SAE Barcelona Session
Acústica para recintos deportivos
(caso Mundial FIFA 2014)

Sergio Molho

Marc Viadiu

USA•EUROPE•LATIN•BRASIL•MEXICO•ASIA

www.wsdg.com

INTRODUCTION

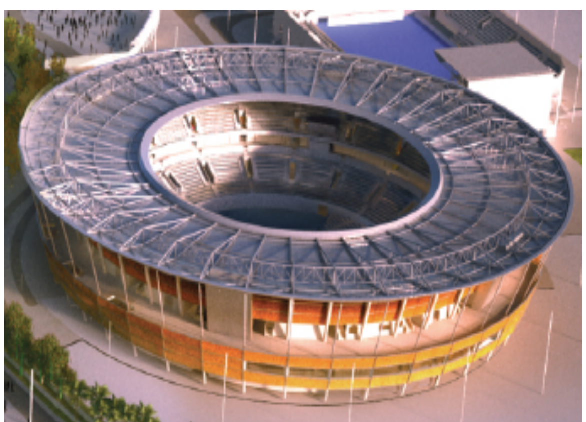
LARGE SPACES

Large Spaces come in many different flavors…

KKL – Concert Hall

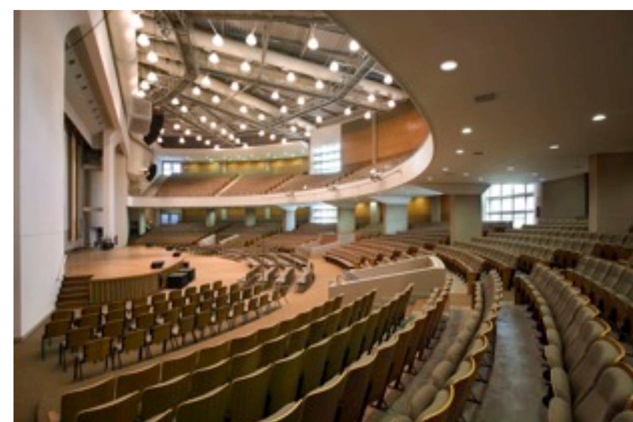
Maracanã Stadium

St Gallen Train Station



Olympics 2014 - Tenis Arena 01

Zurich Airport



IBC Church

Large spaces have some things in common:

- High Reverberation Times
- Architectural (and Structural) Conditions
- Long Distances
- Requirements
- Extensive Coordination

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INDEPENDÊNCIA STADIUM

INTRODUCTION

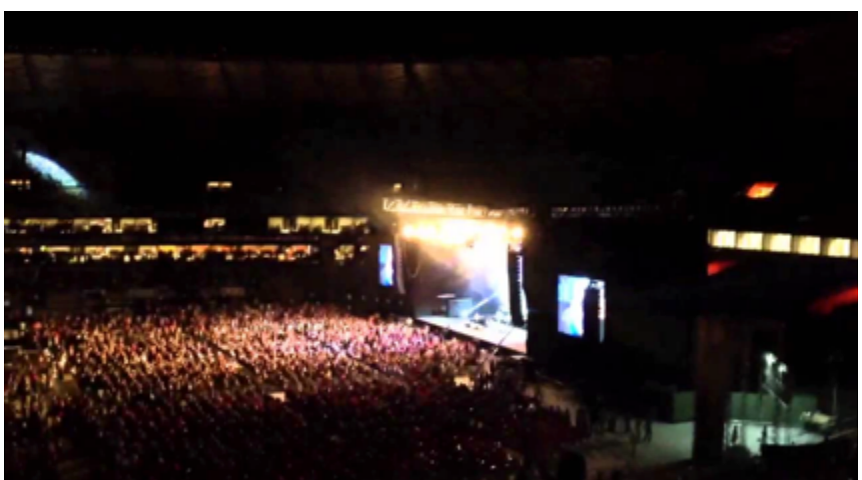
1965…

Mineirão Stadium

INTRODUCTION

Mineirão Stadium

Installed Speaker!



