is easily preserved in a supported archive such as those of the RIT Libraries who have agreed to permanently archive our project's data; additionally, it can be stored on solid state media (such as an SD card or USB flash media) and maintained redundantly; the data could also be made available for public access via the project website or other open hosting platforms such as Github, for example. In addition, photographs and geometric data/mappings of measurement points will be documented to ensure an architecturally contextualized dataset. The project website will have a custom graphic user interface (GUI) where a user can specify and download *properly contextualized IRs* through interactive menu. The raw aural heritage data in the form of acoustical impulse responses (IRs) can be translated to any given platform through the scalable reproduction software that we propose to produce. Thus, preserving and providing documented access to the redundantly archived and accessible IR data sets ensures the sustainability of the aural heritage data. The RIT Multichannel Audio Laboratory will be primarily responsible for organizing archival and access to preserved aural heritage. In order to provide sustainability and redundancy in long-term storage, all collected data (acoustic and perceptual measurements) will be archived in multiple locations, including the local hard drives of computers in the two laboratories, RIT and Belmont University servers (for broad access, please see the next section), and as noted, on an external storage device (for example, a USB drive, SD cards, and/or DVDs) to be physically archived in the RIT Library. The server-stored data will be backed up every two years, and we are working with RIT to develop a protocol for ensuring integrity of the data.

3.7.3 Verification of reconstructed aural heritage

To verify that the reproduced aural heritage authentically reconstructs the captured aural heritage, we will objectively measure authenticity, a magnitude of homogeneity between the two. To do so, we make acoustical measurements of the reproduced aural heritage (e.g., in the RIT Multichannel Audio Laboratory). An identical sound source will be played through a pair of loudspeakers located in both a target and reproduction space, which will then be re-recorded using a Head-And-Torso Simulator (HATS) or a pseudo-binaural microphone technique. Physical analyses of the original and reproduced binaural recordings will reveal important room characteristics, which can be objectively and systematically compared, as Dr. Kim previously conducted in his previous studies (Kim, 2009; Watanabe et al., 2013). For instance, a *correlation coefficient* indicates a statistical relationship between two variables and a similarity of two recorded signals can be induced from this parameter. The recordings also will allow the research team, Advisory Board—and perhaps a public audience, via an interactive web application on the project website—to subjectively evaluate the perceptual authenticity of the aural heritage *auralizations*.

3.8. INTENDED AUDIENCE AND DISSEMINATION

Our project seeks to bring to the attention of Humanities scholars, the cultural heritage community, and broader audiences the overlooked preservation of aural heritage. We are especially concerned with serving the cultural heritage preservation community, historians of music and architecture, and other specialists who might adopt our protocol, such as archaeologists, audio engineers, musicians, artists, and virtual media practitioners. Important to our project is facilitating the use of specialized technologies by non-specialists; therefore, our dissemination of project products must be interdisciplinary in address. Our team's demonstrated cross-disciplinary expertise, supported by an Advisory Board of leaders from different communities, will help foster communication across fields.

To make aural heritage viable for any project, we seek to provide conceptual guidelines and software tools that enable the inclusion of aural heritage in Humanities collections and preservation activities, among other potential applications. Multiple channels of dissemination and outreach, detailed in our attached **Dissemination Plan**, will widen the accessibility of specialized research tools with instructed workshop events, web-based tutorials, and other forms of documentation that guide the adoption of the aural heritage protocol. In this way, our project will aid the expansion of aural heritage exploration beyond audio and acoustical specialists. A related outcome is the consideration of our three case-study projects as augmented and virtual reality applications in cultural heritage. Though multiple channels of dissemination, these case-studies will provide models for learning about aural heritage preservation and access, as well as demonstrations of our method.

In addition to site-specific demonstrations open to the public, and instructed workshops for targeted heritage professionals, our project website and associated digital repositories will allow interested audiences to transcend locale through internet access. Research information and aural heritage products will be freely available through the project's website, and also via specific events for target audiences, such a public "concert" in virtually reconstructed studios at Belmont University.