

1. Introduction

JEAoustics (JEA) was retained to conduct evaluations of acoustic reflection patterns, geometry, materials and surface finishes, with respect to the existing and future planning for the Center of the Universe (COTU) acoustical experience on the Boston Avenue Pedestrian Bridge, in Tulsa, Oklahoma.

The COTU site consists of a multimodal pedestrian, bicycle and vehicle bridge, paved with concrete and brick, and with curved concrete bench seats and planter beds that create a low, circular feature at the bridge’s center. The curved benches support an acoustic echo and audible sound focusing feature, which has made the location an iconic place for locals to stop in, speak or holler, listen, and experience the phenomenon.

This report presents our findings regarding the acoustic feature, feasibility recommendations, and comments on conceptual designs for proposed redesigns, and preservation of iconic acoustic features.

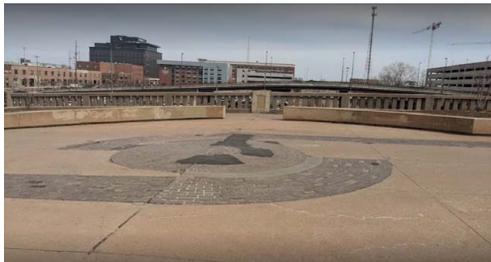


Figure 1 – Existing Project Site, View Looking East

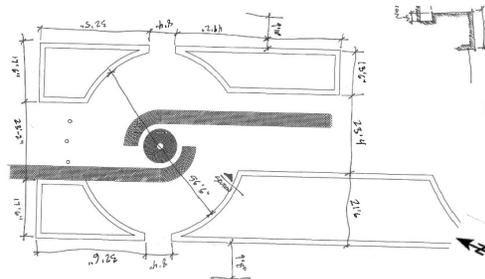


Figure 2 – Existing Project Site, Plan View (provided by Selser Schaefer Architects)

2. Goals

The following provide the basis for our review and assistance to the Design Team with proposed COTU redesign concepts and feasibility study:

- Understand what causes and creates the acoustic properties that make the Center of the Universe such an attraction.
- Work with the Design Team to preserve and protect those essential acoustic features as part of the bridge rehabilitation and above deck design enhancement.

3. Acoustic Focusing Features in General

Acoustic focusing features have been built, experienced, and documented through recent human history. Some of the more remarkable examples are called a “whispering gallery” feature, in which two people may have a normal conversation at an unusually large distance within the presence of an acoustic focusing parabolic or elliptical arch or dome. Examples of “whispering gallery” features are illustrated below (left) and can be experienced at the Statuary Hall in the United States Capitol, the rotunda of the Texas State Capitol, and Cincinnati Union Terminal, among other places in the US.

Central focusing of voices or sounds within the presence of a circular arch (illustrated below, right) are similar to the “whisper gallery” feature, but tend to be experienced by only one person at a time (a conversation with oneself, as it is heard only at the central focusing location (at the star in the diagram below, right).

COTU is a good example of central focusing. Circular reflection patterns can also produce a “whisper gallery” which COTU may also exhibit at certain locations inside the concrete benches.

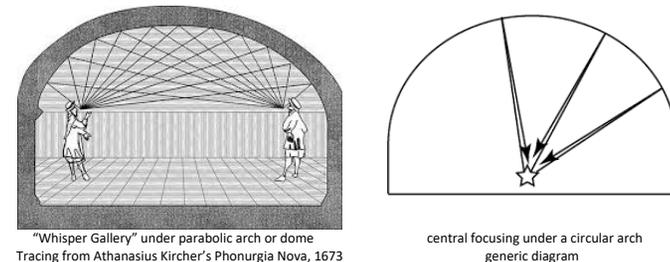


Figure 3 – Examples of Acoustic Focusing Features

4. Acoustic Focusing at COTU

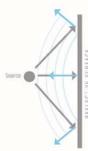
Selser Schaefer Architects (SSA) visited the project site to conduct observations and measurements of the COTU acoustic feature, along with audio recordings with paper sheet to obstruct the reflection patterns for our review and analysis. JEA has also reviewed various recorded examples of the acoustic feature in publicly available videos posted online (e.g., YouTube).

Based on our review of site plans and recordings, we worked with the MKSK and SSA to develop the following conceptual illustrations of the primary focusing features at the COTU site.

THE SCIENCE AND THE PHENOMENON

Sound Reflection

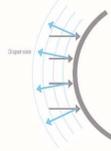
Sound waves are reflected from a surface similar to light waves from a shiny surface or prism



Example: The strategic parallel and perpendicular walls of a gymnasium reflect sound and create an echo

Anti-Focusing Surface

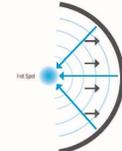
Convex or angled surfaces disperse reflecting sound waves outward and produce a more even sound



Example: An auditorium has convex or angled walls to project sound evenly and avoid echoes

Focusing Surface

Concave surfaces focus the reflecting sound waves inward and produce "hot spots"



