Acoustics Modeling

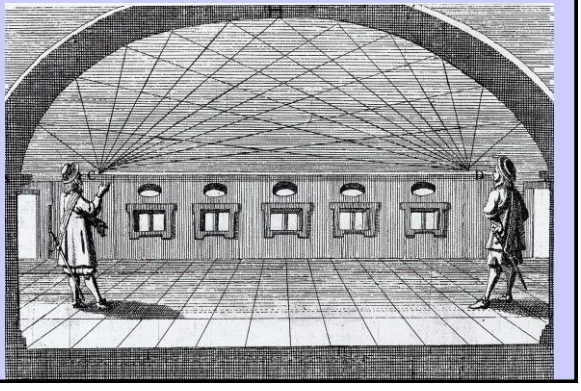
1. Graphic
2. Physical
3. Digital

Bridgewater Hall
Manchester, UK
Arup Acoustics

1

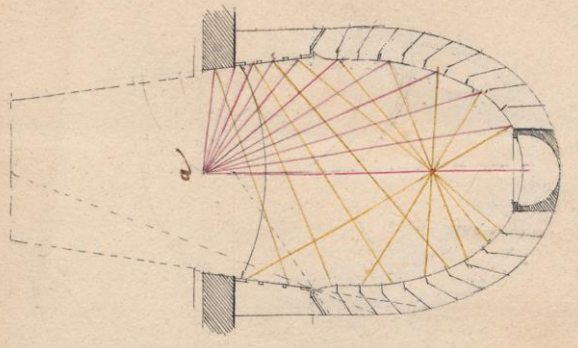
Graphic Modeling

Early ray tracing to predict performance…



2

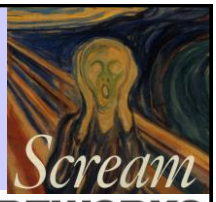
This ray-trace is in error!



Model carefully…angles of incidence and reflection are equal

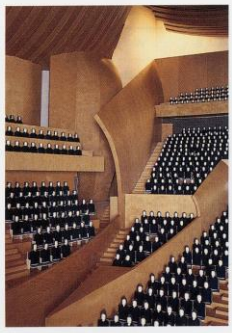
3

How do you visualize sound?
Like Edward Munch or typographically?

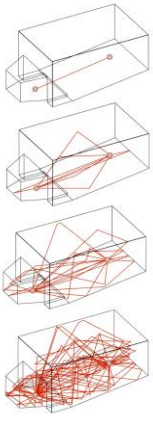


JACKHAMMER FIREWORKS
THUNDER ROCK CONCERT
CAR ALARMS MOTORCYCLE
LAWNMOWER BLOW DRYER
RINGING PHONE BARKING DOG
LAUGHTER BABBLING BROOK
GENTLE RAINFALL WHISPER MOTORS

4



Concert hall scale model with terraced seating (see text at right).



Choose a physical or computer model?

5

Physical Models…size matters…

UNIVERSITY OF FLORIDA
Department of Architecture Gainesville, Florida 32611
904-392-0205

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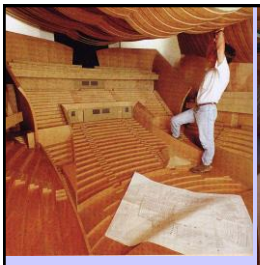
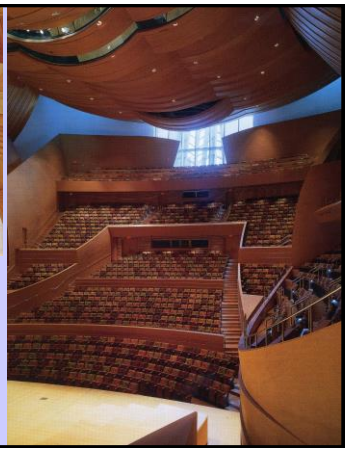
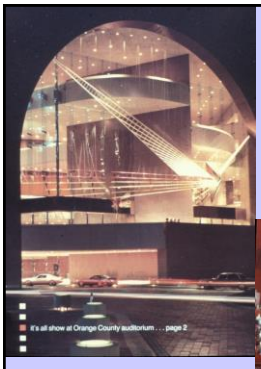




