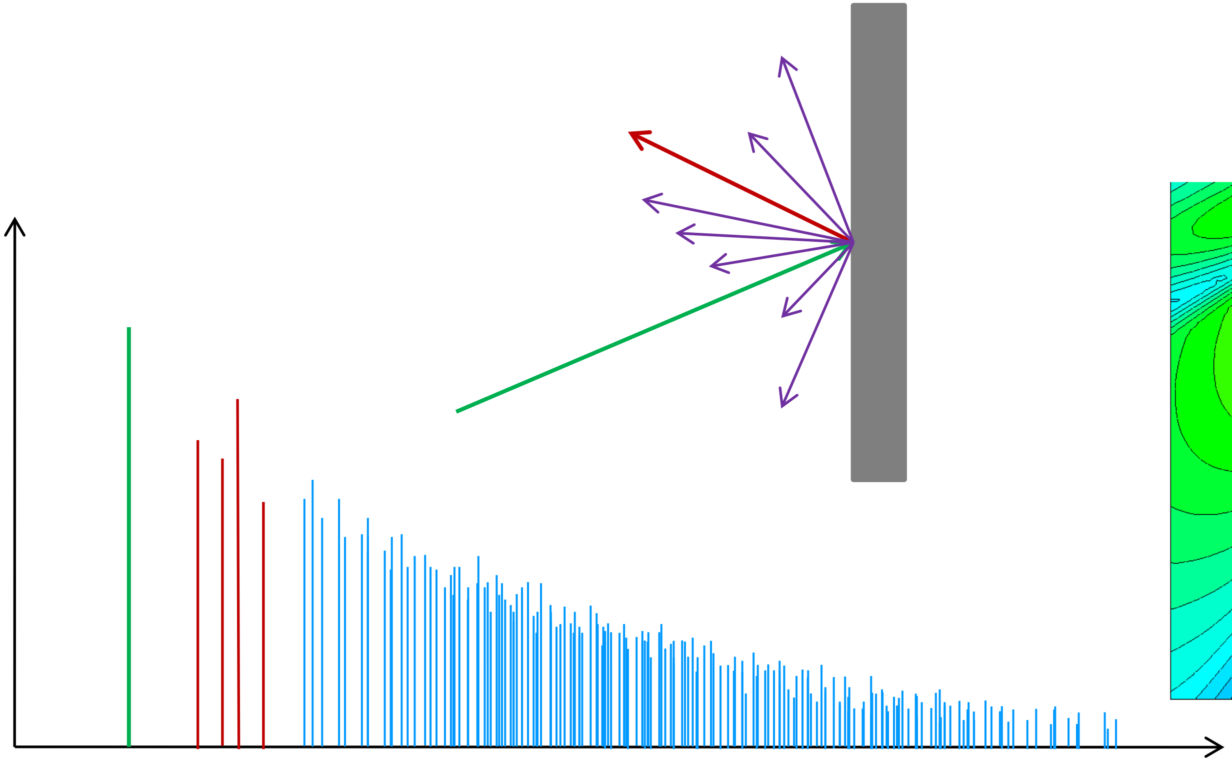
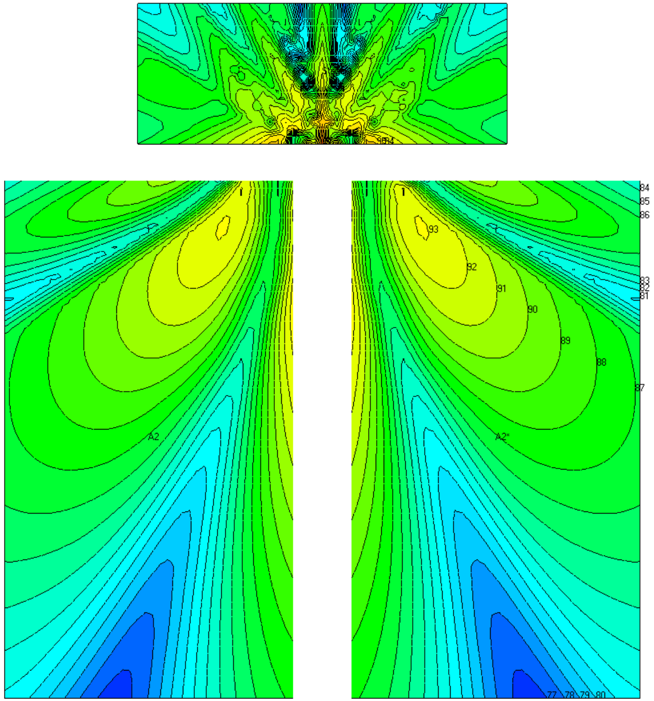
Sound System Modeling





Caveats About Acoustical Modeling

Acoustical modeling is only an approximation.

The results are limited by the accuracy of the model.
(Don't confuse accuracy & precision)

An architectural model is not an acoustical model.

The results are limited by the accuracy of the loudspeaker and materials data used in the model.

Always keep these in mind!

Benefits of Acoustical Modeling

Confirm initial design performance

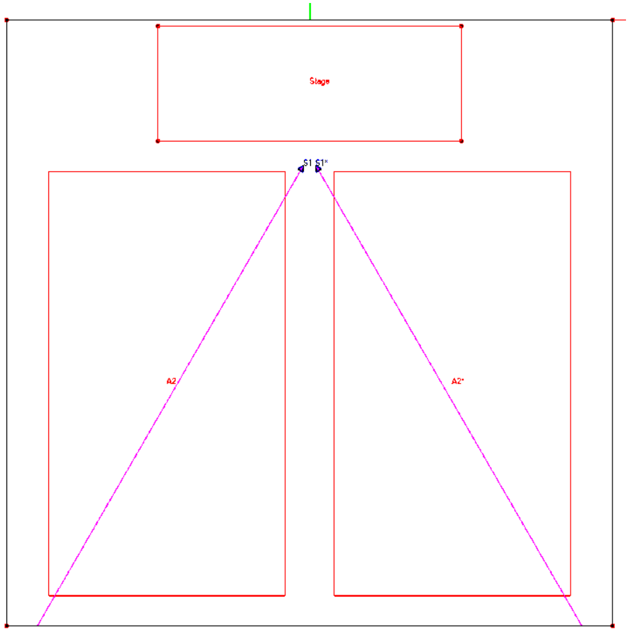
Find potential problems we didn't anticipate

Compare the model of an existing room/system to the proposed changes to get an idea of the improvements.