Elton John, Paul McCartney, Beyoncé - 2013

INTRODUCTION

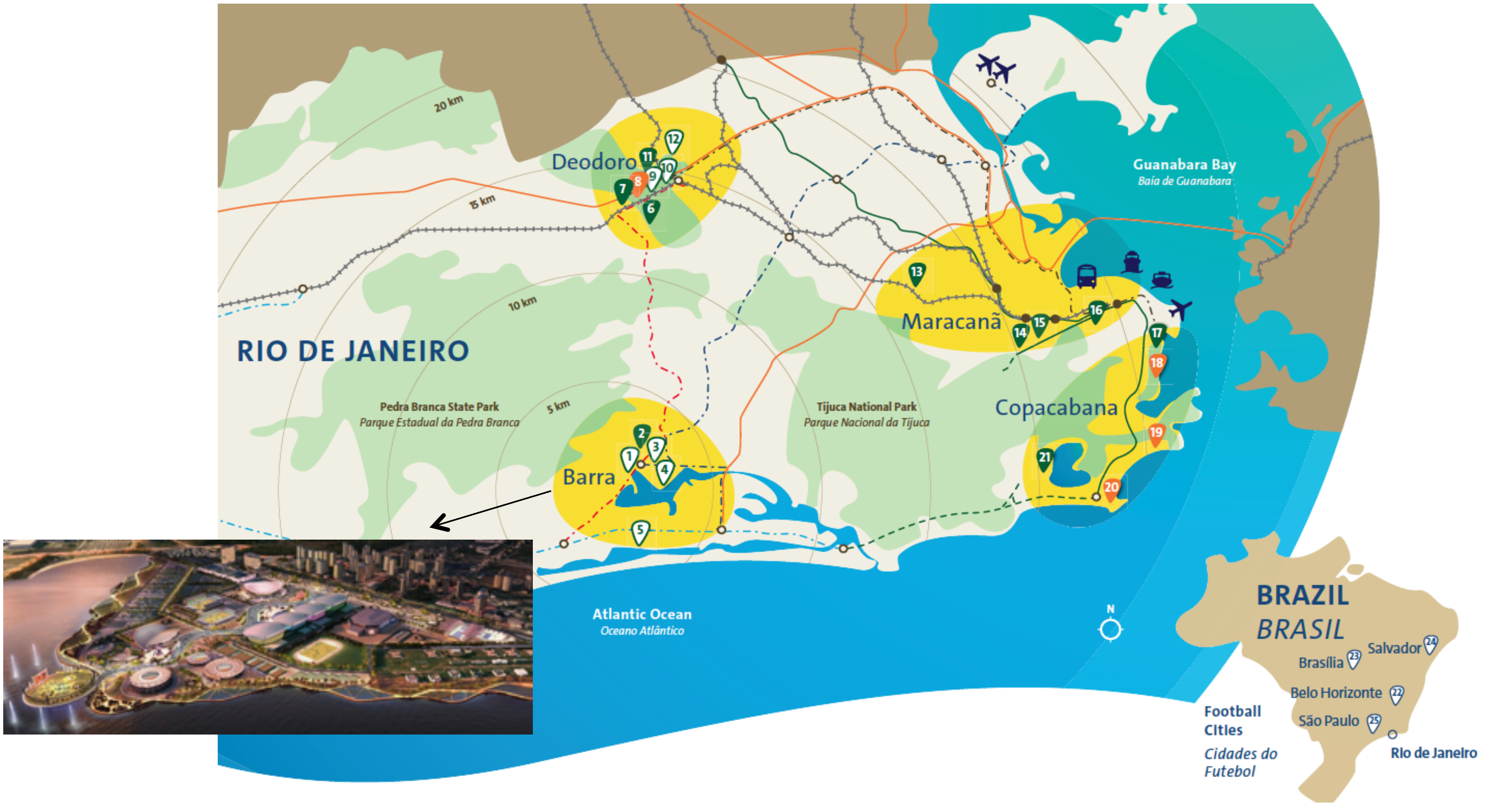
1950…

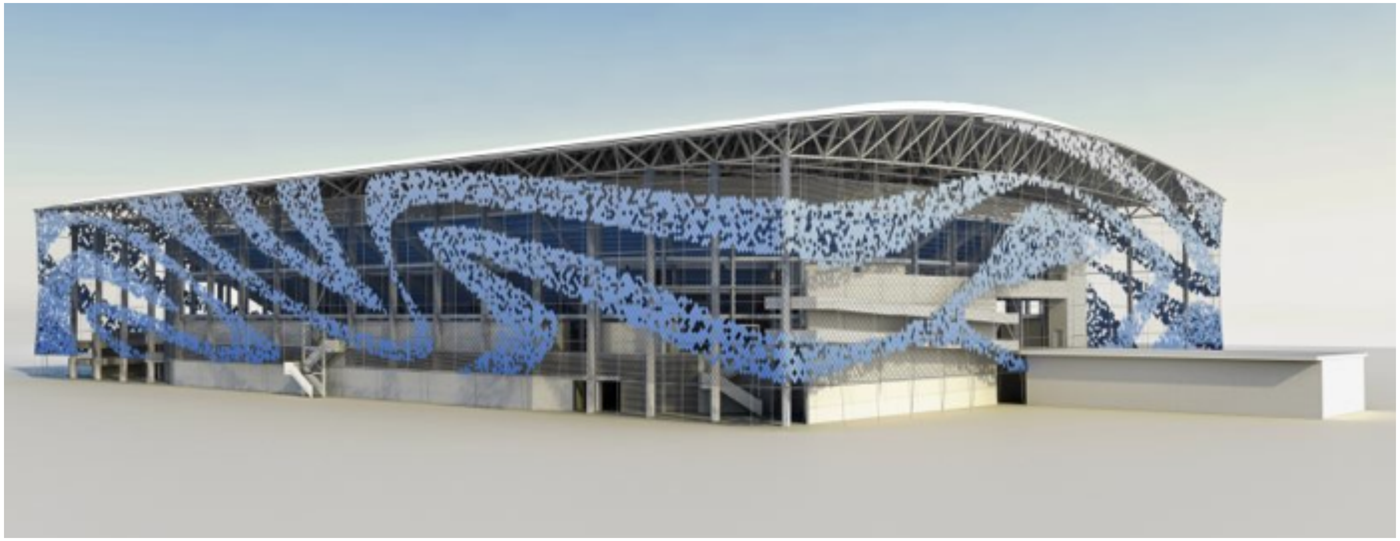
Maracanã Stadium

“Temple of Soccer”

