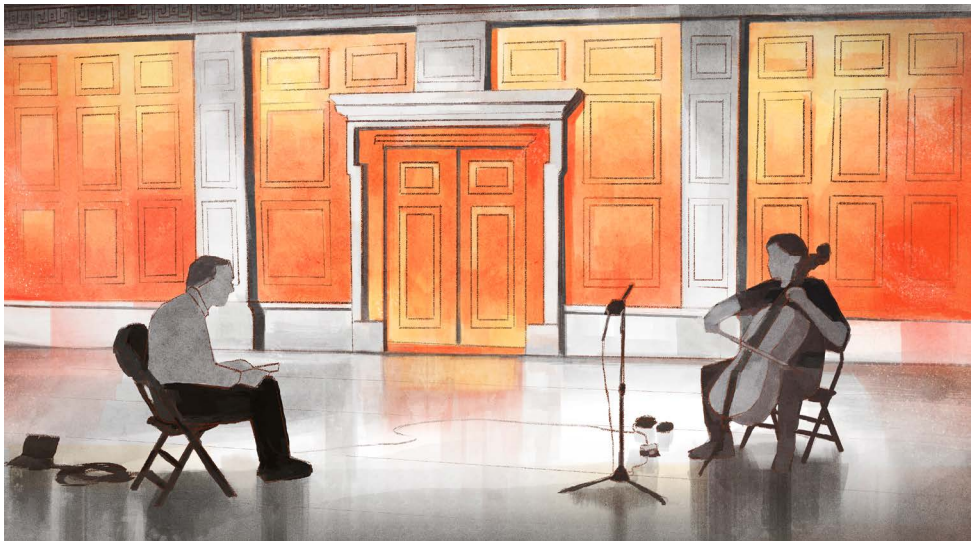

A HISTORY OF COLLABORATION

ACENTECH'S LONG-STANDING PARTNERSHIP WITH THE BOSTON SYMPHONY ORCHESTRA

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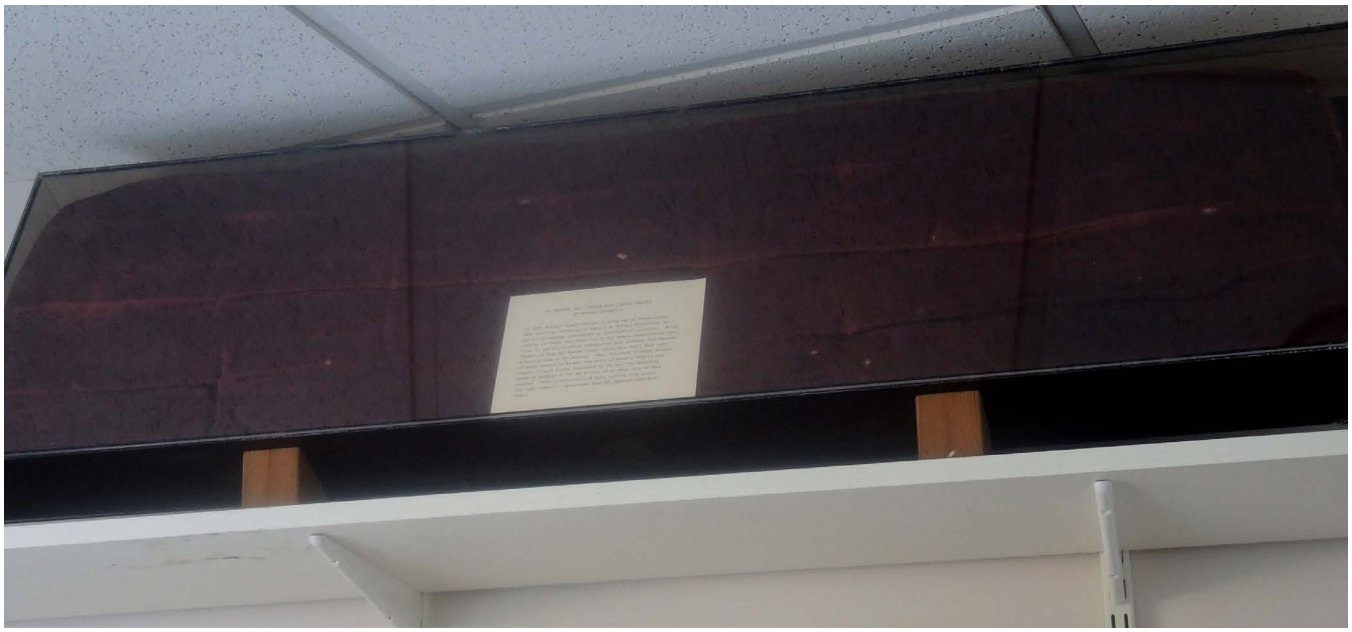
01: Introduction

