Interactive Public Sound Art: a case study

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ABSTRACT
Physically situated public art poses significant challenges for the design and realization of interactive, electronic sound works. Consideration of diverse audiences, environmental sensitivity, exhibition conditions, and logistics must guide the artwork. We describe our work in this area, using a recently installed public piece, *Transition Soundings*, as a case study that reveals a specialized interface and open-ended approach to interactive music making. This case study serves as a vehicle for examination of the real world challenges posed by public art and its outcomes.

Keywords
Music, Sound, Interactivity, Arts, Public Art, Network Systems, Sculpture, Installation Art, Embedded Electronics.

1. INTRODUCTION
With the advent of inexpensive and often readily available delivery mechanisms, the scope of public art has expanded to include a wide range of methodologies and outcomes. For example, there have been a number of radio broadcast and more recent internet projects, including our own work [10, 9], that reach a wide public audience. Newer ubiquitous technologies, such as cell phones, have also served as a platform for public sound art [4].

However, for the purposes of this study, we restrict ourselves to a conventional definition of public art and examine the challenges posed by the realization of physically situated works that are directly accessible and freely available to public audiences. Public art in this scope is housed outside of traditional art settings and is intended to engage a public audience that might not otherwise seek art experiences. Furthermore, as this work does not live in a virtual or broadcast context, it is dependent on site-specific circumstances in the physical world.

There has been extensive prior work with art that seeks new forms outside traditional contexts. For example, Chico McMurtrie's recent work, *Growing Rain Tree*, serves as an example of engaging kinetic public art that speaks to a broad audience and integrates expressive technologies [6]. The work has proven to be robust, but it does not face the challenges of an outdoor exhibition environment.

Sound artist and composer Max Neuhaus has undertaken a number of outdoor sound installations [8, 7]. While these pieces generate environmentally sensitive sound experiences in outdoor contexts, they do not provide a mechanism for audience interaction.

Artists such as Ned Kahn have utilized sound as a medium in permanent installations [5] that leverage naturally occurring sound production mechanisms. This work has been influential in our own conception of approaches to public sound art. However, this work is not audience interactive and does not address the logistical challenges posed by the use of electronic sound production mechanisms.

In our own recent work we have realized installations that utilize sound, digital media, and embedded electronics [2, 1]. Although this work has been exhibited in diverse contexts including galleries and indoor public spaces, it was not conceived for a public art context and does not address those unique challenges.

This paper describes an approach to physically situated public art that requires the design and realization of new frameworks for interactive music making. In Section 2 we identify challenges for the design and realization of interactive public sound art. Section 3 examines a case study of these points through our recent work, *Transition Soundings*. Finally, we evaluate our results and provide conclusions.

2. PUBLIC ART CHALLENGES
The realization and presentation of interactive sound art in the public sphere poses important challenges for artists.

Sound art is finding increasing acceptance in the culture of galleries and museums as artists, curators, and directors have sought to find new strategies for the presentation of this work. Nonetheless, even in the relatively controlled atmosphere of these venues, audiences can find sound art to be a challenging experience as it undermines many of the norms and conventions of exhibition attendance. Furthermore, interactive art has proven to be sometimes vexing and frustrating to even the most experienced audiences in a museum [3]. In this light, exhibition conditions outside a traditional gallery setting can be viewed as having distinct advantages and disadvantages. On the one hand, audiences will not be bound by expectations of traditional venues. On the other hand, the artist can make no assumptions about the audience's familiarity with the domain of interactive sound art, and artists must generate work that is sensitive to this context.

Public art exhibitions in outdoor environments demand an acute environmental awareness. Sound art work in particular must be embedded in the sonic context without overwhelming the existing soundscape. Extensive work has been undertaken to identify sources and attributes of noise pollution in our communities [11, 12]. This research reveals that society's perception of the role of the source can play a large part in the identification of sound as a nuisance. Public sound art, as an unusual element in the environment, must be particularly sensitive to both noise levels and qualities of sound to avoid becoming a source of distraction or annoyance for the public.

Public art must be designed and realized with careful attention to unique exhibition dangers. Specifically, weather and vandalism pose risks to this work, and electronic components are particularly vulnerable to both factors. Legal liability issues including public safety and regional building and electrical code requirements are also brought to bear on art presented in a public area rather than a gallery.