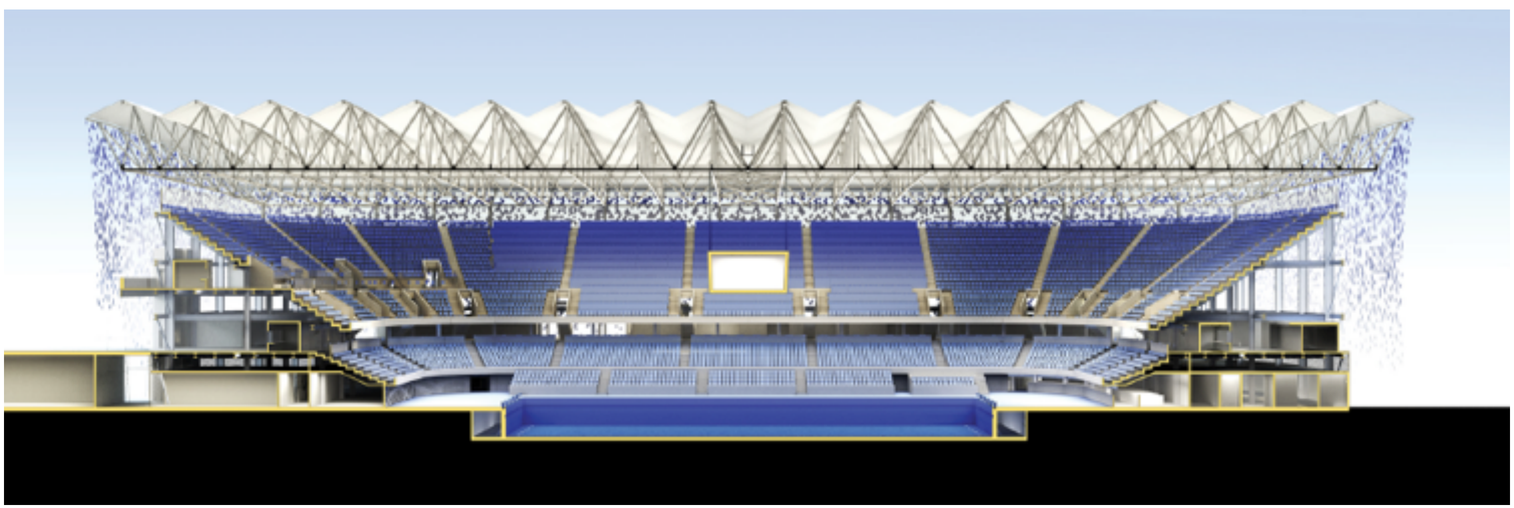

RIO 2016 – Olympic Games

INTRODUCTION

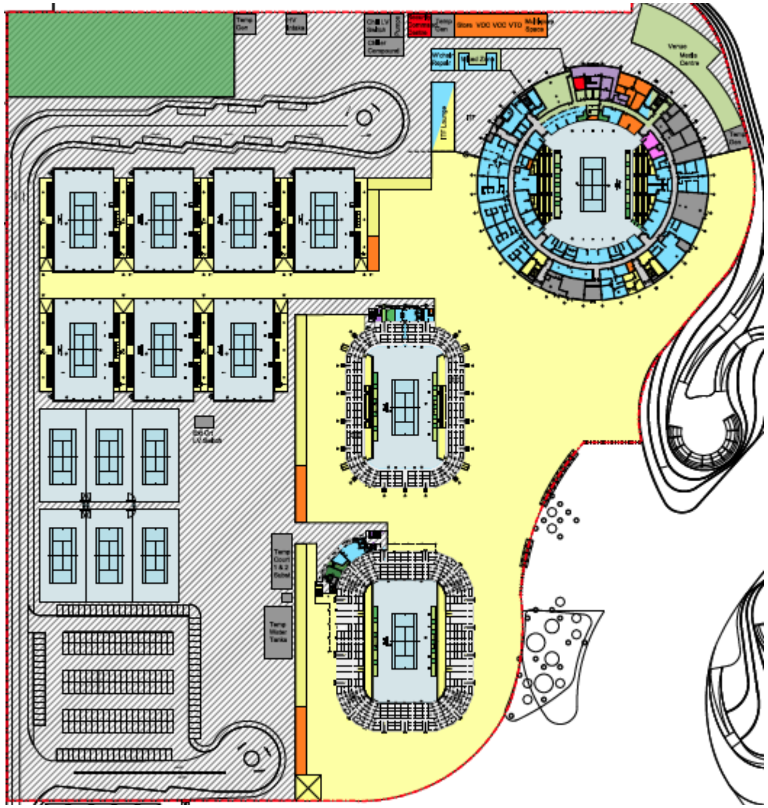




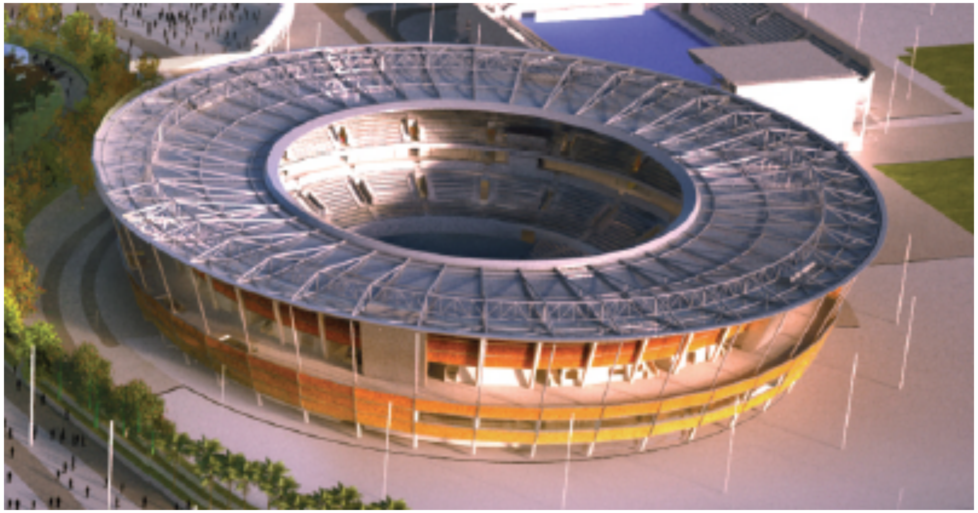
RIO 2016 - AQUATIC



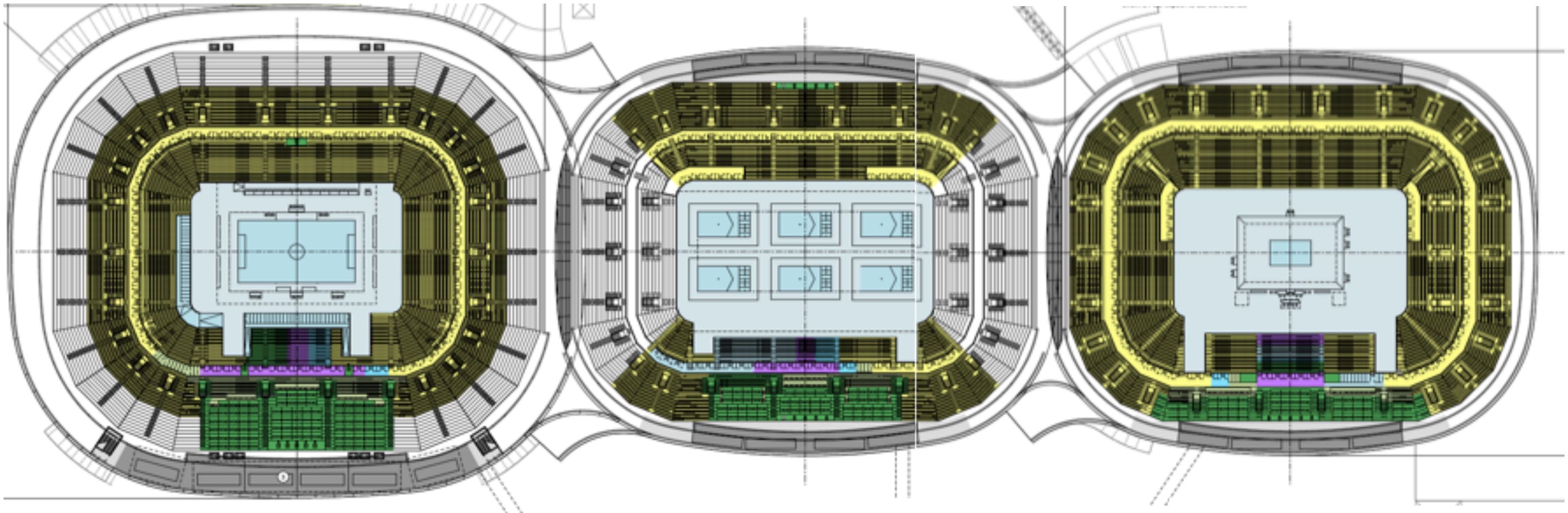
INTRODUCTION



RIO 2016 – TENNIS ARENAS



RIO 2016 – COT ARENAS



Basketball Judo Wrestling

Designing sound systems for large spaces

Getting Started…

Analysis of Requirements:

FREQUENCY RESPONSE

COVERAGE (SPL DISTRIBUTION)