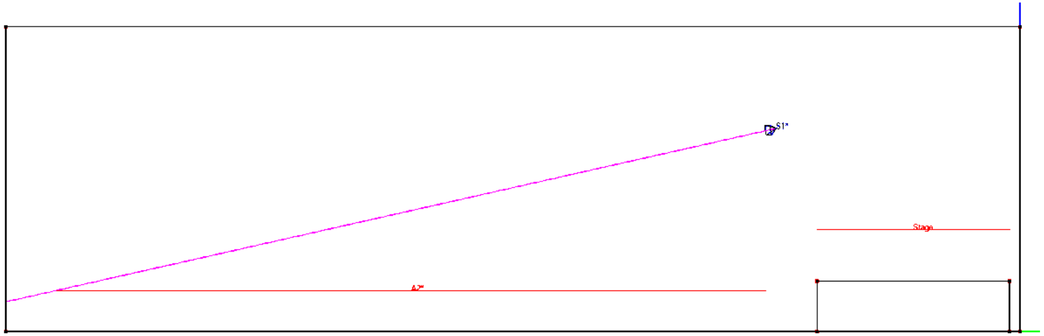
Can be very useful for presentation to clients

Reasons for Using Acoustical Modeling

Confirm the loudspeaker's direct-field coverage of the audience area



Center cluster aimed toward the back of the audience area

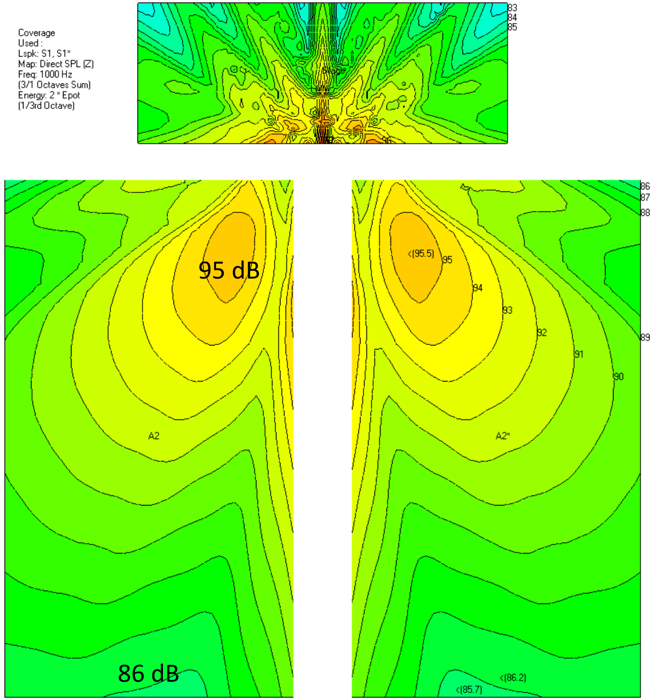


Reasons for Using Acoustical Modeling

Confirm the loudspeaker's direct-field coverage of the audience area

3 Octaves
Centered at 1 kHz

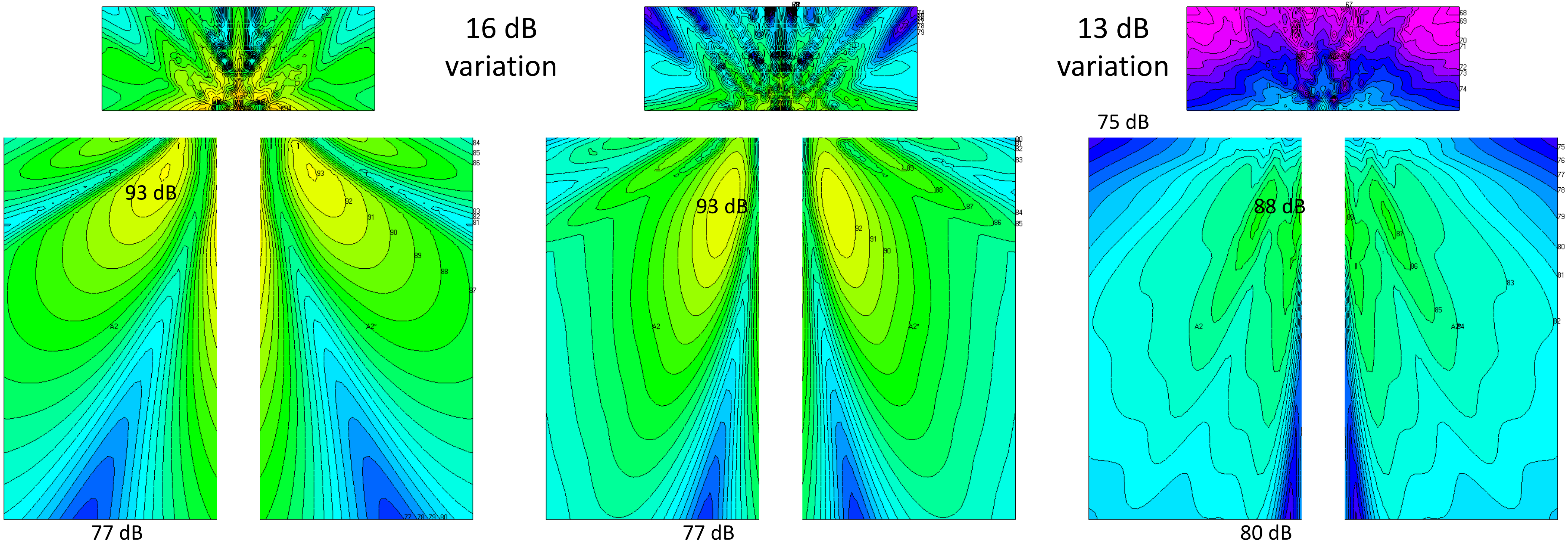
9 dB variation



Reasons for Using Acoustical Modeling

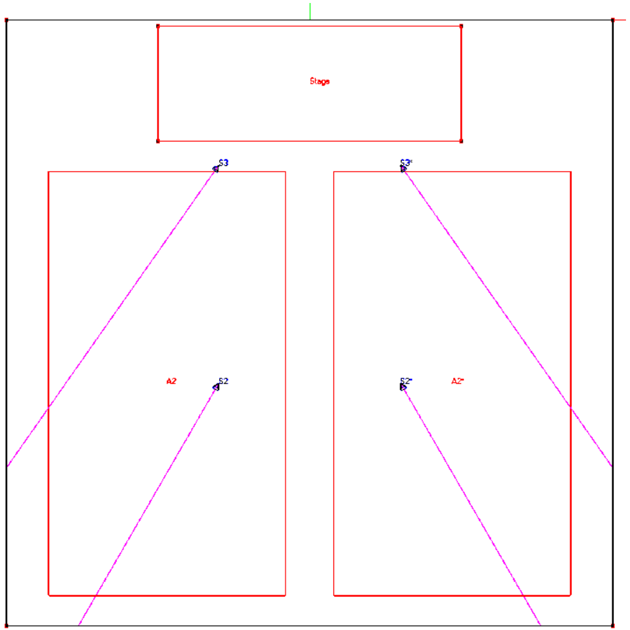
Confirm the loudspeaker's direct-field coverage of the audience area