Boston Symphony Hall holds a significant place in history, representing a turning point in the evolution of concert hall design. It was the first concert hall to have an acoustician actively working with its architectural design team, establishing a precedent for incorporating acoustical expertise in the design of critical spaces.

In 2002, Acentech's Studio A began its collaboration with the historical hall, serving as its lead partner in optimizing the venue's acoustic design for the future.

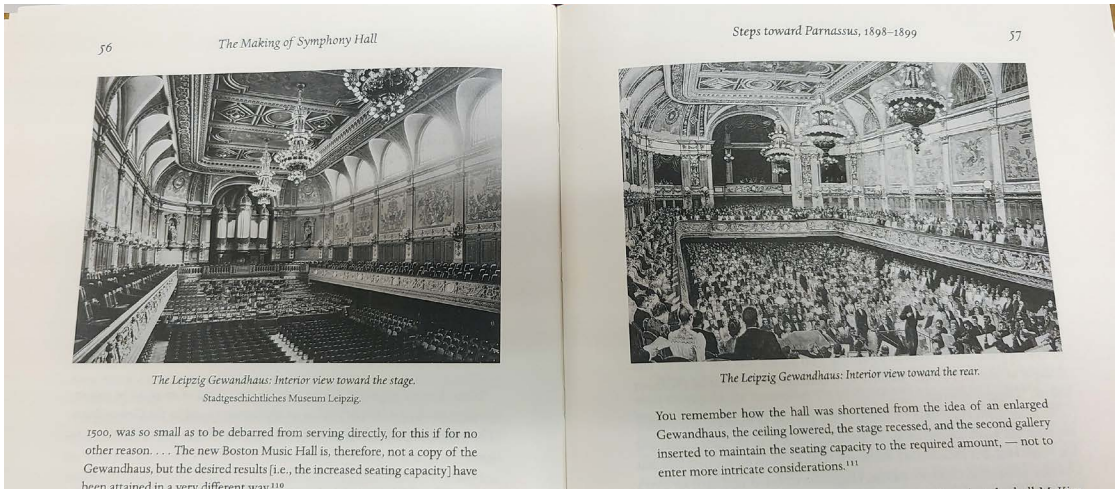


Preserved Sanders Theatre seat cushion in Acentech's library of artefacts, Cambridge, MA.

In 1885, Wallace Clement Sabine, a young physics professor at Harvard, made a founding discovery of architectural acoustics: defining the relationship between reverberation of sound in a space, its volume, and the quantity of sound absorption within it (**a story worth telling in and of itself**). His simple yet groundbreaking discovery connected sound and architecture in a new, scientific way.

News of Sabine's discovery quickly spread throughout Boston, prompting influential figures to seek his input on the design of a new concert hall for the **Boston Symphony Orchestra,** which was then still in the early stages of its development.

02: Boston Symphony Hall



56 The Making of Symphony Hall

The Leipzig Gewandhaus: Interior view toward the stage.
Stadtgeschichtliches Museum Leipzig.