Example: This is the phenomenon experienced at the Center of the Universe

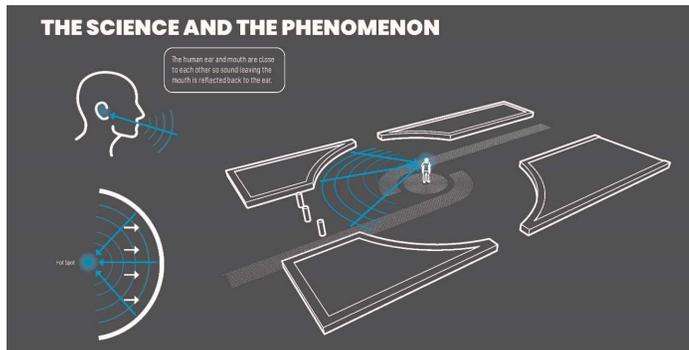


Figure 4 – COTU Focusing Features (excerpts from MKSK/SSA presentation 12-Dec-2022)

Several factors could affect the audibility of the focusing feature at COTU:

- The location of the observer (needs to be at central medallion, or "eye")
- Weather conditions (we understand dry weather conditions seem to be ideal)
- Presence of ambient noises (best in quiet conditions, low winds, no trains)
- Obstruction of inner bench faces (obstructions interfere with the focusing)
- Height of observer (may need further study)

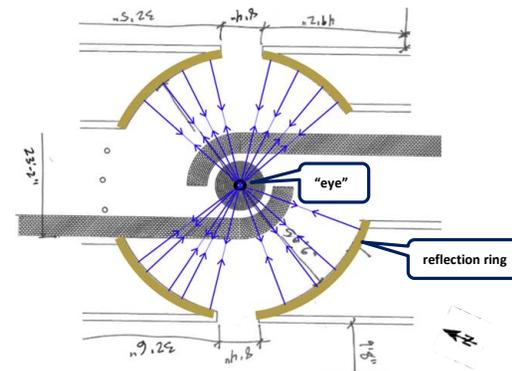


Figure 5 – COTU Focusing in Dimensioned Plan

As a person standing at the "eye" of COTU speaks, sound of their own voice will emanate in all directions. Some of that vocal sound may reflect from the hard bridge pavement surrounding them, and reflect again from the hard, curved, vertical concrete bench surfaces surrounding them back to their ears. The time it would take for that sound to travel (at the speed of sound through air at 75° F) from one's mouth back to their ears as illustrated below would be approximately 50 milliseconds (50 ms delay). Many 50-ms "first reflections" would happen simultaneously around the observer, front, back, and sides, reinforcing a strong echo experience.

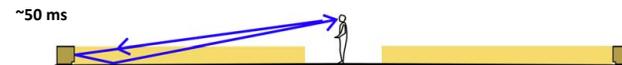


Figure 6 – COTU Focusing "First Reflection"

In general, a reflected echo is considered to be audible or noticeable to human ears if it has a delay around 50-60 ms or more, and becomes very noticeable or distracting at more than 80 ms.

In addition to the “first reflection” having approximately 50-ms delay, further reflections within the COTU reflection ring can propagate onward. Just a couple of those onward reflections are illustrated below, producing potentially 100-ms and 200-ms delay echoes, and possibly longer, up to 300 ms (or 0.3 seconds).

Longer delays are perceived as more prominent or more noticeable echoes. Longer delays may be perceived more often or more prominently by shorter observers, as shown with the 200-ms illustration below, compared to taller folks.

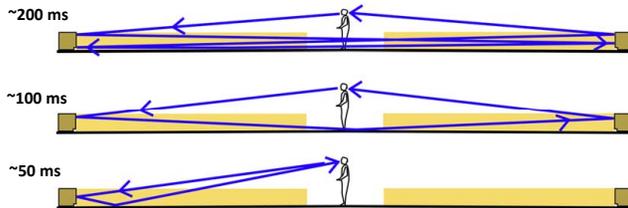


Figure 7 – COTU Focusing “Onward Reflections”

5. Recommendations

Preservation

In order to preserve the existing acoustic feature along with proposed redesign and renovations on the bridge at COTU, we have developed the following recommendations:

1. Avoid new features inside the reflection ring that could obstruct the primary mouth-to-ear sound reflection paths illustrated in Figures 5-7.
2. Avoid new features or structures outside or above the reflection ring that could reflect much sound back to the ear (at a different distance or with a different quality than the existing bench-and-pavement reflections provide).
 - New curved bench walls, planter beds, backrests, and overhead shades outside of preserved reflection ring could add a new and different focusing reflections that “muddle” the existing acoustic feature and experience.
 - New benches or planter boxes need to “hide” tucked entirely behind and outboard of the existing reflection ring as much as practical.
 - Utilize careful shaping and design of new bench backrests and upper lips of outer planter bed rings that may reflect sounds inward.
 - Bench seat backs or other new railings above existing reflective benches

should maintain at a minimum 22% open area to allow sound to pass through without reflecting back into the reflection ring or back to the “eye” location. Natural plantings tend to be acoustically transparent.