Accurate modeling at 1:10 if frequency is at 10x

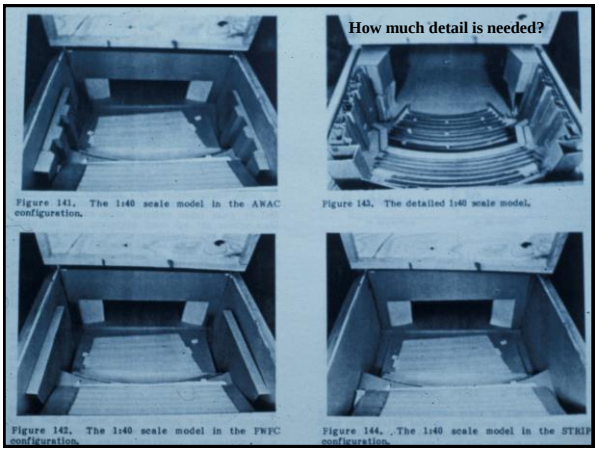
7



Orange County Auditorium

8

How much detail is needed?



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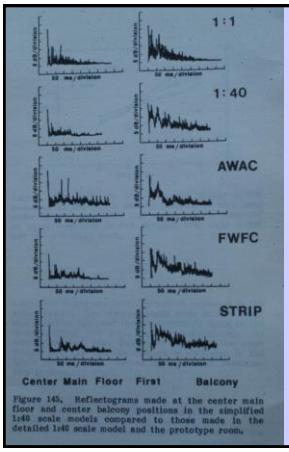


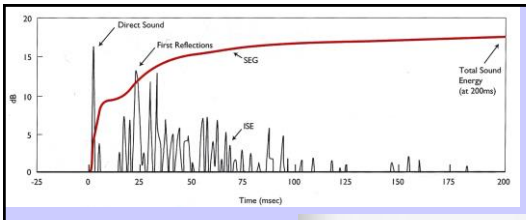
Figure 145. Reflectograms made at the center main floor and center balcony positions in the simplified 1:40 scale models compared to those made in the detailed 1:40 scale model and the prototype room.

The 'real' building vs.

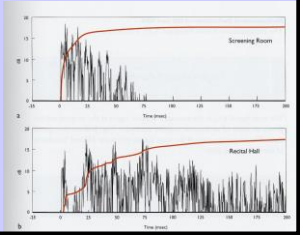
1:40 corrugated board models ranging from detailed…

…to stripped down…….

10

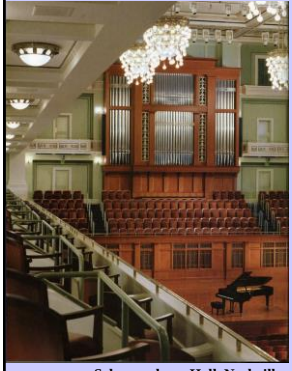


…which are all accurate enough to determine its basic acoustic characteristics…dead or live…and length and smoothness of reverberation…



11

…so, is this model ok?



Schermerhorn Hall, Nashville

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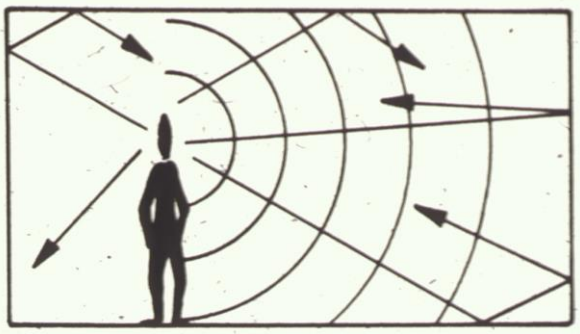
An alternative modeling theory…