1500, was so small as to be debarred from serving directly, for this if for no other reason. . . . The new Boston Music Hall is, therefore, not a copy of the Gewandhaus, but the desired results [i.e., the increased seating capacity] have been attained in a very different way.[110]

Steps toward Parnassus, 1898–1899 57

The Leipzig Gewandhaus: Interior view toward the rear.

You remember how the hall was shortened from the idea of an enlarged Gewandhaus, the ceiling lowered, the stage recessed, and the second gallery inserted to maintain the seating capacity to the required amount, — not to enter more intricate considerations.[111]

Images of Leipzig Gewandaus from *The Making of Symphony Hall* by Richard Poate Stebbins

An Early Exemplar of Architectural Acoustics

Inspired by old world halls like the New Gewandhaus in Leipzig[1], and the local precedent of the Boston Music Hall, the new design boasted more seats and overall larger dimensions. Sabine, however, cautioned that the volume of the space was excessive and would lead to prolonged reverberation times within the space. Adjustments were made and the resulting hall, inaugurated in 1900, set a new standard for acoustical excellence that has informed nearly every hall designed since.

Boston Music Hall, early 1900s

While architectural acoustics have continued to evolve, the fundamental balance of room volume, absorption, and reverberation endures. In 2002, the Boston Symphony Orchestra (BSO) engaged Acentech's Studio A team to assess and advise on these essential elements throughout a series of meaningful updates and renovations.

[1]To differentiate it from the demolished Old Gewandhaus, and from the extant Third Gewandhaus built following wartime damage to the second iteration.

Robert Berens has led Studio A's work with the BSO since 2002

Pipe Organ Rebuild and Chamber Renovation

First among these renovations was the concert hall's pipe organ. Positioned behind the orchestra stage, it was to be rebuilt and the organ chamber refinished. During this process, all organ components were removed, leaving the chamber empty for the entire 2002-2003 symphony season, with only the façade pipes in place. Since the chamber is open to the concert hall and directly behind the orchestra stage, there was a concern that the empty chamber would function as a coupled volume and thereby affect the acoustics of both the stage and the audience area.

Pipe organ chamber exposed and bare, organ pipes on floor in foreground

Boston Symphony Hall Renovations

Organ pipes on concert hall floor, awaiting re-installation. Photo taken from bare organ chamber above the stage.

To investigate the potential changes this might create in the space, our acousticians conducted a series of measurements of reverberation time–the same metric established by Sabine over a century prior–in the empty organ chamber, on the performance stage, and in the audience. Significant reverberation time differences were noted in the chamber, less so on stage, and virtually none in the house. We first investigated the possibility of maintaining the reverberation characteristics of the organ chamber by adding absorptive material to compensate for the removal of the pipes. Several BSO musicians were invited to participate in listening tests of the space as we brought up the absorptive curtain, and we concluded that there would be a small change in the sound of performances, perceptible only onstage and not in the audience. This was received as good news by the Orchestra, and the symphony season took place as planned with no special action required.

Stage Floor Replacement

By 2004, the original wood stage floor was badly worn and in need of replacement.

The stage floor plays a crucial role in the concert's acoustics, alongside the concert hall and the orchestra itself. Not only does it reflect sound from the instruments; it also vibrates in response to the instruments and re-radiates this vibration as sound. This effect is especially noticeable for instruments like cellos, basses, and percussion that make direct contact with the floor. These factors greatly influence what both musicians and audiences hear.

To understand this better, we conducted tests on the old and new stage floors. We advised that the new stage floor be built to match the construction of the old floor in every way possible: the wood species and cut, the configuration of planks, even the historical "cut" nails. The inescapable difference was that the new floor lacked 100+ years of wear, which made a profound difference to its appearance: the new floor was a light blond color and unfinished, in contrast to the dark brown patina of the old worn floor that was covered with a quarter inch of old varnish. Across the stage, the new floor exhibited a far more uniform acoustic response to vibrations induced by cellos and basses. The feedback from musicians was strongly positive, with a few comments that the new floor sounded "brighter" and more immediate in its response.