Finally, artists must address important logistical challenges including maintenance, durability and longevity of their work. Public art administrators typically expect works to have a serviceable life that is measured in years rather than weeks. This presents a unique challenge for interactive electronic works, given that many emerging technologies are still in their infancy and can require close monitoring to assure reliable operation. Careful consideration must be given to material selection and design in all respects to ensure an operable life of the work with minimal maintenance requirements.

3. *TRANSITION SOUNDINGS*: A CASE STUDY

Over the course of nine months during 2005, we designed, built, and installed a public art work, *Transition Soundings*, as a commissioned piece for the City of Tempe Cultural Services. Our piece is part of a larger series of works through a commissioning project entitled Artist Adorned Transit Stops. The work is currently installed at a bus transit stop in Tempe, Arizona. The work is a dynamic, interactive sound installation that is environmentally sensitive and is rooted in metaphors drawn from transit networks in our community. In this section we use this newly realized work as a case study to examine challenges and strategies for interactive public sound art.

3.1 Description of Audience Experience

As a user approaches the transit stop, they find a large wall positioned behind the waiting bench, ten feet wide and extending from just above the ground to over their head. The face of the wall is reminiscent of a typical transit map as it is multi-dimensional, attractively colored, and contains a network of elements that are arranged in clusters and paths. However, this wall houses a large matrix of sound producing elements and nearly fifty embedded sensors that allow for interactive sound-making exploration.

As the user comes in closer proximity to the face of the wall, their presence is detected, and a burst of sound ignites from the spot mirroring where they are standing. Just as a stone dropped in a pond will ripple waves across its surface, the sparkling sound washes across the face of the wall, shifting in color and tone as it emanates from the original source in all directions. As the transit user moves in front of the wall, freely exploring the way in which hand-waving and movements toward and away from the wall yield different sound shimmers, another user approaches the stop. This second user approaches the wall and the two play together, exploring how their movements can trigger simultaneous musical patterns that sparkle across the sound wall and heighten their awareness of the urban soundscape that previously went unnoticed.

Figure 1. *Transition Soundings* onsite

Later in the evening, this same transit user returns to the stop, and approaches the piece again. Remembering the interaction of earlier in the afternoon, the user waves their arms in front of the sound wall. Sound bursts still ripple across the surface of the wall, igniting from the locations where their arms travel. However, as darkness has now fallen and the sounds of Tempe have shifted, so too have the sounds of the piece. Now clicks and rushes emerge from the wall as they glide across its surface and into the sounds of the night.

The work seeks to engage transit stop users on two levels. First, the work encourages them to be active, up off the bench and moving - engaging with both the work and with one another – as they explore the sonic possibilities of the piece through playful interaction. Second, the work encourages them to reflect upon larger issues regarding the interconnectedness of our communities, the role of transit in uniting us, the role of technology in our society, the sonic world around them, and the importance of environmental sensitivity.

3.2 Motivation and Aesthetic Ideas

In the conception of an interactive installation for public exhibition, we were mindful of the challenges of this environment. In addition, we sought to create an experience which is immediately communicative and engages a broad public audience. As a commission relevant to transit networks in an urban desert environment, the work is motivated by concepts that are pressing for the public community it is intended to serve. Specifically, we engage the transit network, environmental concerns, and site-specific circumstances.

Relevance to transit system

The proposed work is inspired by the form and function of transit networks. This inspiration is present in the visual layout of the piece, and in the way that sounds propagate across the network, linking remote portions of the sound wall through hubs and direct routes of travel. We hope that our re-imagination of the transit network encourages the public to reflect on the ways in which transportation networks build links across our physical world, and how we can better unite our communities through networks formed of social, cultural, and intellectual ties.

Environmental relevance

Our work seeks to address issues that are central to urban communities that are situated in the desert environment. It is also inspired by the metaphor of water, and the interaction behaviors of the piece mimic the way in which ripples will emanate from a disturbance in the water. We sought to generate a sonic and technology-based equivalent of this visceral and universal experience that references water resource concerns in the metropolitan area and the western United States.

The sun is a dominant environmental feature in Tempe, and a highly practical source of power. Although we could have arranged access to the urban grid, we chose to integrate solar energy panels in our work to raise awareness of renewable, reusable energy sources. Clearly this energy source serves as a logical and sustainable solution for the requirement of powering the embedded electronics.

Site-specific relevance

We sought to integrate site-specific sonic and geographic considerations into the design for *Transition Soundings*.