…reflections of sound can be predicted by rays… therefore a narrow beam of light (a laser) can demonstrate the path of sound in space…

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Quick and dirty acoustics models are similar to daylighting models…

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Model reflective surfaces with foil, non-reflective with cardboard

15


'Scanning' with laser shows distribution of light and effectiveness of reflectors…

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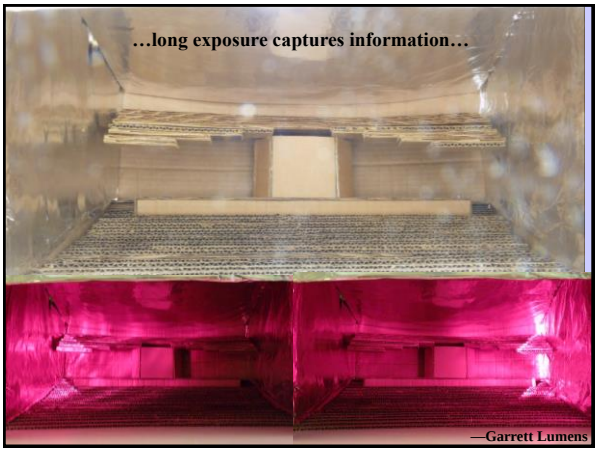
…long exposure captures information…
—Garrett Lumens

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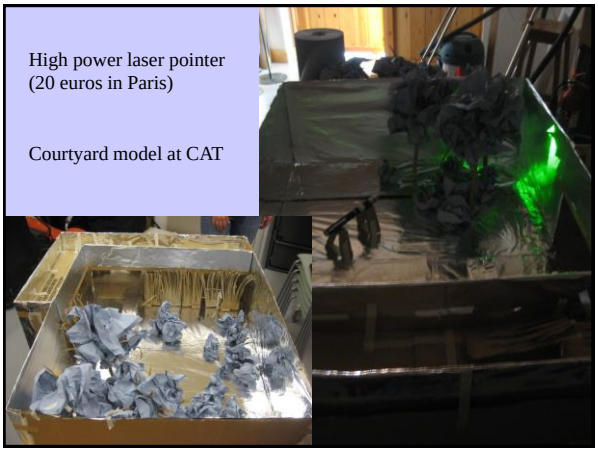
High power laser pointer (20 euros in Paris)
Courtyard model at CAT

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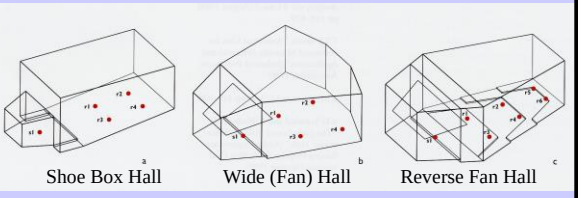
Computer-based ray tracing



Shoe Box Hall | Wide (Fan) Hall | Reverse Fan Hall

…can draw rays and display the effect…

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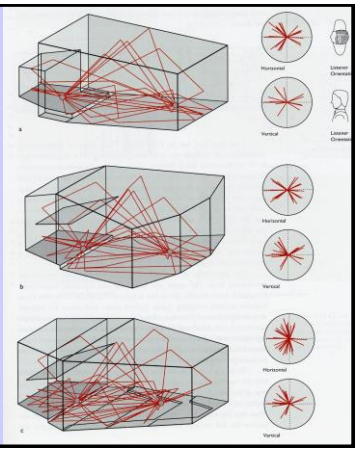
…options can be compared