Acousticians James Moore and Jonah Sacks measure the response of the new stage floor to excitation by cello.

"As the resident Acentech cellist, I had the pleasure of providing one of the sound and vibration sources for these tests. We placed vibration sensors on the floor at many locations and microphones in the hall and measured the vibration response of the floor to the cello, and of the floor to impacts made by a mallet fitted with its own vibration sensor. This allowed us to map out the floor's vibrational and acoustic behaviour across its surface."

- Jonah Sacks

Boston Symphony Hall Renovations

Clerestory Window Replacement

Symphony Hall was originally built with half-moon shaped windows along the tops of its side walls. According to legend, these windows were shuttered during 1940s wartime blackouts to avoid presenting a visual target for aerial bombing. They were finally restored with new windows and light-control shutters in 2009, allowing natural light back into the hall and conveying a sense of activity to the city around it. Our contribution to this effort involved documenting sound transmission through the original shuttered windows and assisting in the design of the new window system to minimize street noise disruption during performances.

To measure this, we conducted tests by placing loudspeakers on the low roof outside the windows and measuring noise levels both outside and inside, using a long pole to place our microphone from the second balcony.

The data guided our recommendation to include a new acoustical storm window, installed with a deep airspace to the restored historic interior window. The result is a visually striking upgrade and an acoustical win.

Measuring sound levels on the roof outside concert hall clerestory windows

Measuring sound transmission through a shuttered clerestory window in the concert hall

Impedance tube loaded with sample seat bottom for acoustical measurement

Seat Re-cushioning

Despite being widely loved, Symphony Hall had a reputation for uncomfortable seating. In 2009, the Orchestra responded. Rather than replacing the historic chairs, they opted to install new seat cushions, replacing the hard horsehair padding. However, concern arose over the acoustical impact of the softer cushions and how they could change the absorption within the concert hall. To address this, we took a sample seat bottom to a specialized testing lab equipped with a large rectangular impedance tube. These tubes are commonly used to measure the acoustical absorption of small material samples, a process we frequently conduct in our own lab.

In this case, measuring the entire seat bottom—including both the top (where contact occurs) and the underside (which is always exposed to the hall)—rather than a small sample, was crucial. We compared the absorption characteristics of the old and new seat cushions and found that due to the non-porous leather-like covering, the differences were negligible.

Boston Symphony Hall Renovations

Chorus Room Expansion

John Oliver directing the Tanglewood Festival Chorus in the pre-renovated chorus room.

The Boston Symphony Orchestra is often joined by the Tanglewood Festival Chorus, a volunteer choir of up to 200 voices originally formed by—and operated under the direction of—the orchestra. The Boston home of the chorus is a rehearsal and storage space in the lower level of Symphony Hall.