1 Octave, 500 Hz   1 Octave, 1 kHz   1 Octave, 2 kHz

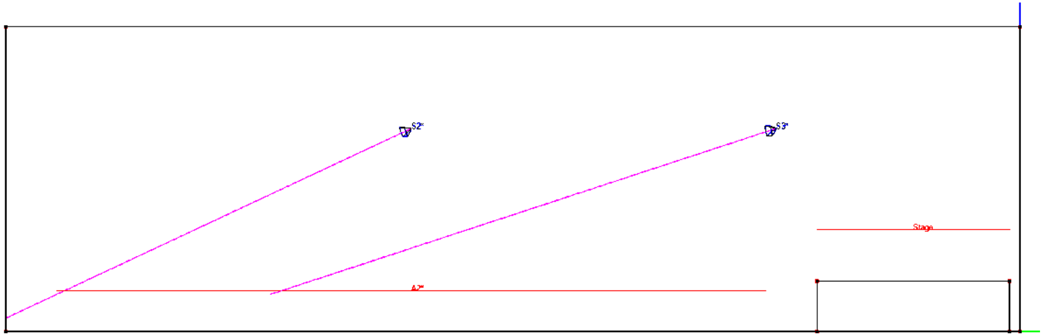


Reasons for Using Acoustical Modeling

Confirm the loudspeaker's direct-field coverage of the audience area



Exploded cluster with delay loudspeakers

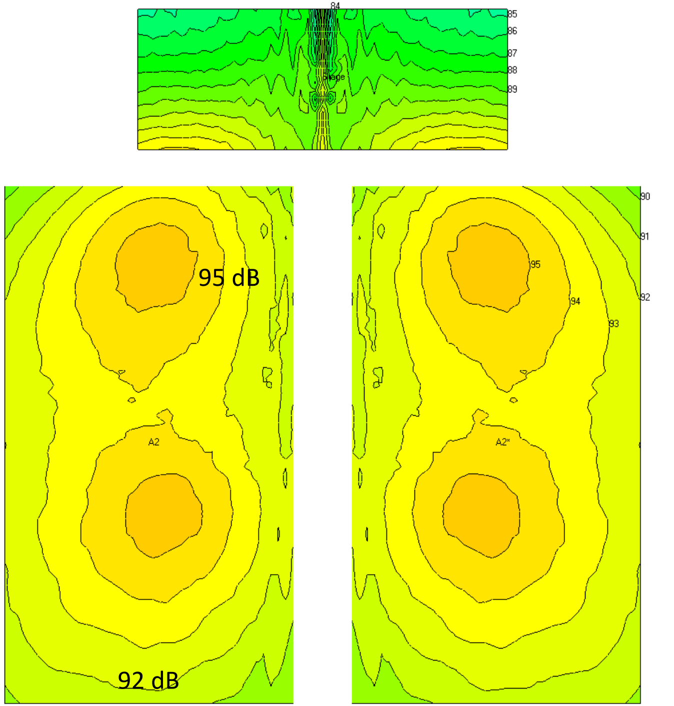


Reasons for Using Acoustical Modeling

Confirm the loudspeaker's direct-field coverage of the audience area

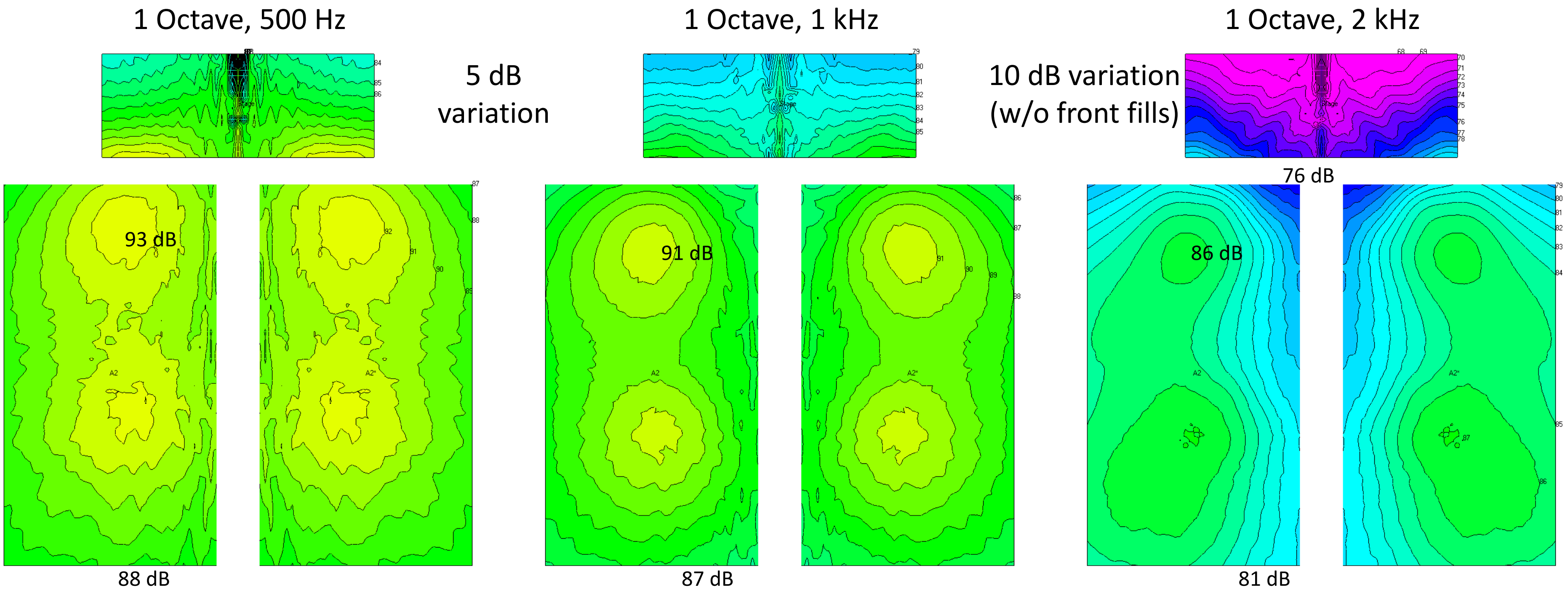
3 Octaves
Centered at 1 kHz

3 dB variation



Reasons for Using Acoustical Modeling

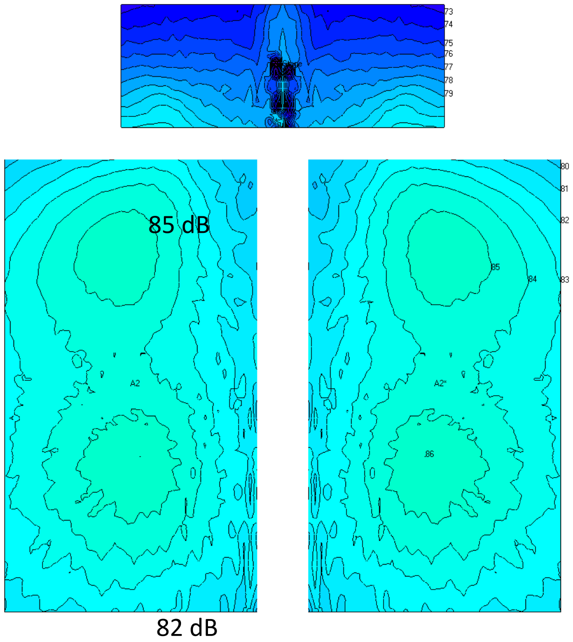
Confirm the loudspeaker's direct-field coverage of the audience area



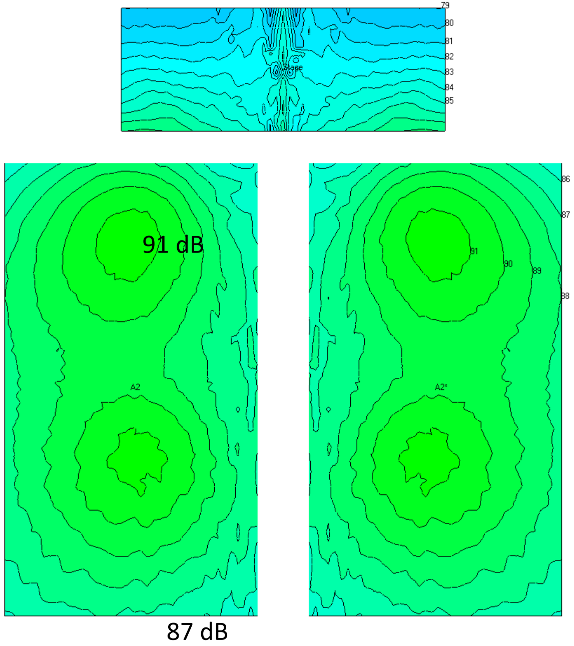
Reasons for Using Acoustical Modeling

Confirm the required SPL can be achieved in the audience area – *Bandwidth*

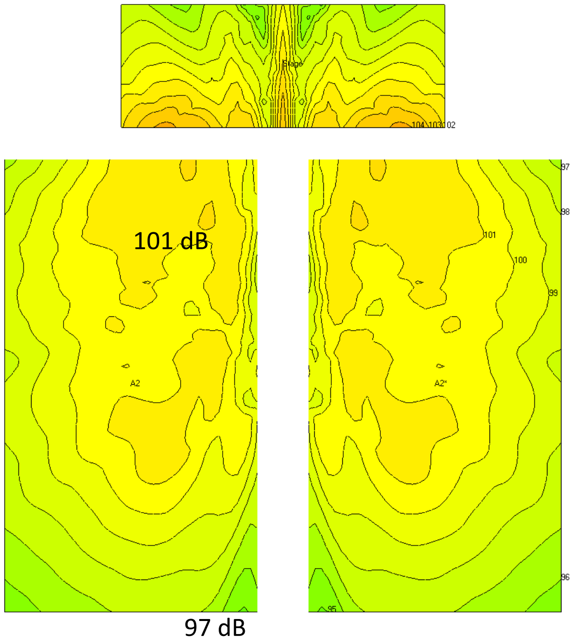
1/3 Octave, 1 kHz



1/1 Octave, 1 kHz



Broad Band



Reasons for Using Acoustical Modeling

Confirm the required SPL can be achieved in the audience area

Is the maximum SPL data for the loudspeaker correct?

Items that affect the maximum SPL:

- Loudspeaker sensitivity
- Loudspeaker maximum input voltage (MIV) or power handling
- Spectral content of the input signal

Most often our concern is for the continuous SPL .
This is analogous to the MIV or a continuous (long term) power handling.
NOT program or peak power handling

Reasons for Using Acoustical Modeling

Confirm the required SPL can be achieved in the audience area

Modeling programs typically don't consider peak SPL or take the crest factor of program material into account. This should be done when determining the amplifier requirements.