The installation site is oriented along a major east/west thoroughfare. We have implemented a topological design that mirrors the growth of the greater metropolitan area of which Tempe is a part. Just as the areas to the west of Phoenix are more densely populated than those to the east, we have created a greater density of sound resonators toward the west side of the sounding wall that will thin as sound travels to the east.

Given that sound plays a central role in the piece, we worked to develop and refine a sound language that both enriches and reflects the ambient soundscape of the site. We first spent time listening and analyzing the sonic characteristics of the site, and physically tested prototype sounds in the environment to ensure that the sounds were attractive and meaningful. In addition to the musical notes that were present in the submitted prototype, we developed a broad palette of sounds including chirps, rhythmic clicks, flutters, and abstract sound events reflecting the diversity of sources in the urban environment. The sonic palette of the work is described in detail in *Section 3.3.3*.

3.3 Design and Realization

At the heart of the piece is a sounding wall six feet high by ten feet wide that houses a network of sensors and sound producing elements. This wall is comprised of twenty-seven modules that have the same basic design and function. There are two types of modules that differ only in the layout of their speakers as either hubs (clusters) or straight paths. Each module contains two proximity sensors, one light sensor, ten piezo-electric speakers, and one microcontroller computer (Atmel Mega 8) with supporting circuitry for sensing, sound output, and networking. Adjacent modules are connected to one another such that they form a network across the entire wall that allows sounds to wash across its surface following the structure of hubs and paths. In this section we describe the realization of this work and discuss our solutions to the challenges posed by public art.

3.3.1 Physical Implementation

Transition Soundings is installed in an outdoor environment that required us to be particularly mindful of the challenges of vandalism, harsh weather conditions, and maintenance concerns in designing the physical body of the work. In addition, we wanted to create a work that is visually inviting to audiences as well as functionally interactive.

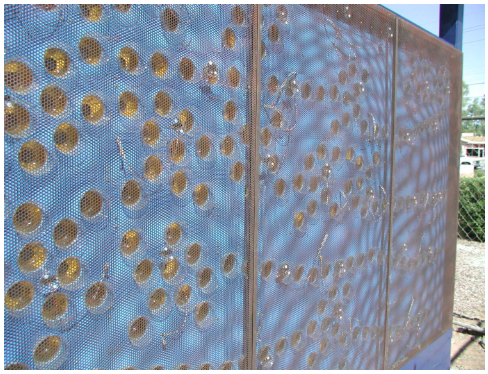

Figure 2. Close view of interactive sound wall onsite

Vandalism - To protect against unauthorized access to the inner electronics, we created a layered design that conceals most structural fastening points and exposes a minimum of security screws and locks. The outer layer of the facade is perforated steel, with small enough holes to prevent most types of damage by potential vandals. Sensitive elements are some distance from the front of the enclosure, while the perforations allow sound to easily emanate from the speakers and provide visibility to the sensors and resonators embedded on the inner panels.

The solar panel is one of the most expensive single elements in the piece. To guard against theft and vandalism, this panel is mounted well out of reach of passers-by, and is seated in a solid steel frame with security bolts. This design is similar to numerous solar panel mounting schemes employed on devices throughout the city.

Weather - Rain poses a risk to any outdoor installation, especially in the later summer months. The front panel, while perforated, has enough solid surface to combine with the shelter provided by the top-mounted solar panel and deflect most rainwater from entering the piece. The resonators, and their mounting panels, provide full weather resistance to any water that does pass through the front panel, and all electronics are safely mounted behind this barrier. Any rainwater that splashes off the inside panels is harmlessly routed downwards and drained past the waterproof battery enclosure and out the bottom of the structure. Each proximity and light sensor is protected by its own transparent weather enclosure that is easily replaceable and mounts directly to the face panel. The back access panels of the piece are fully sealed when closed.

Heat is a special problem in the Phoenix area, where summer temperatures frequently exceed 100°F and may reach 115°F or more. All of the electronic components in the work are guaranteed by their manufacturers to function in temperatures up to 135ºF. In practice, components can often withstand temperatures in excess of this mark. We have also temperature tested the selected plastic resonator cups and have determined that they retain their integrity at temperatures up to 150ºF. As a consequence, it is only necessary to keep the internal temperature of the enclosure at the same level as the ambient environment. By designing weatherproof vents in the enclosure at the bottom and top, we can evacuate excess heat from the electronics by simply creating an upward draft.