STI VALUES

project documentation

ZONING

ARCHITECTURAL AND STRUCTURAL CONDITIONS

REDUNDANCY

international standards

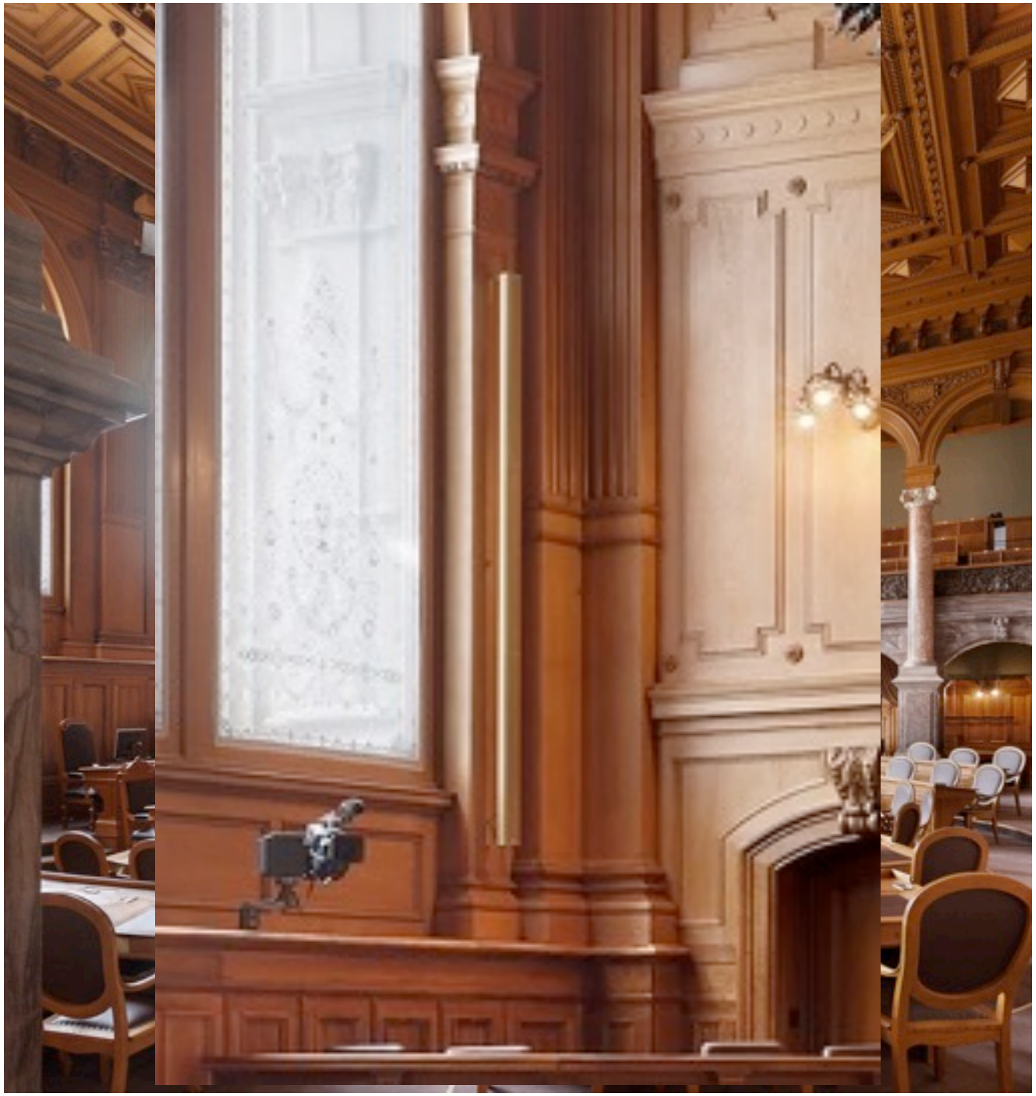
ADEQUATE ACOUSTICS

ARCHITECTURAL AND STRUCTURAL CONDITIONS

KKL CONCERT HALL – LUCERN - SUIÇA

FIXED /
RETRACTABLE INSTALLATION

SWISS PARLIAMENT



ARCHITECTURAL INTEGRATION

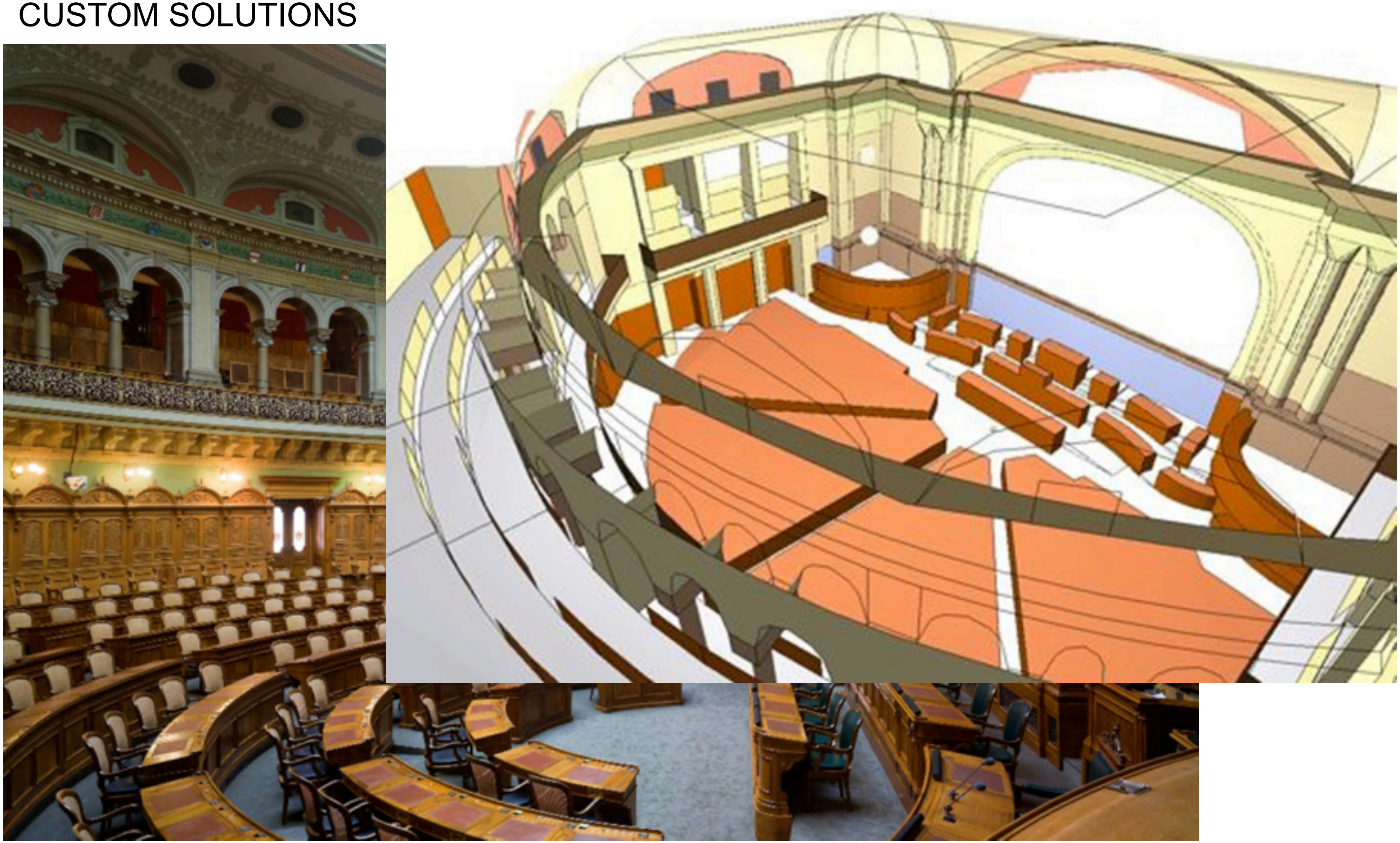
ST. URSEN CHURCH – SOLOTHURN - SWITZERLAND

ARCHITECTURAL INTEGRATION

ST. URSEN CHURCH – SOLOTHURN - SWITZERLAND

ARCHITECTURAL INTEGRATION

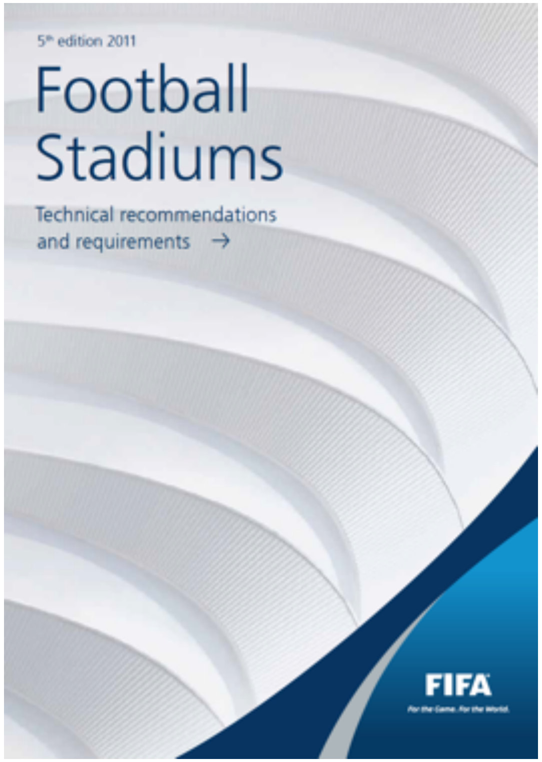
CUSTOM SOLUTIONS



CUSTOM SOLUTIONS

CUSTOM DESIGNED BY WSDG AND MANUFACTURED BY THE LOUDSPEAKER COMPANY
(SIZE, FREQ. RESPONSE, SPL, TECHNOLOGY)