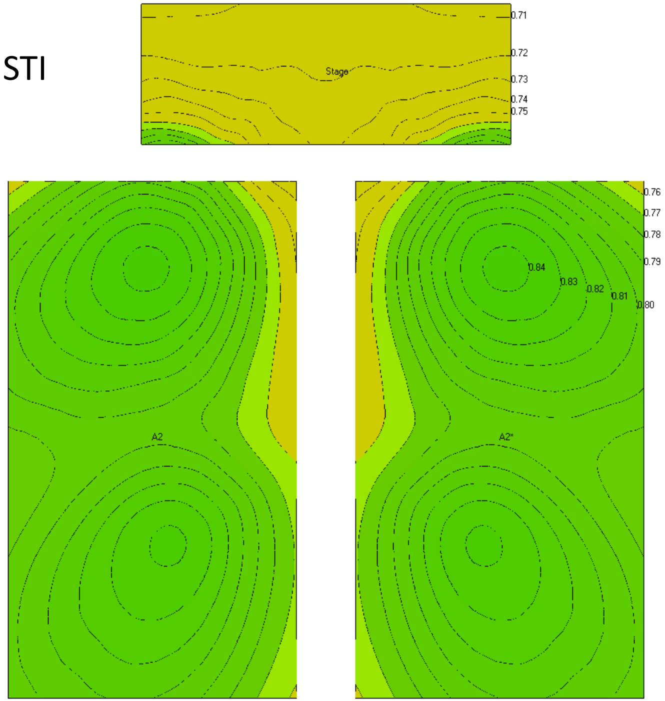
Size the amplifier so that the rms voltage required to generate the desired SPL will pass the signal peaks without clipping.

This often means de-rating the amplifier by a factor of anywhere from 4x (9 dB crest factor) to 10x (13 dB crest factor).

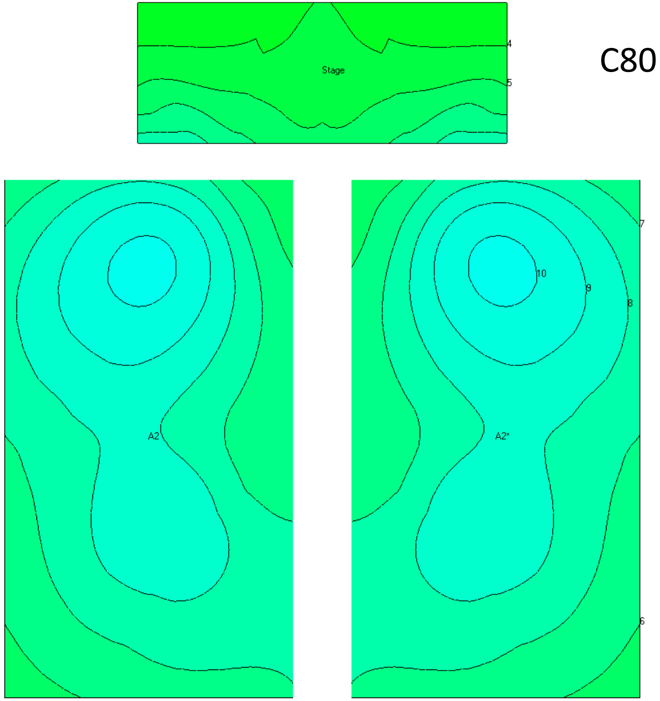
Reasons for Using Acoustical Modeling

Predict intelligibility: STI (speech) and Clarity (music)

STI



C80



Reasons for Using Acoustical Modeling

Predict intelligibility: STI (speech) and Clarity (music)

Must have information about the reverberation time in the room

Statistical Modeling

- Relatively easy & quick (computationally)
- Limited accuracy due to general assumptions

Geometrical Modeling

- Ray Tracing
- Takes more time
- Generally yields more information than statistical modeling

Room Acoustics – Statistical Modeling

Sabine Equation

$$RT = \frac{0.161 * V}{S\bar{\alpha}}$$

0.161 is for SI units
(use 0.049 for imperial units)

V is the total volume enclosed by the room
S is the total surface area of the room
$\bar{\alpha}$ is the average absorption coefficient for the surfaces of the room

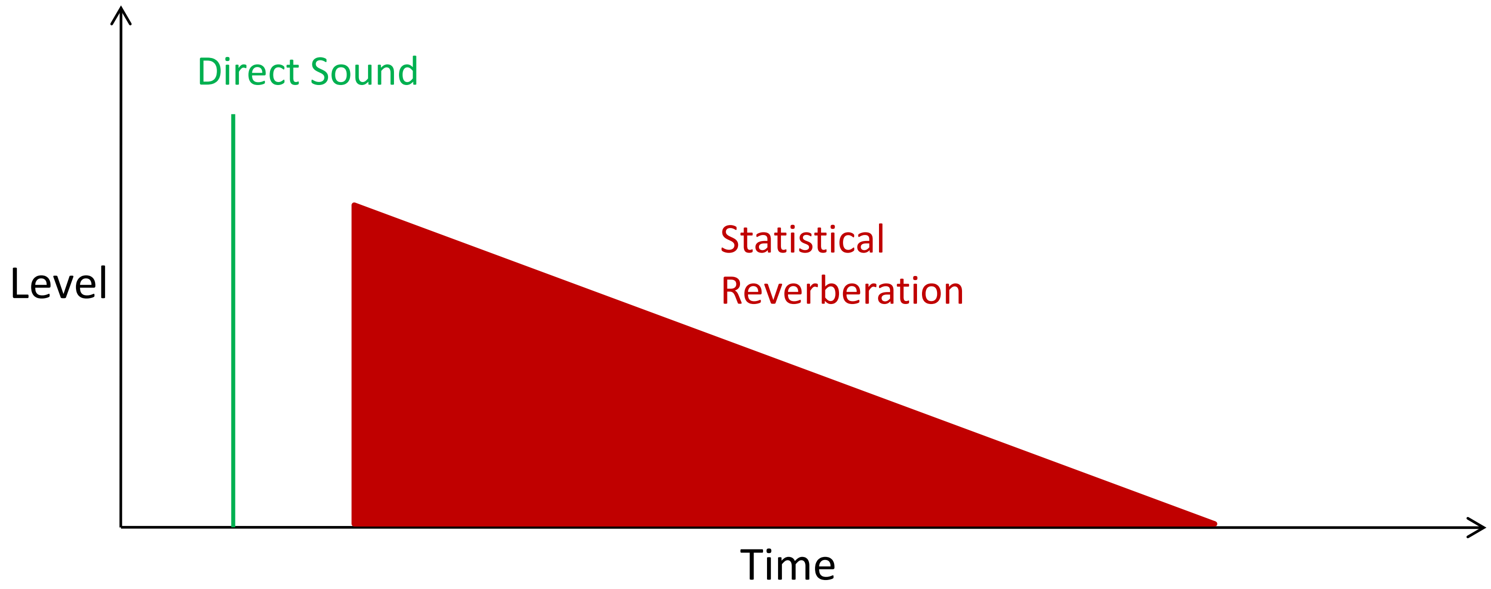
General Assumptions:

- Uniform distribution of absorption in the room
- Relatively low absorption (“live” room)
- Homogenous sound field in the room

Yields no knowledge of individual reflections

Room Acoustics – Statistical Modeling

Calculate the direct sound, D, from the loudspeaker(s) at the desired location(s)
Calculate a single value (statistical) reverberation level, R, for the room
Calculate the direct to reverberant ratio, D/R, at the desired location(s)



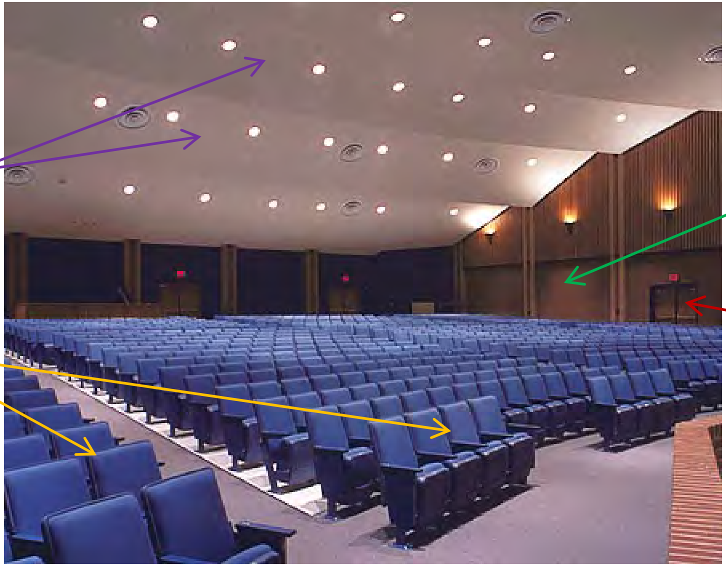
Room Acoustics – Statistical Modeling

Accuracy and Precision – How much detail is needed?

Statistical modeling does not consider the geometry (shape) of the room.

Only the total volume (V), surface area (S), and absorption of the surfaces ($\bar{\alpha}$) are used in the calculations.

Individual ceiling sections?



Reliefs in wall?

Location & shape of seating area?

Location of door?

Room Acoustics – Geometrical Modeling

Geometrical Acoustics / Ray Tracing

Assumes sound acts like a ray (laser)

Valid only for acoustically "large" rooms (i.e. high modal density).

Schroeder Frequency

$$F_L = K\sqrt{RT/V}$$

K is 2,000 for SI unit (11,885 for imperial units)
RT is the reverb time of the room
V is the volume of the room

Alternate

$$F_L = \frac{3 * c}{RSD}$$

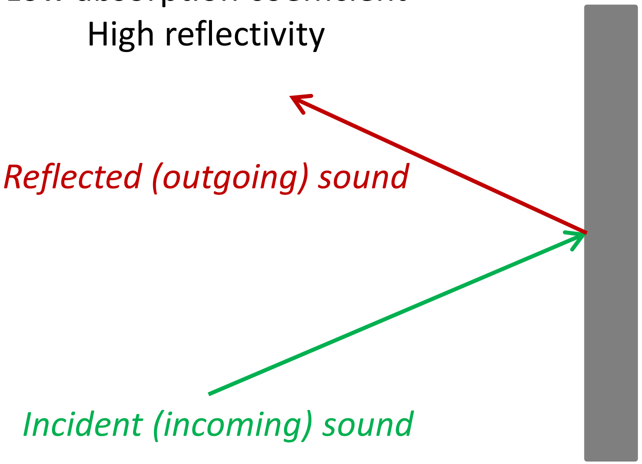
c is the speed of sound
RSD is the room's smallest dimension

Room Acoustics – Geometrical Modeling

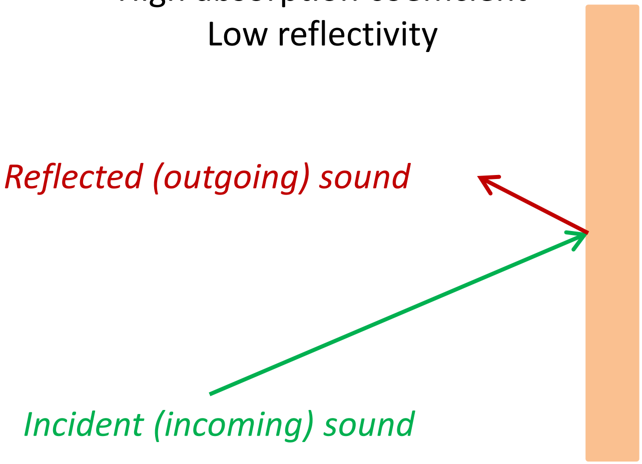
Materials Properties – Absorption Coefficient

Describes how much sound is absorbed when it hits a surface with a particular material. Whatever is not absorbed is reflected back into the room.

Acoustically “hard” surface
Low absorption coefficient
High reflectivity



Acoustically “soft” surface
High absorption coefficient
Low reflectivity

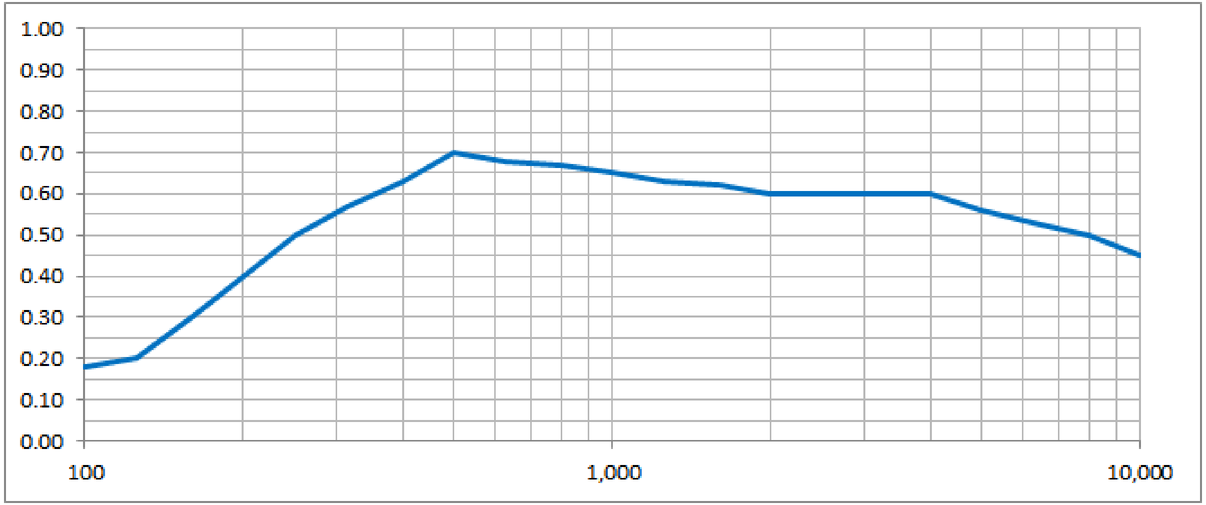


Room Acoustics – Geometrical Modeling

Materials Properties – Absorption Coefficient

Absorption coefficients are frequency dependent.