…multiple listener points can be analyzed

…complexity of analysis can be selected



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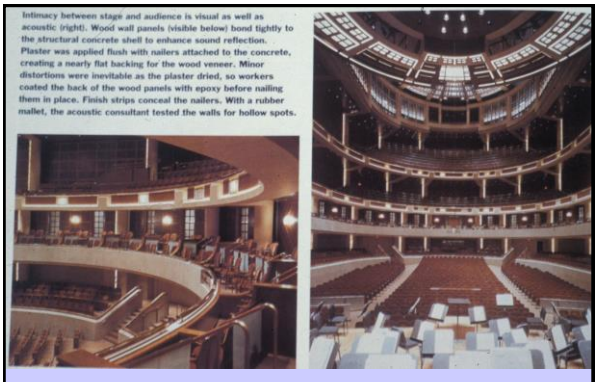
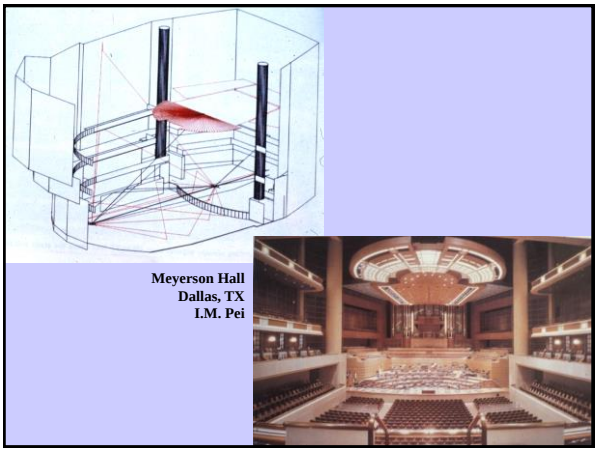


…beauty and performance can be imagined, if not guaranteed

21



Meyerson Hall
Dallas, TX
I.M. Pei

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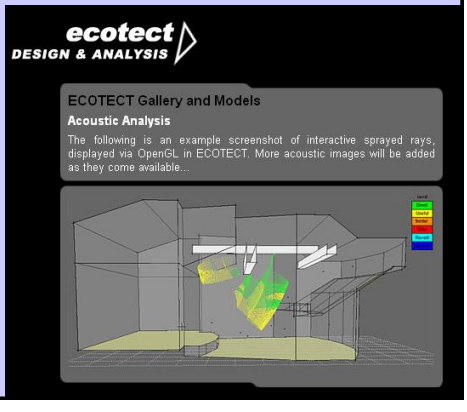
Animation is possible!



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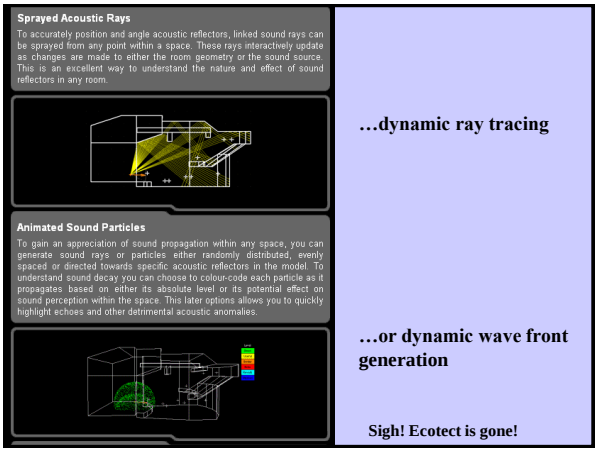


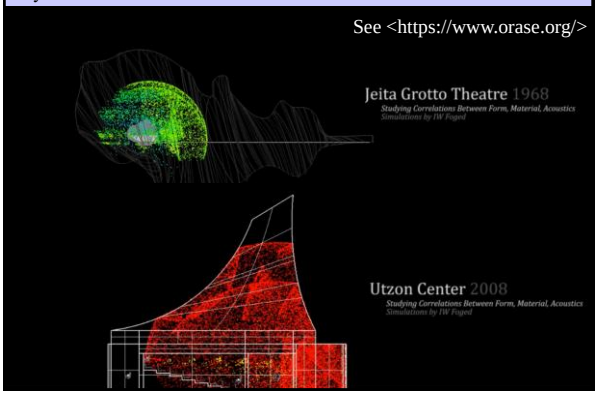
…dynamic ray tracing

…or dynamic wave front generation

Sigh! Ecotect is gone!