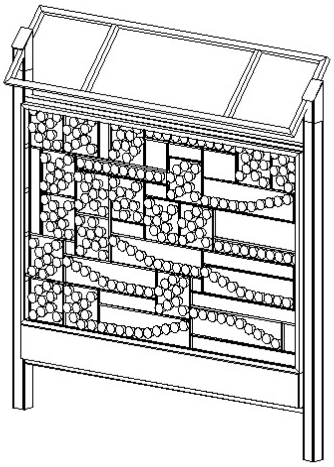

Figure 3. Diagram of physical structure

Materials for the structure have been chosen with heat, rain, and ultraviolet resistance in mind. We selected solar charging panels that are intended for exposure to the elements. They are similar in structure and function to solar panels that are currently in use in city traffic and lighting structures at many locations in the southwest United States.

Maintenance

The electronics of the work are designed in a modular fashion such that even if an element is damaged, it does not jeopardize the overall function of the piece. If one of the electronic modules should fail for any reason, it can be readily extracted and replaced. This internal wall of sensor/speaker circuits and controllers is enclosed by three solid back panels that keep the electronic elements out of sight and reach of the public. These panels as well as the front panels are hinged so that complete access can be had to any part of the piece.

Funds were budgeted to cover repair and replacement of any damaged components. During the initial six-month installation period, we have scheduled weekly visits to the site to inspect for any damage, and should the installation be extended we have a plan for continued maintenance.

3.3.2 Interaction Design

The work's interaction framework addresses concerns of both audience engagement and environmental sensitivity. A distributed network of proximity and light sensors blankets the front panel of the installation. Each module has either one or two infrared proximity sensors with a sensing range of up to 80cm extending out from the front panel. The resulting sensor density is one sensor per 2 square feet on average, and proportional to the speaker density as illustrated in Figure 5. Each module also contains one photovoltaic sensor to detect ambient light levels.

In order to engage all types of audiences, we needed to develop an intuitive and expressive framework for interaction that is suited for adults and children of all levels of education and experience. Furthermore, we have sought to engage both individuals and groups of audiences by facilitating simultaneous and collaborative interaction. The work facilitates multiple interaction paths to ensure that complex and varied musical structures can emerge. For example, if a user makes a broad, full-bodied sweeping gesture across a section of the wall, it will erupt with a diverse sound explosion that similarly races across the wall. Conversely, if a user instead holds a stationary hand in one isolated spot, a small region of the wall will be activated as it cycles through a sequence of sound transformations.

We were also concerned with accommodating transit riders, who have little choice about sharing the environment of the piece and whose level of interest may vary widely for reasons completely external to the work. For this reason the wall will only sound if actively engaged by the audience.

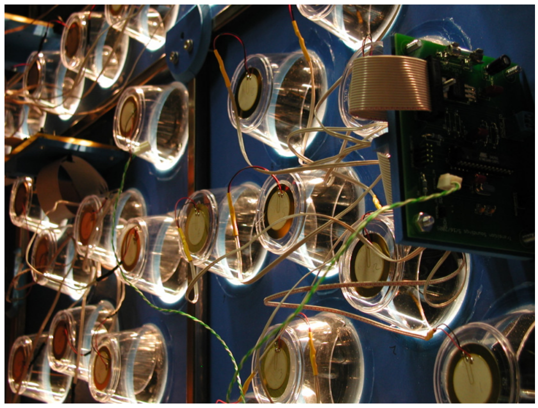

Figure 4. Partial inside back view of embedded electronics

3.3.3 Interactive Sound Generation

We have given particular consideration to two aspects of sound design for this work. First, we considered the ambient sound levels of the site to ensure that our work would not pose a noise pollution hazard. Second, we worked to design a strategy for interactive sound that would yield complex musical results with sounds and timbres that would engage a broad public audience.