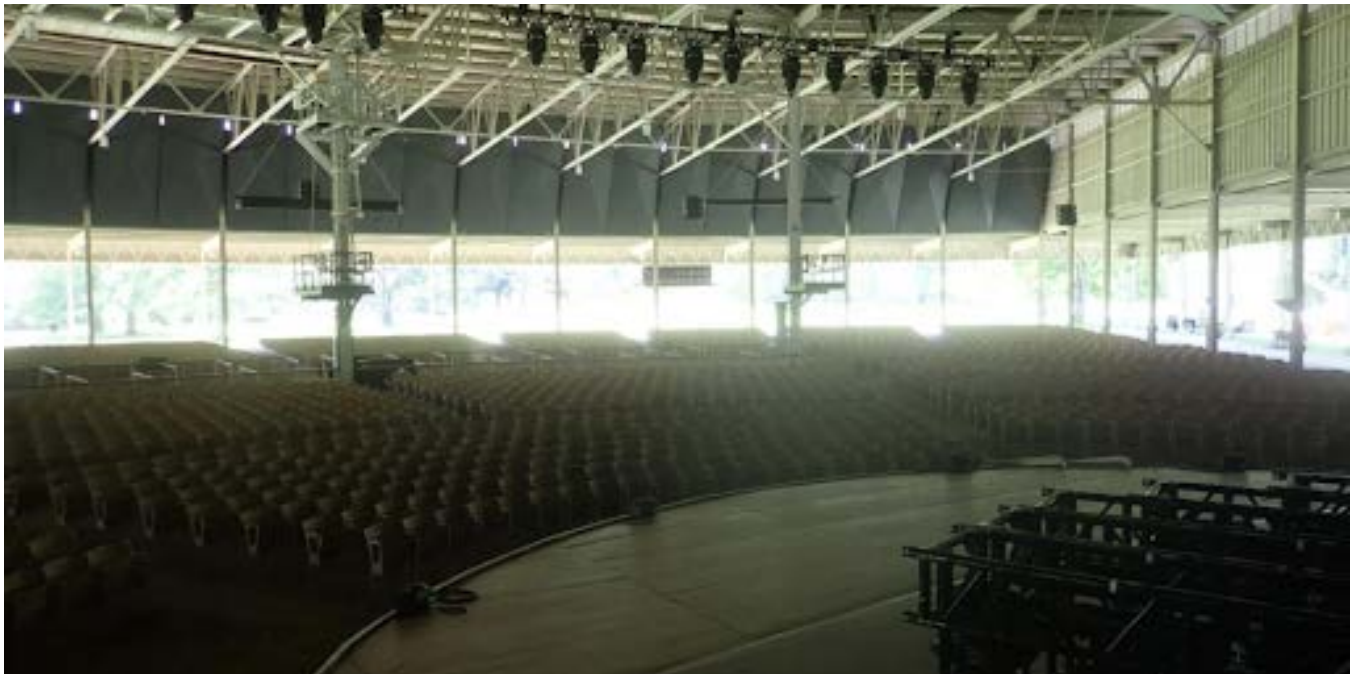
By 2014, the chorus had outgrown the space, and its director, John Oliver, had reported challenges in hearing the singers in the crowded room with its overly loud acoustical conditions.

The renovated and expanded chorus room

We helped design a new, highly articulated ceiling and wall system to absorb and diffuse sound in specific locations while providing the sound reflective properties necessary for good ensemble hearing. The result is a comfortable and attractive space with acoustics that are clear and controlled.

A custom grid ceiling system uses perforated metal panels at varying angles to provide a blend of sound absorption, diffusion, and reflection.

Tanglewood Music Center



Koussevitsky Music Shed seen from the stage. Upper walls at rear and sides contribute to the shed's excellent concert acoustics.

The Koussevitsky Music Shed, the summer home of the orchestra and Tanglewood's primary concert venue, accommodates 5,000 seats under cover, with additional lawn seating for thousands more. The Shed is widely regarded as the first large, covered, open air venue to provide excellent concert acoustics for orchestra without amplification. This was achieved through a clever design featuring a partial enclosure, with an open ground level and enclosed upper side and rear walls.

Koussevitsky Music Shed Wall Panels

Several times in recent decades, portions of the upper walls required replacement due to weather -related wear. These replacements provided opportunities to refine panel positioning and upgrade to modern materials. In every case, we have advised on the design of the new wall components ensuring optimal sound reflectivity, distribution of reflected sound, and sound transmission characteristics.

New quiet ventilation fan on roof of amenities building behind the Koussevitsky Music Shed

Ventilation Upgrades:

Koussevitsky Music Shed

An open-air venue, the Koussevitsky Music Shed had long used on-stage fans to move air around for musician comfort. New vent fans were installed in 2021, as proper ventilation became an urgent safety matter during the COVID pandemic. Equally urgent was the need to ensure that the new fans and ductwork were inaudible to musicians as well as the audience.