- Slanting the seat backs should also help, and further study can determine ideal angle to plan for those seat backs to reflect sound upward and away from center “eye” location, along with >22% open area to be safe.
 - Overhead shade structures above the ring or outside the ring (if any) should be designed with care, mindful of adding possible reflections back into the central ring area. Shade panels, sheets, fabrics, solid framing members and structural elements such as beams or edges, all need to have attention to shape, material, perforation, or geometry that does not focus reflected sound towards the center at ear level. Those things could possibly reflect sounds inward at heights well above ear level if needed.
 - Large surfaces of shade panels, fabrics, or sheathing should have enough open perforation (again, 22% or more open and breathable) to let sound pass through without bouncing sound downward or inward.
3. Avoid significantly changing the existing texture or reflectivity of the bridge’s pavement surfaces and inner vertical concrete bench surfaces within the reflection ring.
 - Hard brick or concrete pavers or similar surfaces equal to the existing conditions should be fine at the bridge deck in order to repair or replace damaged areas.
 - Porous paving units, grated surfaces, granular rubber, earth/grass pavers should not be planned.
 4. Avoid new features or structures that could generate noise to disturb or distract occupants, detracting attention from the acoustic feature experience (parts moving, squeaking, whistling, rustling in windy conditions).
 - Shade constructions need to be stiff enough that light breezes do not often set panels in motion to generate uncontrolled noise.
 - It could be a challenge to know which shapes like that can generate noise in winds unless we have built examples to rely on. Hanging fabric panels would certainly flap in the wind, and should be avoided. Tree or shrub leaves can also rustle in the wind, but would likely be fine.

Enhancement

In addition to preservation, MKSK asked for suggestions on enhancing the acoustic features (perhaps so it could be better experienced on rainy days or for people of different heights). JEA does not recommend significant additions or enhancements. The existing feature is a simple reflection system, and yet, it seems to have complexity and nuance. Given the slight bend in the bridge

center, the non-symmetrical ring array of four benches, and other existing things that make it unique and not a perfect circle. Messing with that to provide some enhancement would be tricky; nevertheless, the following are suggested concepts that could be tested or evaluated:

- a) For example, more length of curved concrete bench could be added “in line” with the existing ring, replicating the same bench profile, texture, toe kick dimensions, etc. Maybe that would be an enhancement, maybe not.
- b) Adding to the height of the existing bench could add reflective ring surface to boost the focus inward, but adding too much height makes the benches impractical for sitting, or effectively builds a walled enclosure for a different experience. Maybe that would be a feature enhancement; probably not.
- c) It may be possible to smooth out the existing concrete, grind it smoother, or add concrete sealer finish to fill in pores so it does not retain moisture, or dries quicker. Tricky, tricky. We do not know that these sorts of modifications would improve the feature.

Given the guidelines recommended above, the Team developed conceptual plans dated 12-December-2022, shown below.

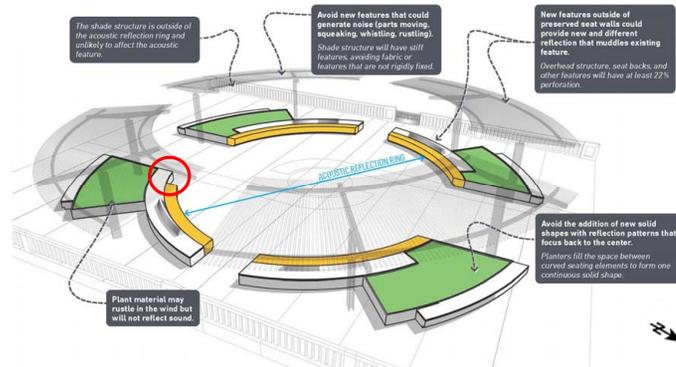


Figure 8 – COTU 12-Dec-2022 Concept Plan

The current schematic plan is showing a short section of new curved bench and planter bed on the southeast quadrant, extending out behind the existing acoustic reflection ring or “echo feature” bench, which is not recommended (see the red outlined bench corner above, left). This is an example of new additions to avoid, or which need to be designed with special attention to solid geometry such

that it is shaped to reflect sound away from the center, or is simply eliminated, in order to avoid a new contributing reflection pattern (red reflection arrow in Figure 9, below).

Another approach in this specific case is to modify the schematic plan, to tuck any new additions of southeast planter bed and benches east of the blue dashed line where the existing planter bed now resides.

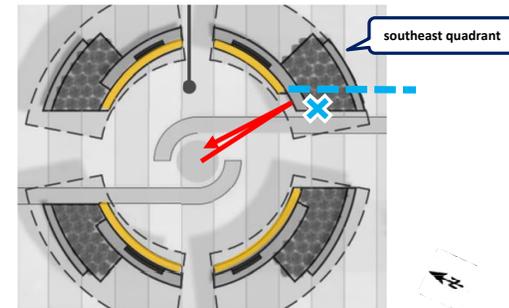


Figure 9 – Comments for 12-Dec-2022 Concept Plan Southeast Quadrant

We hope this discussion of acoustic features and recommendations for Center of the Universe assists with your evaluation and planning for the proposed project. Please contact me directly with any questions.

Submitted by,

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