Frequency	Absorption
100	0.18
125	0.20
160	0.30
200	0.40
250	0.50
315	0.57
400	0.63
500	0.70
630	0.68
800	0.67
1000	0.65
1250	0.63
1600	0.62
2000	0.60
2500	0.60
3150	0.60
4000	0.60
5000	0.56
6300	0.53
8000	0.50
10000	0.45



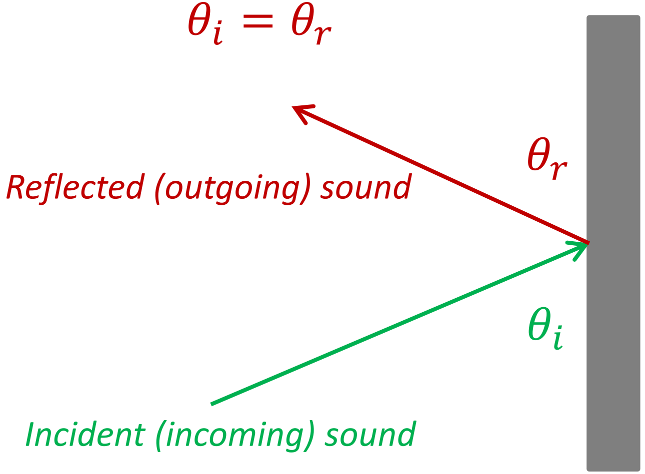
Room Acoustics – Geometrical Modeling

Materials Properties – Scattering Coefficient

Describes how much of the reflected sound is not a specular reflection (i.e. reflected in different directions).