FIFA



6.3 → Communication with the public

Sound reinforcement and acoustics

Public address system

It is essential that stadium operators and authorities are capable of communicating with spectators inside and outside the stadium by means of a sufficiently powerful and reliable public address (PA) system. The PA system should be designed to meet the following minimum operational requirements:

- The PA control centre shall be located in a position where the operator has a clear view of the stadium spectator areas.
- The control centre shall have the ability to select audio signals from the PA announcer, stadium video control, outside broadcasters and local sources within the control centre.
- The PA system shall be capable of addressing messages exclusively to individual sectors within and adjacent to the stadium.
- The PA system shall be capable of having its volume level automatically increased in response to increased crowd noise to ensure intelligibility of voice messaging.
- The PA system shall have an override facility, which would permit the stadium operator or authorities with jurisdiction for the stadium to interrupt the sound system in the event of an emergency.
- The PA system shall provide an emergency alternative power supply to ensure the system remains operative without interruption in the event of a power failure for a minimum period of three hours.

To ensure that adequate speech intelligibility for public address and emergency messages is achieved in the stadium spectator areas, the PA system should be designed to meet the following performance requirements and standards:

- The system is to achieve STI values (measured using the STI-PA method or calculated from the impulse response) of not less than STI 0.55 in the fixed spectator seating areas.
- The system shall provide maximum continuous sound levels of not less than 100 dBA and peak sound levels of at least 105 dBA, with deviations in overall direct sound levels across the spectator seating not exceeding +/-3.5 dBA.
- Frequency response as measured in the seating areas shall be at least 120Hz to 5000Hz +/-3 dB.
- Documentation of performance is required.

Depending upon funding availability, stadium owners may wish to consider installing a "sound reinforcement system" as opposed to the more basic, and less expensive, public address system. A sound reinforcement system is more effective for relaying music and other entertainment and informational audio programmes. The system would have to meet the minimum speech intelligibility requirement and exceed the performance requirements for loudness, frequency response, and uniformity.

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OLYMPICS

RIO 2016 – PAVA PERFORMANCE TARGET

Tabela C11: Metas de Desempenho Preliminar de Audio/Video (PAVA

Espaço	Nível típico de funcionamento dB(A)	SPL Max.	STI	Freq. Response	RT60
Áreas de Arquibancada da Arena	85 ±3	103	0.45	100Hz -12kHz ±5dB[2]	≤ 2.5
Concourses	85 ±3	95	0.45	160Hz - 12kHz ±5dB	≤ 1.5
Áreas de mídia	80 ±3[4]	90	0.50	160Hz - 12kHz ±5dB	≤ 0.8
Coletiva de Imprensa	80 ±3[4]	90	0.50	160Hz - 12kHz ±5dB	≤ 0.8
Zona Mista	80 ±3	90	0.50	160Hz - 12kHz ±5dB	≤ 1.0
Escritório da Segurança	73 ±2[4]	80	0.50	160Hz - 12kHz ±5dB	0.5
Recepção atletas	80 ±3	90	0.50	160Hz - 12kHz ±5dB	≤ 1.0
Vestiários de Atletas	75 ±3	90	0.45	250Hz - 6kHz ±5dB[3]	≤ 1.5
Academia	80 ±3	95	0.50	100Hz - 12kHz ±5dB	≤ 1.0
Sala de Chamada de atleta	73 ±2	85	0.50	250Hz - 6kHz ±5dB	≤ 0.8
Sanitários	73 ±2	80	0.50	250Hz - 6kHz ±5dB	≤ 1.5
Júri e Recursos	73 ±2[4]	80	0.50	250Hz - 6kHz ±5dB	≤ 0.8
Centro de Fisioterapia	73 ±2	80	0.50	250Hz - 6kHz ±5dB	≤ 1.0
Centro Médico de Atletas	73 ±2	80	0.50	250Hz - 6kHz ±5dB	≤ 1.0
Centro médico do espectador	73 ±2	80	0.50	250Hz - 6kHz ±5dB	≤ 1.0
Controle de Doping	73 ±2[4]	80	0.50	250Hz - 6kHz ±5dB	≤ 0.8
Sala do Árbitro	73 ±2[4]	80	0.50	250Hz - 6kHz ±5dB	≤ 0.8
Sala de Reunião de árbitros	75 ±3[4]	85	0.50	250Hz - 6kHz ±5dB	≤ 0.8
Sala de Oficiais Técnicos	73 ±2[4]	80	0.50	250Hz - 6kHz ±5dB	≤ 0.8
Gerenciamento da Competição	73 ±2[4]	80	0.50	250Hz - 6kHz ±5dB	≤ 0.8

OLYMPICS

RIO 2016 – PAVA PERFORMANCE TARGET

Tabela C11: Metas de Desempenho Preliminar de Audio/Vídeo (PAVA

Espaço	Nível típico de funcionamento	Nível máx. exigido	STI (média - 1 desvio	Resposta de Frequência	Tempo de Reverberação
Áreas de Arquibancada da Arena					
Concourses					
Áreas de mídia					
Coletiva de Imprensa					
Zona Mista					
Escritório da Segurança					
Recepção atletas				±5dB	
Vestiários de Atletas	75 ±3	90	0.45	250Hz - 6kHz ±5dB[3]	≤ 1.5
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Tabela C11: Metas de Desempenho Preliminar de Audio/Vídeo (PAVA

Espaço	Nível típico de funcionamento dB(A)	Nível máx. exigido dB(A)	STI (média - 1 desvio padrão)	Resposta de Frequência
Áreas de Arquibancada da Arena	85 ±3	103	0.45	100Hz -12kHz ±5dB[2]
Concourses	85 ±3	95	0.45	160Hz - 12kHz

SYSTEMS
REQUIREMENTS - USE

STI
VALUES

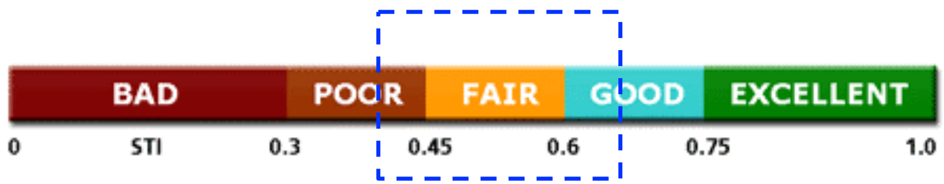
Speech intelligibility depends directly on:

- Background noise level,
- Reverberation time;
- Size of the room

For typical paging applications, STI values should not be lower than 0,5 (equivalent to % ALcons = 12%)

$$\mathrm{ALcons} = 10^{\frac{1-\mathrm{STI}}{0.46}}$$

$$\mathrm{STI} = 1 - 0.46 \cdot \log(\mathrm{ALcons})$$



$$\%ALcons = \frac{200\, r^2 \boxed{T_{60}{}^2} (1+n)}{V\, Q\, M} + K$$

r = Distance from the nearest loudspeaker
T60 = RT (averaged over 1 and 2 kHz)
V = Volume of the room
Q = Directivity of the nearest source
M = Acoustic modifier for reverberant power = 1 is a conservative assumption
(1 + n) = Total number of equal sources
K = Listener factor ≈ 2 % for a good listener.