Seiji Ozawa Hall

Seiji Ozawa Hall is a 1,200 seat concert hall with a rear wall that opens to lawn seating. The hall is well loved and used extensively for chamber music performances and for rehearsals of various ensembles. Among the hall's prized features is its quiet background sound conditions. The COVID pandemic prompted a new look at the hall's ventilation system, which includes an array of under-seat air openings and ductwork under the audience floor.

Collaborating with Tanglewood facilities staff and mechanical engineers, we conducted extensive measurements in both venues to help design upgraded systems for improved ventilation without noise. The Koussevitsky Music Shed's new system was operational for the 2023 summer season, while upgrades for Ozawa Hall are slated to be ready for the 2025 season.

Acentech intern Jehan Diaz and acoustician Allie Lam in Ozawa Hall's underfloor air circulation spaces.

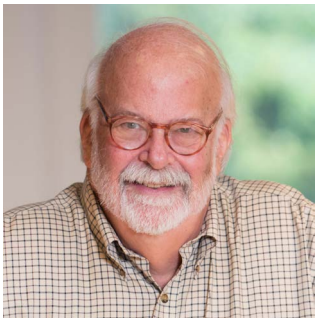
Continuing the Collaboration

The relationship between the Boston Symphony Orchestra and Acentech's Studio A has been long and fruitful, and continues today. Robert Berens has led this work, with help from many, including Ben Markham, Jonah Sacks, Jeff Zapfe, Jim Moore, Rose Mary Su, Jen Hinckley, Allie Lam, and others.

About the authors

Jonah Sacks is Director of Architectural Acoustics at Acentech, a world-class acoustics, technology, and vibration consulting firm. A lifelong musician who has performed in many concerts as a cellist, guitarist, and bassist, Jonah brings his passion for music to his acoustics consulting role and practice leadership. He is instrumental in the creation of 3DListening® computer models to evaluate acoustically critical spaces. His portfolio includes conservatories, academic institutions, K-12 schools, public gathering venues, laboratories, commercial offices, and residential developments.

"Design is collaboration. Design consulting in acoustics requires technical expertise, and it requires understanding the goals of our collaborators. Many of our technical tools, including acoustical modelling and 3DListening, are also powerful communication and collaboration tools, helping the team to understand and realize multiple goals in a coherent design. The process of weaving good acoustics into a design vision, and then bringing it to life, is one that I find deeply satisfying."



Robert Berens is a Principal in the Architectural Acoustics Group at Acentech, a world-class acoustics, technology and vibration consulting firm. With over 50 years of consulting in architectural acoustics, noise and vibration control, and noise impact assessment and mitigation, his portfolio consists of diverse projects from fine arts and performance venues and educational teaching spaces to high-rise building conversions and multi-family residential construction. Much of his work has involved collaborating with architects on sound isolation, room acoustics and reverberation control, and with mechanical engineers on the control of noise from HVAC and other mechanical systems.

Bob is an active French horn player, and is a member of the Cambridge Symphony Orchestra, the Charles River Wind Ensemble, and several other Boston-area brass groups.

About the Lab @ Acentech

Innovation is in the Acentech DNA, stretching back to our earliest origins at Bolt Beranek and Newman (BBN). In the early days, BBN was likened to a university faculty where research and development was encouraged, nurtured and supported. A culture of curious and rigorous inquiry lies at the core of what we do, stemming from a desire to advance our knowledge, and share our findings with the world. We are more than a workplace – Acentech is also a research lab, playground, support system, jam space, and vehicle for positive social change.

The Lab @ Acentech is a space where we can share some of the exciting things we have been working on. The projects you will read about are but a small sample of the innovation culture at Acentech. The Lab is where our passion intersects with our clients, colleagues, and future coworkers. The work described herein builds on ideas inherited from our founders, and is nurtured by generations of consultants and scientists along the way. We are delighted to share it with you.

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