24

However, the Pachyderm plug-in for Grasshopper/Rhino does nice dynamic acoustic models…



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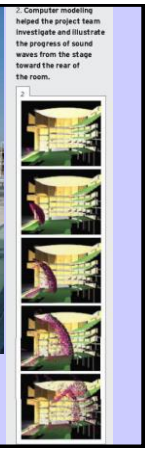
Winspear Opera House, Dallas



—Foster + Partners w/Sound Space

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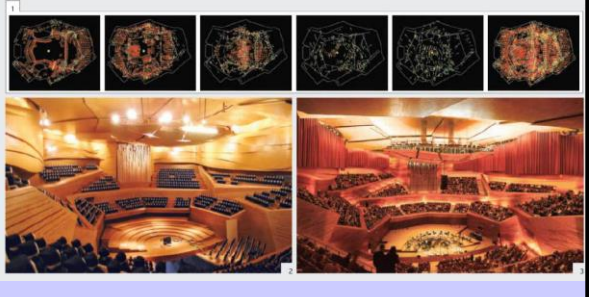
Copenhagen Concert Hall used both computer and physical models:



—Atelier Jean Nouvel w/Nagata Acoustics

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[SECTION 3 | COPENHAGEN CONCERT HALL]

Model behavior

A not-so-miniature version of the real thing helps tune a design BY JOANN GONCHAR, AIA

FROM THE EARLIEST STAGES of the project, the client for Jean Nouvel's Copenhagen Concert Hall, the Danish Radio, had decided that the building's main auditorium should have a so-called "vineyard configuration," or one in which stepped blocks of seating surround the stage. Even though there are many shoebox-shaped halls with excellent acoustics, including Amsterdam's Concertgebouw (Adolf Leonard van Gendt, 1888) and Boston Symphony Hall (McKim, Mead & White, 1900), Danish Radio wanted a vineyard auditorium like the one in Hans Scharoun's Berlin Philharmonie (1963), along with the more dynamic relationship between audience and performers that such a layout could provide.

Vineyard concert spaces – sometimes referred to as arena-shaped or terraced halls – typically have much more challenging geometry than their more orthogonal counterparts, making acoustical design difficult and requiring intensive analysis. Where shoebox halls rely on their long sidewalls to produce early reflections (those reflected sounds that arrive at the listener's location within a short time after the direct sound, increasing its apparent loudness), vineyard halls depend primarily on the position and angles of low walls defining each section of seating.

In order to better understand the complex relationship between the room's size and shape and its acoustics, and the contribution of the low walls in particular, consultant Nagata Acoustics conducted computer simulations. Later in the design process, the firm built a 1:10 physical model of the concert hall. Because of the model's size, with an interior more than 7 feet tall, consultants could precisely measure actual sound, helping them take into account characteristics that computer simulations generally don't, such as diffraction and scattering. As a result of the tests, wall angles were slightly adjusted to prevent detrimental echoes. "We typically don't make dramatic changes with the physical model," says Yasuhisa Toyota, president of Nagata Acoustics America. "But we use it to do things we can't do with the computer," he adds.

Team members conducted the tests by transmitting specialized signals from two small speakers and recording them at receiving points throughout the room. In order to compensate for the model's scale, they chose frequencies 10 times greater than those that would be produced by an orchestra. And because water vapor in air causes attenuation at such high frequencies, they filled the model with nitrogen to correct this effect. Since air is roughly 80 percent nitrogen, the substitution does not alter important sound characteristics, says Toyota.

Although the model was primarily for acoustical analysis, the architects also found it useful for finalizing design decisions and for explaining the room's geometry to management, musicians, and contractors, says Stefan Zopp, an Ateliers Jean Nouvel partner. "Before building at 1:1," he says, "it helps to have this understanding."

Nagata Acoustics used computer modeling to map the path of early reflections (1) **and understand the relationship between their distribution and the concert hall's geometry.**

Later in the design phase, acousticians built a 1:10 physical model (2) **that allowed for more detailed and precise analysis. By transmitting sounds from small speakers and recording them at various points throughout the room, team members could identify potential problem areas and adjust them during construction of the actual performance hall** (3).