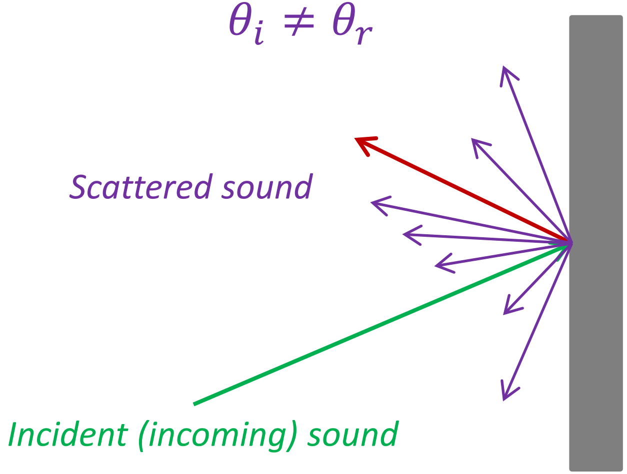
Specular Reflection

$$\theta_i = \theta_r$$



Scattered Reflection

$$\theta_i \neq \theta_r$$

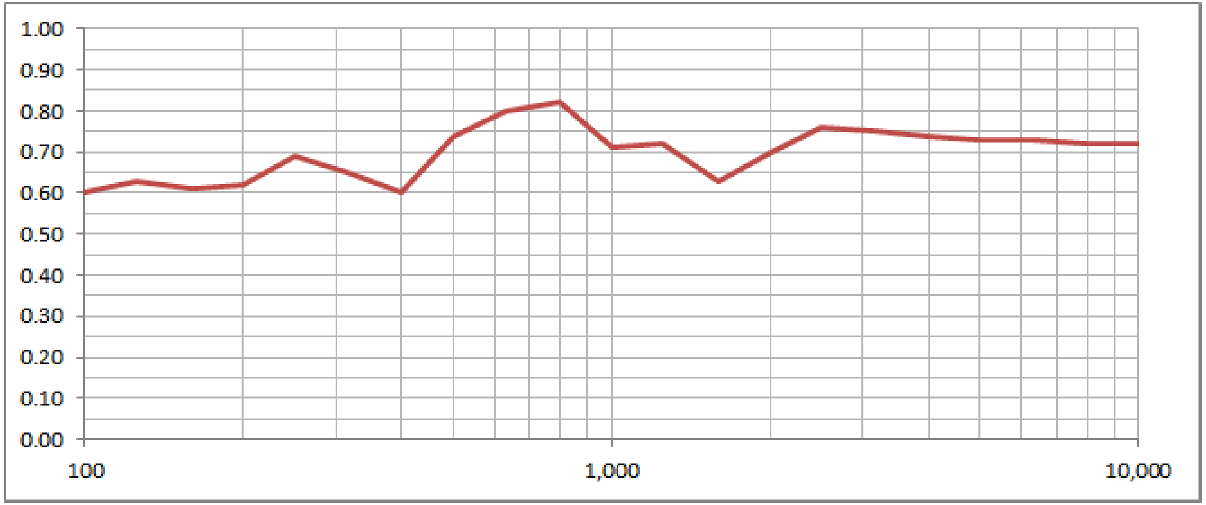


Room Acoustics – Geometrical Modeling

Materials Properties – Scattering Coefficient

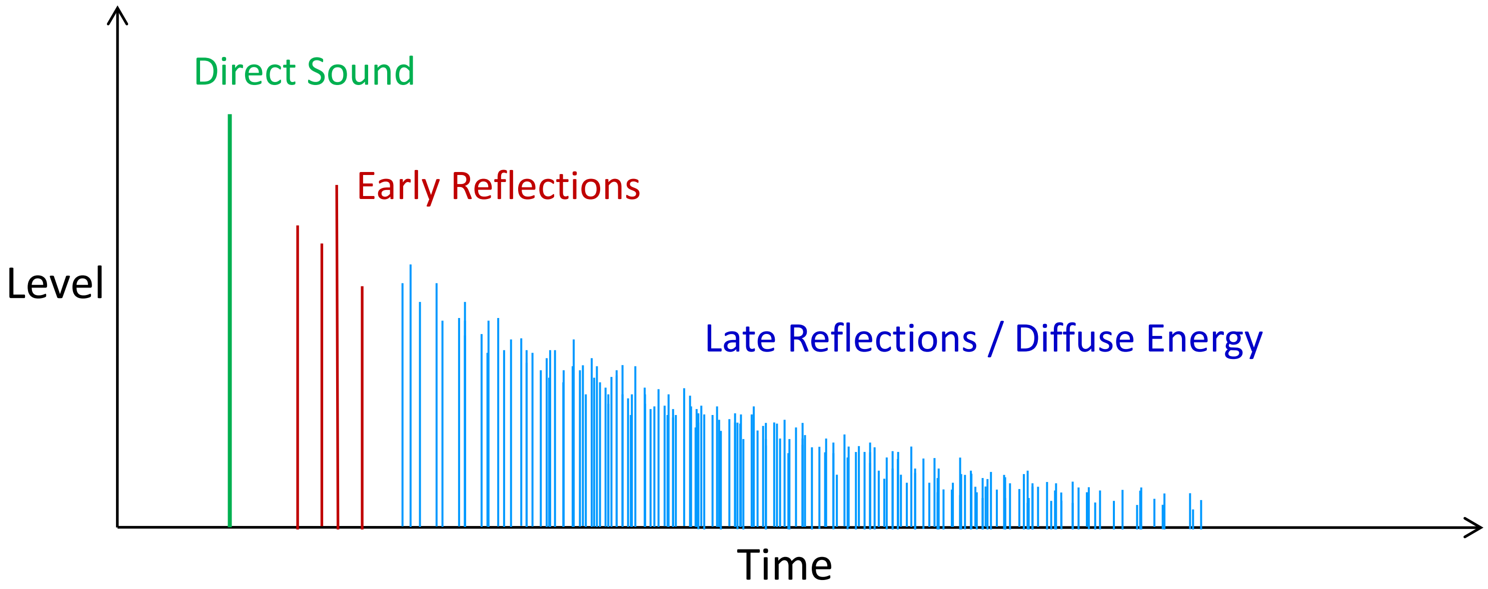
Scattering coefficients are frequency dependent.

Frequency	Scattering
100	0.60
125	0.63
160	0.61
200	0.62
250	0.69
315	0.65
400	0.60
500	0.74
630	0.80
800	0.82
1000	0.71
1250	0.72
1600	0.63
2000	0.70
2500	0.76
3150	0.75
4000	0.74
5000	0.73
6300	0.73
8000	0.72
10000	0.72



Room Acoustics – Geometrical Modeling

Calculate the direct sound, D, from the loudspeaker(s) at the desired location(s)
Calculate the reflections, R, arriving at the desired location(s)
Calculate the direct to reverberant ratio, D/R, at the desired location(s)



Room Acoustics – Geometrical Modeling

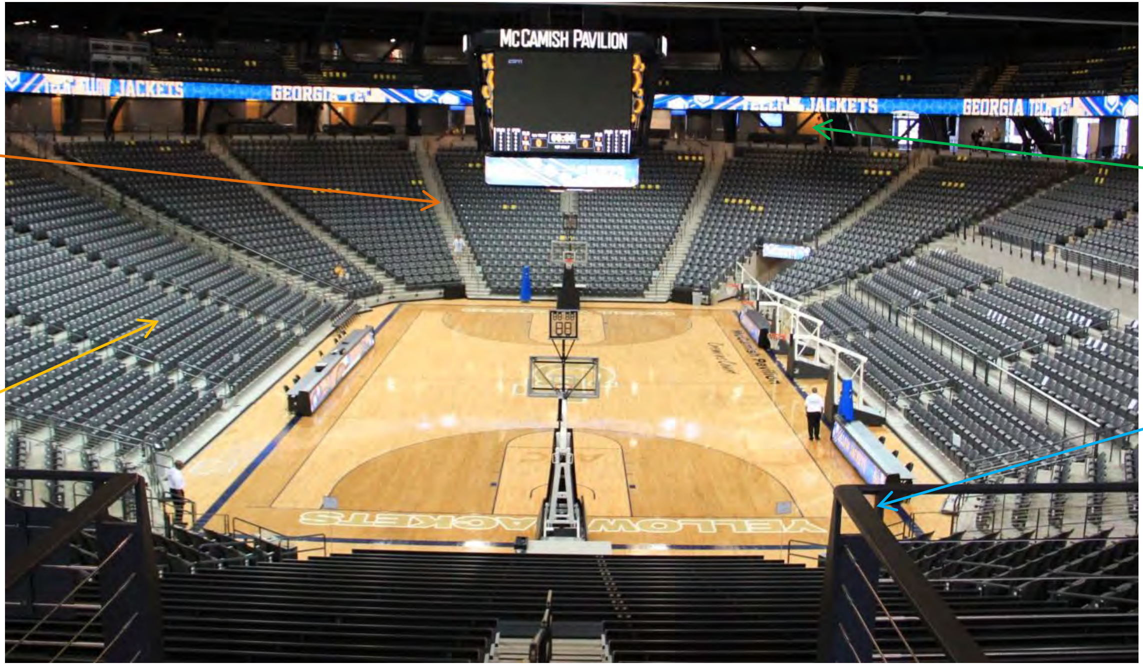
Accuracy and Precision – How much detail is needed?

Individual steps?

Overall slope & add scattering to material

Individual seats?

No, add scattering to material if not already present

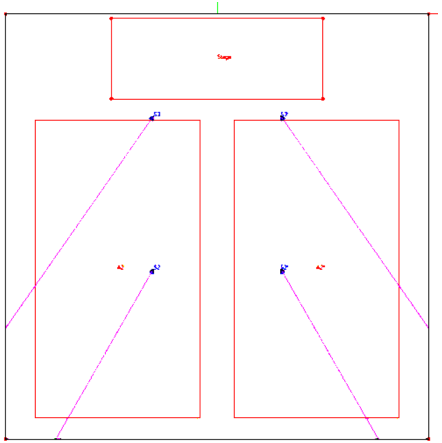


Structural supports?

No, probably too small

Railing?

Sound System Modeling



Thank You!