Sound Levels

Given that the work is in an open environment, we first considered the sound design in light of the existing site-specific soundscape, to ensure that our piece would not dominate the ambient environment. The installation site is at the corner of a major intersection that has heavy traffic during peak hours and high variance due to the passage of cars and trucks according to cyclical traffic patterns. We first took sound level measurements at the site in both the afternoon (12:30PM on a Tuesday) and in the evening (8:30PM on a Tuesday) and found the following conditions

60-80 decibels (day) and 55-65 decibels (night)

We then measured a prototype sound module and found a rise above the ambient sound environment for the sounding wall when active is:

12 decibels at proximity of 2 ft. (simulating a listener who is interacting with the piece)

7 decibels at proximity of 8 ft. (simulating a listener at the transit stop, but not necessarily interacting)

2 decibels at proximity of 15 ft. (simulating a listener who is not at the transit stop)

These sound level readings reveal that the sound of the wall is well within the range of the ambient and traffic sound levels of the sites under consideration. The sound wall is audible for transit stop users without being intrusive, and does not compete unpleasantly with the ambient sounds of the site. In addition, it is evident that the wall is not a source of noise pollution for the community around the stop as the work is very quiet at a distance and is only audible when a user is interacting with it.

Interactive Musical Expression

Given the challenge of designing an interactive sonic work for a broad audience of users, we have endeavored to create interactive musical structures that are intuitively meaningful to listeners, and indicative of the nature of transit networks and the surrounding environment. Although we wanted to provide diverse and variable musical paths through the work for transit passengers who might visit the site on a daily basis, we also wanted to ensure some measure of shared experience for the broad spectrum of the public who might experience the work. All sound for the piece is generated via 1-bit digital to analog conversion using the embedded Atmel microchips. Algorithms for sound generation and DSP functions are programmed directly on the microchip.

First we discuss the behaviors of sound within an individual module. As described in *Section 3.1*, as a user moves or gesticulates in front of any of the proximity sensors, a wash of propagating sound originates from the location of the triggered sensor. Because each module functions independently, sounds can originate in parallel as multiple modules can be simultaneously activated by a user.

We have designed four classes of sound events:

(1) sustained square wave

(2) pitched pulse train with three-eight pulses

(3) clicking pulse train with three – eight clicks

(4) noise with a subtle central pitch

These sound classes were designed to integrate and reflect on the sonic environment and abstractly narrate a conceptual sonic day at this site. Combinations of harmonic square waves (Class 1) embody the notion of a bright, dawning day. Pitched pulse trains (2) reflect the vibrant activity of the transit network at peak hours. Clicking pulse trains (3) link to the evening hours when insects begin to emerge. Finally, the pulsing noise bursts (4) fuse to sound like cicada colonies on a summer evening.

There are ten stages for each of these events that dictate the frequency and duration of an event. For example, stage 1 of a pitched pulse train specifies frequencies of 200Hz with four short pulses. Stage 2 specifies frequencies of 400Hz with seven short pulses. When a given proximity sensor is triggered, the sonic event for that module will propagate through each of the ten ordered speakers. For example, a short noise burst can originate in speaker 0 of a straight line. Identical noise bursts will sequentially emanate from speakers 1-9. With each trigger of a given proximity sensor, the module stores an interaction history counter that flags the number of triggers. As a module moves from zero to a maximum of forty triggers, the originating sound will move through a fixed sequence of sound events, frequencies and durations. After a period of three minutes, each module will reset this history flag so that new users who approach the work will find an empty history. This timing value was selected to approximate an average transit wait period. This reset assures a relatively shared experience for all users and serves as a practical function to provide robust performance.

Now we describe how sound propagates through the network. Module junction points occur where the topology of the speaker network has 'touching' speakers. See Figure 5 for a diagram of speaker module and example junctions. As a sound travels within an individual module, when the sound reaches a junction, via an embedded serial bus, a ping will be transmitted to the adjacent module. The receiving module will in turn propagate the sound in the same fashion. In this way, sound will mushroom from the point of origin across a region of the wall. A radius feature that depends on the interaction history counter limits the number of linked modules that will carry the originating sound. Specifically, when a new sound class is revealed, the radius will range to a maximum of four. With each additional interaction this radius diminishes until the radius is at a minimum of one. The variable radius allows for a mixture of local, regional, and global sonic events that emerge depending on how users engage the interactive wall.