Other issues…

- Distance from Source;
- Directivity
- Distortion

STI
VALUES

Bad news:

Large spaces often have:

- High RT60
- Long Distances
- Limitations for acoustical treatments

Good news:

Simulation tools - results can be predicted with great accuracy

better input (level of detail) => better output

REQUIREMENTS +

ARCHITECTURAL PLANS

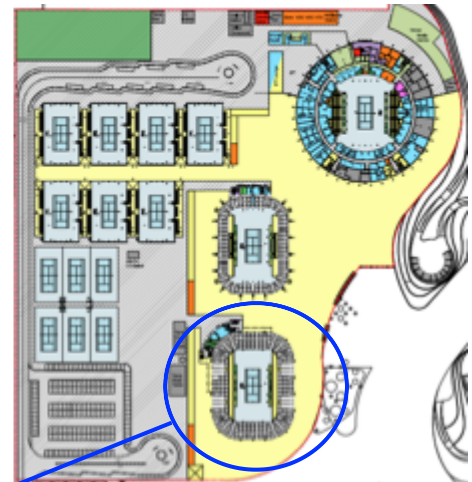
MODELING

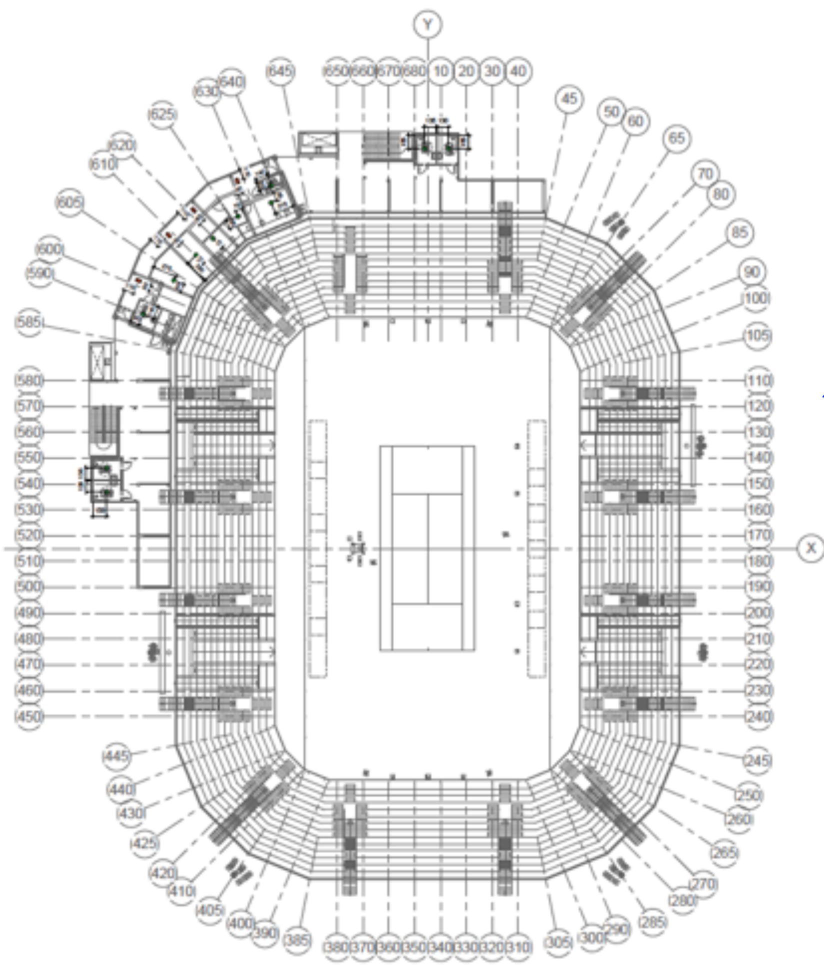
SYSTEM / TECHNOLOGY

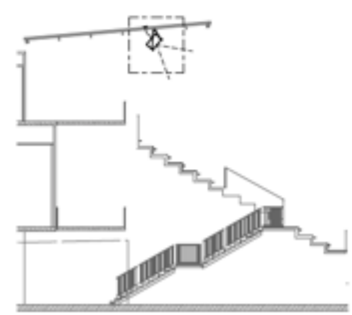
EQUIPMENT SELECTION

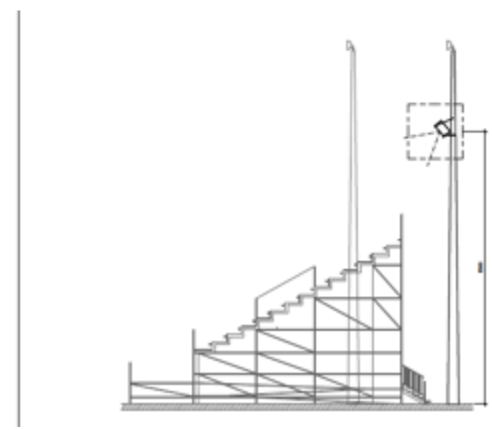
RESULTS

RIO 2016 - TENNIS COURT 2