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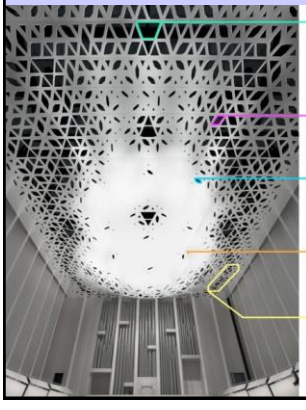
Voxman Hall, University of Iowa, integrated design goals



Audio Speakers - Large openings allowing sound profile of each speaker to pass through unimpeded. Two of the speaker openings must be large enough for the speaker arrays to be lowered through the reflector into the audience portion of the hall. Speaker locations provided by A/V Consultant.

Stage Lighting - Medium openings allowing light cone to pass through unimpeded. Stage lights are loosely arranged along contours of the reflector to ease layout of catwalks. Layout criteria provided by Theater Consultant

House Lighting - Small openings allowing light cone to pass through unimpeded. House lights are distributed throughout the reflector. Lighting locations provided by Lighting Consultant.

Fire Protection - Small openings allowing sprinkling from below ceiling in areas where openness is less than 70%

Acoustic Transparency - Inserted into areas where increased acoustic transparency is needed. Size of openings is determined based upon a combination of acoustic transparency and size of surrounding openings.

How to get there?

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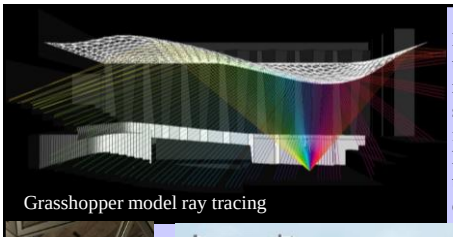
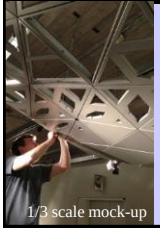


Grasshopper model ray tracing

LMN Architects used parametric modeling, 1/3 scale mock-up for the concert hall's theatroacoustic ceiling.



1/3 scale mock-up

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Acoustic consultant Jaffe Holden

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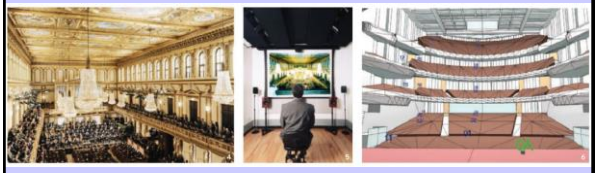
Auralization combines digital models with sound tracks



Auralization and specialized listening environments, like Sound Lab in Arup's New York City office, allow for side-by-side comparisons of rooms that have sought-after acoustics with spaces that exist only as digital models. Here, an Arup acoustician compares Vienna's Musikvereinssaal (1870) with an unbuilt concert hall (right).

Photos: Andreas Pessenlehner/EPA/Corbis (left); Arup (middle)

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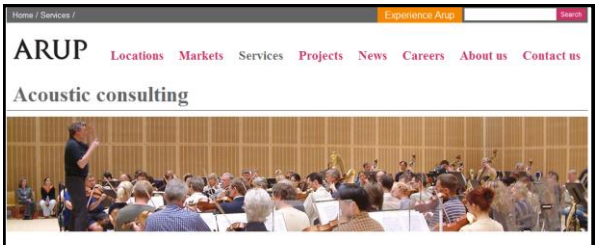

http://www.arup.com/Services/Acoustic_Consulting

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Hagia Sophia, Istanbul

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Now imagine - it's the early 13th century. You're sitting inside the Hagia Sophia. Marble pillars rise up around you. Dusty light filters into the windows in the massive dome above. And this is how you might hear Cappella Romana.

Acoustic convolution

https://www.npr.org/2020/02/22/808404928/listen-the-sound-of-the-hagia-sophia-more-than-500-years-ago

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