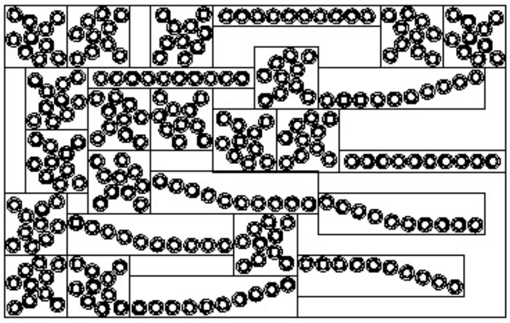

Figure 5. Diagram of front face speaker network

This propagation algorithm yields diverse musical events as users interact through varied gestures in different regions of the wall. Furthermore, the musical experience of the wall will vary greatly depending on whether individuals or groups engage it. In addition to impacting the sheer number of sonic events, each sound class event yields different combinatorial structures. For example, when a square wave sound is passed from one module to another, the frequency of the sound will select from a frequency array. Frequencies are organized into regions that yield simple harmonic relationships in groups with some dissonant transitions that yield moments of musical tension and release through interaction. This structure is simple enough to be readily perceived by novice users, but the interaction algorithm provides numerous paths to explore varied musical outcomes. Similarly, as clicking pulse trains pass from one module to another, the speed and number of clicks is varied to yield gradually accelerating and decelerating events.

The sound generation algorithm is also sensitive to the ambient light levels. When bright light is detected by the photovoltaic sensor, the interaction history advances slowly through the four sound classes. However, when light levels are dim or dark, the progression from pitched square waves to noise bursts is very rapid. This design allows for a varied experience for users who approach the work in the morning or night. The algorithm thus highlights the sounds associated with the appropriate time of day. For example, in darkness, users will quickly hear noise bursts that approximate the sound of night insects after even a brief interaction.

4. EVALUATION

Transition Soundings was installed in the city of Tempe in September, 2005 and is currently scheduled to remain on exhibit through April 2006. A potential extension of the installation period will be negotiated at that time. We have described a number of challenges posed by public art and have discussed our approach taken in the realization of this work. Here we assess the outcomes.

A critical challenge is to design work that is communicative and engaging for a diverse public audience that is not necessarily seeking an art experience. Given the open nature of the exhibition circumstances, audience evaluation is a challenging task. However, through both informal user studies with our colleagues and direct observation of public audience participation, we can draw some preliminary conclusions. Our initial user studies proved very encouraging. Our colleagues were able to approach the work and intuitively interact through movements and group gestures. Their comments indicate that the resulting sonic washes are timbrally rich and that the spatial sound movement is engaging. They report that the pulse train sounds are most appealing in this context, but that the harmonic richness of the cascading square waves is very rich. Most are intrigued by the sonic fusion of the noise bursts, but few users engaged the work long enough to reach that stage without additional direction.

As of this writing the work has not yet been widely publicized and thus our evaluation of a larger audience sample is inconclusive. Our brief observations reveal that users often do not realize that the work is interactive, and we suspect that our attempts to avoid problems of noise pollution have lead to a situation where the work does not fully attract public users to engage the work. Furthermore, as work is situated on a busy street, we postulate that users might feel self-conscious about engaging in extended interactions.

We took great care to design sonic feedback that is site-specific. We have been pleased with the overall sound design and have received positive feedback from users regarding the relationship of the musical structures. However, while the work is in no way a source of noise pollution, we have been disappointed that it is overwhelmed by the ambient sounds and traffic noises that define the site. During the evening hours the overall sound level of the piece is ideal, but traffic noises mask much of the sound during peak hours and users are unable to decipher many details of the work.

A critical design challenge in our work was to address issues of durability, maintenance and reliability in the work. After several months of uninterrupted display we are extremely pleased with the robustness of the work. Our solar charging power plant provides reliable power throughout the day and night. We have not experienced any failure of electronic components. Despite several rain storms and above average fall heat, we have not observed any ill effects. Finally, we have not observed any effects of vandalism or tampering with the work.

5. CONCLUSIONS AND FUTURE WORK

We have described the challenges posed by physically situated interactive public sound art works, and have discussed these points within the context of our development of a new public art work, *Transition Soundings*. We have been pleased with the outcome of the interaction framework and the strength of the conceptual underpinnings for this project. Our funding partners have expressed great interest and excitement about the innovations of the work and its uniqueness within the field of public art.

We expect that the piece will ultimately greatly benefit from location in a less active sonic environment. In our future work, we plan to find a permanent installation site in our region that is publicly accessible but sonically more appropriate. For example, we have identified a number of transit stops that are situated along local streets that are less heavily traveled.

6. MEDIA DOCUMENTATION

Extensive documentation of the design, development and final realization of the piece can be found online at http://ame2.asu.edu/faculty/dab/transitionsoundings.php. Still images, video clips, and diagrams are published that detail each stage of the design process and outcomes.

7. ACKNOWLEDGEMENTS

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