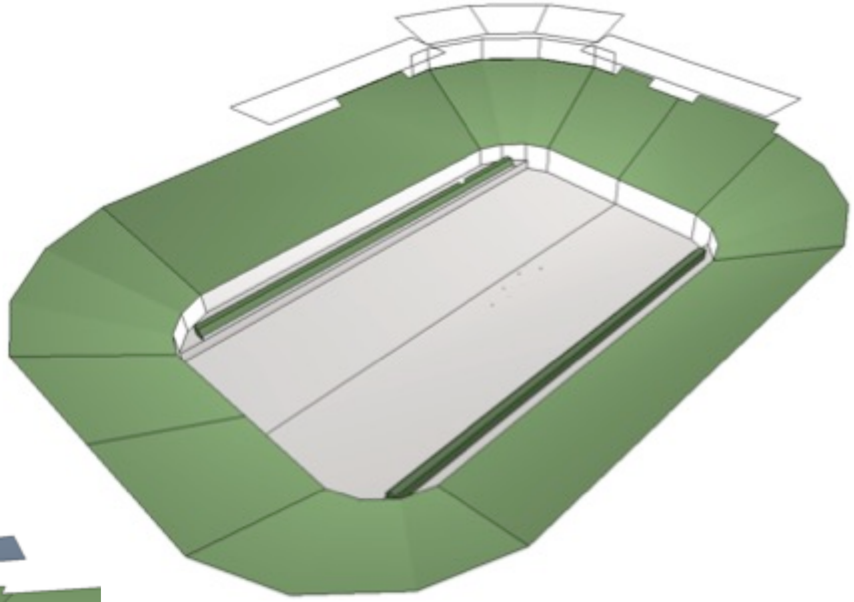


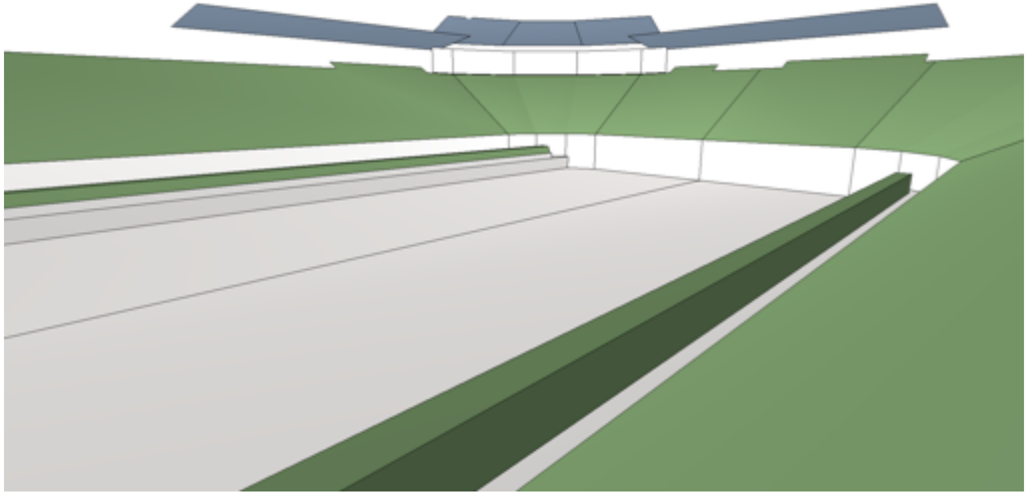


TENNIS COURT 2

OPTION A

SIMULATION MODEL / GEOMETRY





Three Dimensional Computermodel of stadium (CATT-Acoustic)
As used for room- and electro-acoustical studies and design.

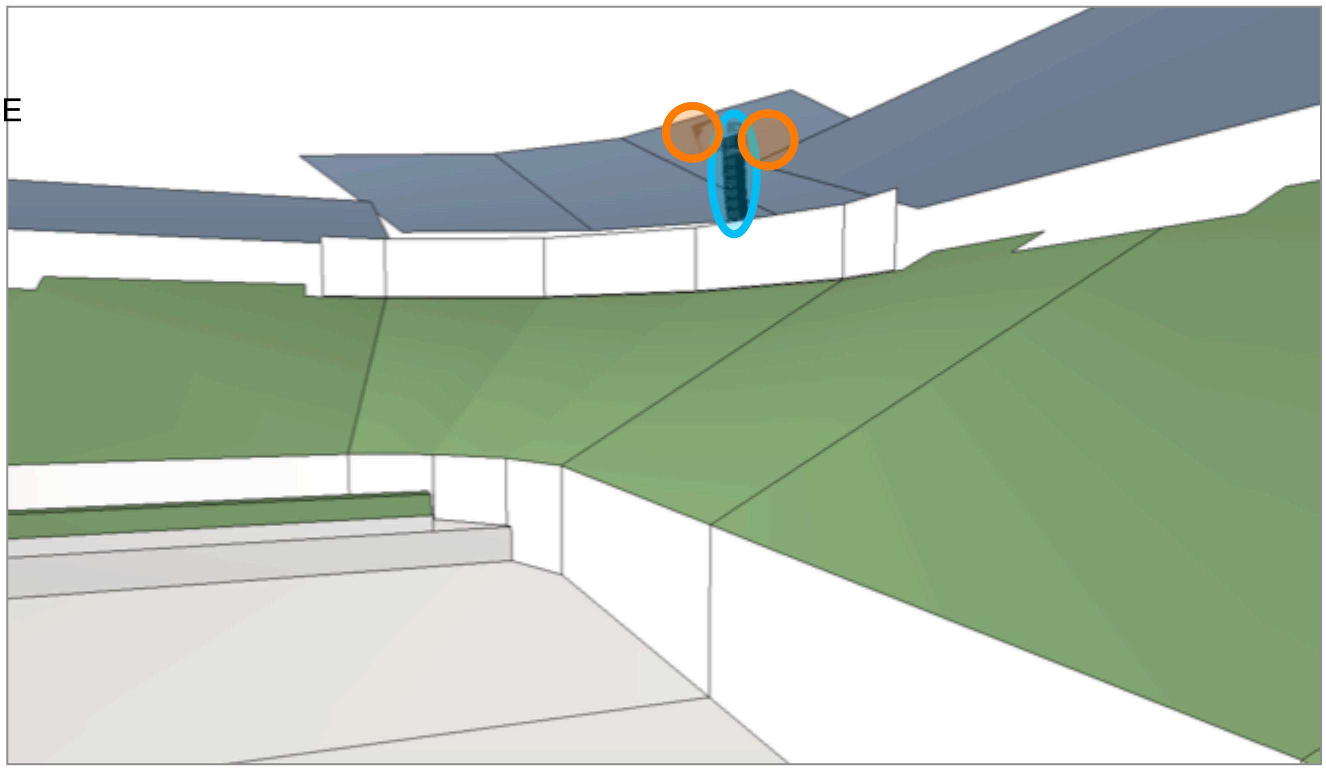
TENNIS COURT 2

MAIN SYSTEM – LINE SOUCRE

1 Line Array consisting of:
8 speakers

NEARFILL – POINT SOURCE

2 speakers



MAIN ARRAY

SYSTEMS

DESIGN DEVELOPMENT

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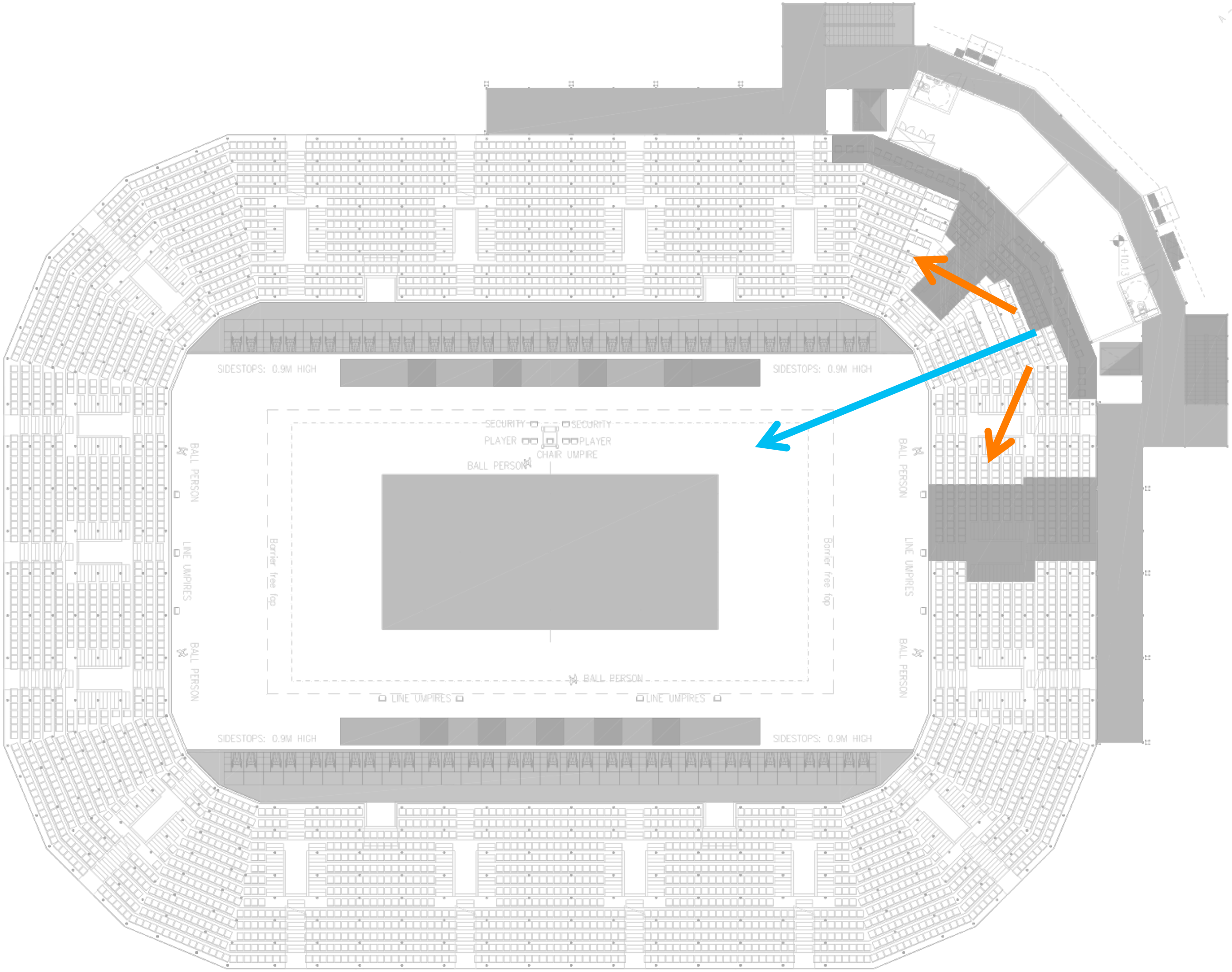
TENNIS COURT 2



