The architecture of sound, Azure, 2005
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When Bob Essert designs the acoustics for a concert hall or an opera house, he starts with a sound we rarely hear—deep silence, the kind you might hear on a still January day in the snow in the middle of the woods. It's a degree of silence you don't hear in most concert halls either, as composer John Cage vividly illustrated in his 1952 silent piece for the piano, 4'33". What you do hear is the whir of the air conditioning and the buzz of electrical equipment, the police sirens and taxi honks, along with the occasional cough or muffled laugh. Even in some of the world's greatest concert venues—like the gilded old shoebox halls of Europe or Carnegie Hall in New York—you hear all kinds of sounds that were not generated by the performers. The rumble of the subway reverberates through Carnegie Hall in the middle of a quiet passage; the clip-clop of horses' hooves punctuates the symphonies played in Vienna's famous Grosser Musikvereinssaal, one of the acoustically greatest halls in the world.

Yet Essert, one of the world's top acousticians, is obsessed with creating silence. "It's all about the drama of the performance," said Essert, on a recent trip from his London base to Toronto, where he is designing the sound for both the opera house, the Four Seasons Centre of the Performing Arts, which opens in 2006, and the Royal Conservatory of Music's 1,000-seat concert hall, which opens in 2008. "There are some pieces where the performers get to the quiet passages, and the audience holds its breath. If the concert is engrossing enough, people make sure they don't cough."

To Essert, creating a silent room is a key part of the architecture of sound. But it is, of course, only the beginning of the complex and mysterious job of creating an acoustical signature for each hall. "You have to have a vision, or the sound equivalent," said Essert, who is also working on the Winspear Opera House in Dallas and has just completed the Yehudi Menuhin School in England. "A sound in your head, what you're going for." That sound would depend on what's the hall's for—opera or symphonies, for example—and what kind of music will be played there. If it's a concert hall, "you want to make the sound strong and enveloping and warm, with the right bit of reverberation and clarity of the repertoire, depending on whether it's Mozart or Stravinsky."

Creating that kind of sound is an art that requires musical judgment, but it is also a science. Unlike many of the previous generation of acousticians, Essert has trained in both worlds. He grew up playing classical guitar and studied music and English at Yale University before earning his masters in mechanical engineering at the University of Texas in Austin. So he can explain why the quality of sound depends on physical properties like the room's scale, its geometry and its materials. He can show you the software he invented that illustrates how sound waves bounce inside a room, and why sound reverberates for longer in tall, narrow room than in a round, wide one. Yet he'll readily acknowledge that, as the troubled and sometimes expensive history of acoustics amply shows, the architects of sound cannot rely solely on diagrams and calculations for their predictions of how a hall will sound. "You have to listen hard and listen critically, go to a lot of concerts and rehearsals and understand what musicians care about," Essert said. "Musicians need to hear each other, and they need to feel the hall is an extension of their instrument. There's a direct line of emotion between the musician's souls and the listeners' souls."

The greatest music halls, the old ones built in Europe in the 19th century, were erected long before the science of sound was invented. The fabled concert halls, like Vienna's gilded Grosser Musikvereinssaal built in 1870, were shaped like shoe boxes, narrow and tall. Opera halls were built in the shape of horseshoes, so the audience could see each other while the balconies reflected the voice of the unamplified opera singer

These halls had great sound, the kind that makes you feel wrapped in music, but builders didn't know why until a century ago when Harvard physicist Wallace Sabine determined that the key was reverberation, the length of time a sound bounces inside a hall. After many experiments, Sabine concluded it was a function of a hall's volume and its materials, and he deployed that knowledge to guide the acoustics of the new Boston Symphony Hall. The concert hall, a shoe box considerably larger than the European halls, opened in 1900 to rave reviews for its sound. The science of acoustics was launched.

The acousticians thought they had discovered the mathematical secrets of sound, and they were confident they could create great sound in new halls that were bigger and wider than the European halls, with comfier seats too. In the first half of the 20th century, as some of Europe's greatest halls were destroyed in war, several U.S. cities built huge music venues with over 3,000 seats. Yet the sound in some of the biggest halls was lifeless, at least for those with musically sensitive ears. In 1962, Leo Beranek, an electrical engineer who became a towering figure in the musical world, applied his analysis of 52 halls around the world to create a new set of rules for the architecture of sound, rules he used to design the sound of the Philharmonic Hall in New York's Lincoln Centre. When the 2,644-seat hall opened in 1962, conductor Eugene Ormandy declared that architects would no longer rely on Lady Luck for great sound: "Musical architecture," Ormandy wrote in the introduction to Beranek's book, Music, Acoustics and Architecture, "stands at the threshold of new and exciting things."

Yet Philharmonic Hall turned out to be a notorious acoustical dud—"great big yellow $16 million lemon," as the New York Times' music critic put it. The musicians complained they couldn't hear each other. The basses evaporated into thin air. There were similar complaints from the musicians and audience in Toronto, where Beranek's firm provided the acoustical guidance for the egg-shaped Roy Thomson Hall, constructed in 1982. Both halls had to be fixed, and tens of millions of dollars later, acoustical science came under withering attack. Acoustics, a New York Times critic complained in 1986, is "not a science, not even an art, but a roll of the dice."

Essert says the problem with the halls in New York and Toronto is their basic shape: They're too wide to reflect sound properly. About 80 per cent of the sound you hear in a great hall is reflected off the walls. The reflections off the side walls are particularly important for that all-around sound. The old European shoeboxes are so narrow the sound doesn't have far to travel before it bounces back, and the base doesn't get swallowed up by the seats en route. The European halls were small too, with fewer than 2,000 seats, which is, for Essert, usually the upper limit for good sound in a musical venue.
But those narrow shoebox halls were deemed to be uneconomic at a time when the cost

of musical performance was rising. To keep the price of each seat affordable, concert halls grew in size. The Philharmonic's architect, for instance, increased the number of seats by creating concave bulges on both side walls, but this ended up focusing the sound on some places while robbing it from others. At Roy Thomson Hall, musicians and listeners complained that the sound was weak. "It didn't grab you, it never hit you in the chest," said Essert, who worked for Artec Consultants Inc. when it was recruited to fix Roy Thomson's sound. The room was too wide to reflect the sound from the side walls. The carpet soaked up the sound that did get reflected. The panels on the ceiling seemed to inhale the base. But when Artec fixed all three problems, the hall's architect Arthur Erickson wrote a bitter rebuke in the National Post: "In the intangible pseudo-science of acoustics, where so much is dependent on the subtleties of personal experience, I question the wisdom of proceeding on a course that contradicts the whole basis on which the hall was based."

Yet the architects designing the opera house in Toronto don't share Erickson's skepticism: They started with sound, as a fundamental part of the design. The goal is to create one of world's great acoustic opera houses, in the same league as La Scala, the glamorous Milan opera house renowned for its clear, warm and brilliant acoustics. The grey brick and glass Toronto opera house might not have La Scala's fabulous name brand, but the architects hope it will sound just as great.

Architects Gary McCluskie and Matthew Lella from Diamond and Schmitt Architects worked closely with Essert to make sure the shapes and texture of the hall create a sound that's distinct enough for voice but resonant enough for the orchestra. First they had to create the silence that Essert demanded. (The degree of silence depends on the purpose of the site: A muffled background sound might be fine in a library but not in a concert hall.) To block out the rumble of the subway, the building was erected on eight-inch thick rubber pads. To block out the sound of police sirens and helicopters and car engines, they built a wall within a wall, with a two inch gap in between. Air vents under the seats were carefully designed to eliminate the whoosh of air. Then they considered the shape of the interior hall, a traditional horseshoe layout. Essert recommended four shallow balconies to reflect the singers' voices without swallowing the sound and advised the architects to make sure the materials on the walls were hard enough to reflect sound. (They went with plaster and concrete.) The orchestra pit was designed to expand for the big Wagner orchestras and shrink for the smaller Handel ones, ensuring that the singer's voice can be heard along with the violins and basses. Essert and the architects worked for a year to figure out the undulating shape of the plaster ceiling, the rings of Saturn, as McCluskie calls it. To test the acoustical properties of the proposed designs on his computer, Essert created software that allows him to actually hear how a hall will sound before it's built. How to adjust the sound to suit the purpose of the hall is one of big the challenges facing Essert and other acousticians. The Four Seasons Centre, like most venues, will host not only opera but ballet. But even halls like the Royal Conservatory's concert hall will have different kinds of music—from Mozart symphonies to contemporary amplified tunes—that will demand different acoustics. Mozart, Essert notes, sounds best in small halls with not too much reverberation, while sacred choral works sound better in louder halls with more reverberation. Amplified sound may need a dead room, with a very short reverberation time.

Beranek tried to deal with this by putting dishes above the stage that could be adjusted. He thought the Philharmonic would be the world's first adjustable, living hall. His solution didn't work, but the idea lives on, in modern adjustable halls such as Jean Nouvel's 1999 concert hall in Lucerne. It's based on the shoebox—a "non-boxy-box," as Essert puts it—but it has plenty of doors that can open or close depending on what's being played. If it's Verdi's Requiem, the hall will open all the doors "give the sound room to breathe," says Essert, who worked on the hall while he was at Artec. "You'd keep the doors closed for Mozart or a chamber orchestra," he said. Curtains can be brought out to cut reverberation even further, to deaden the room for amplified sound or percussion groups.

Lucerne is still based on the traditional shoebox design, and many acousticians, like Essert, believe that shape is best for symphonies. But not all in the business of making musical venues agree. The approach has been challenged. In Berlin, Hans Scharoun veered away from sure-fire shapes by creating "music in the round" at the Berlin Philharmonic Hall, which opened in the early 1960s. The seating plan, called a vineyard terrace, in which people are seated around the stage, was designed to create lots of side reflections from the sides of the seating section. That idea was picked up by Frank Gehry and Japanese acoustician Yasuhisa Toyota in the design of the Walt Disney Concert Hall in Los Angeles. The hall's website puts it this way: Music is "an experience, not merely the hearing of the sound. The feeling of the seat, the visual appearance and temperature of the room all color the perception of the music."

Gehry and Toyota are tapping into one of the most intriguing aspects of acoustics—not just how we hear but how we perceive what we hear, and how our hearing is affected by other senses. John Bradley, an expert on acoustics at Canada's Natural Research Council, says there's a difference between the actual sound and what people think they hear. His tests of the acoustics of halls before and after minor physical changes underline the point: "If you painted a hall a different colour, people would think the acoustics had improved."

Essert doesn't reject this argument. On the contrary, he agrees that our other senses influence our perception of sound. He says he'd love to design the sound of a hall with vineyard-terrace-style seating, as long as the clients fully understand the architectural advantages and disadvantages of this approach. It's great to have the audience seated around the stage, he notes. "But if clients want the vineyard to give the very best acoustics for romantic symphonies, they're fooling themselves. Engaging and enveloping orchestral sound is achieved with a room that is narrow and tall. A vineyard is wide and not so tall.”