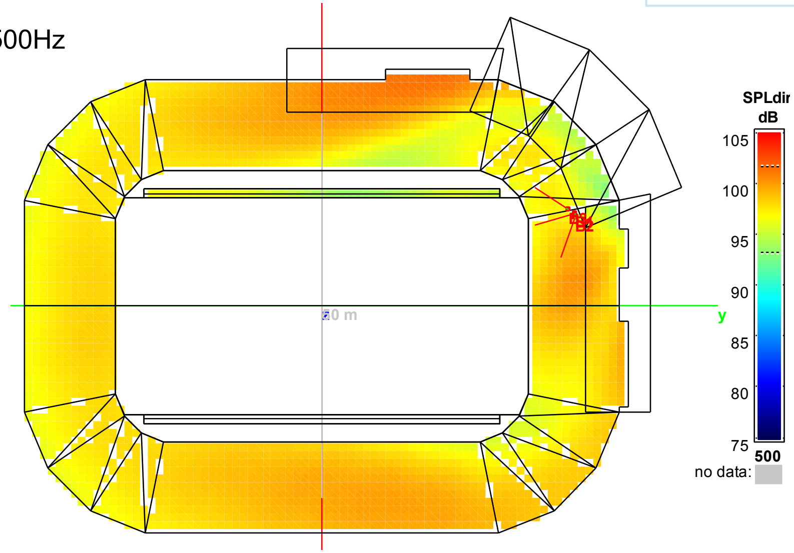
SYSTEMS

DESIGN DEVELOPMENT

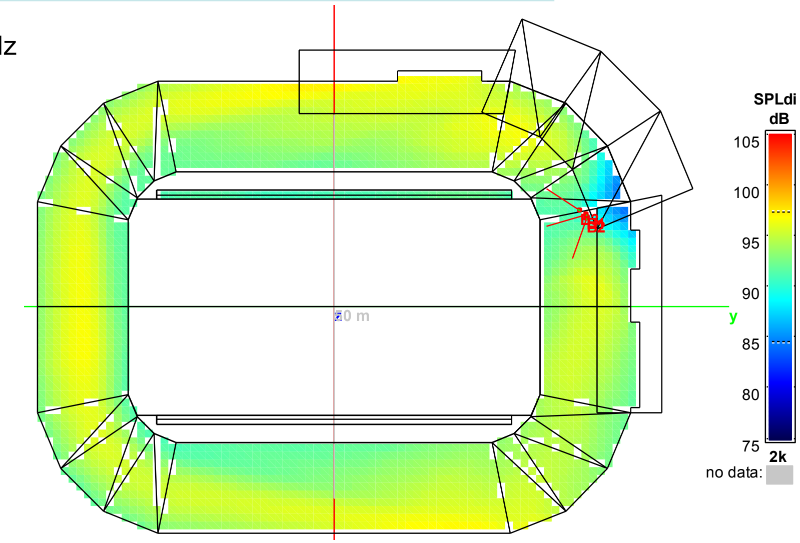
SOUND PRESSURE LEVEL (SPL)
PARTIAL SIMULATION WITH AUDIENCE PRESENT

TENNIS COURT 2

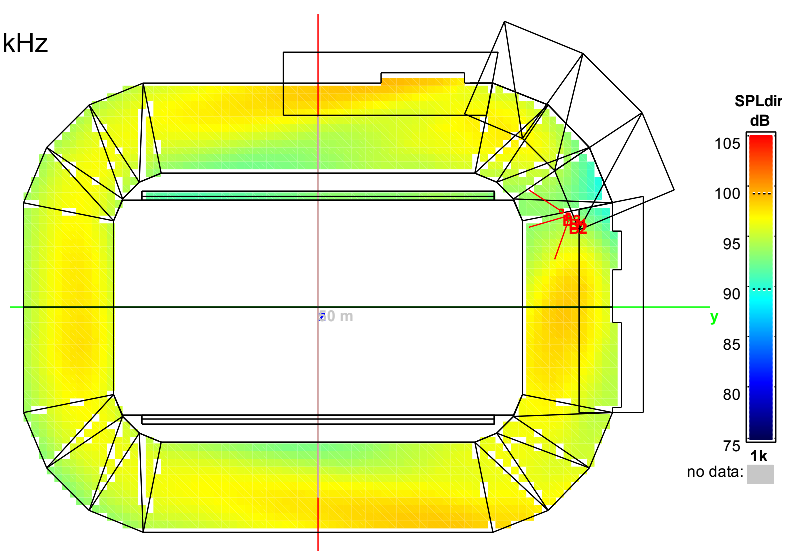
500Hz



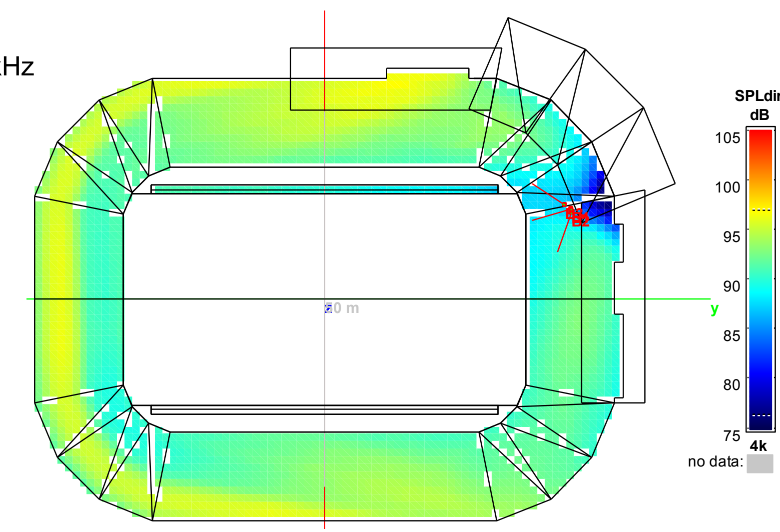
2kHz



1kHz



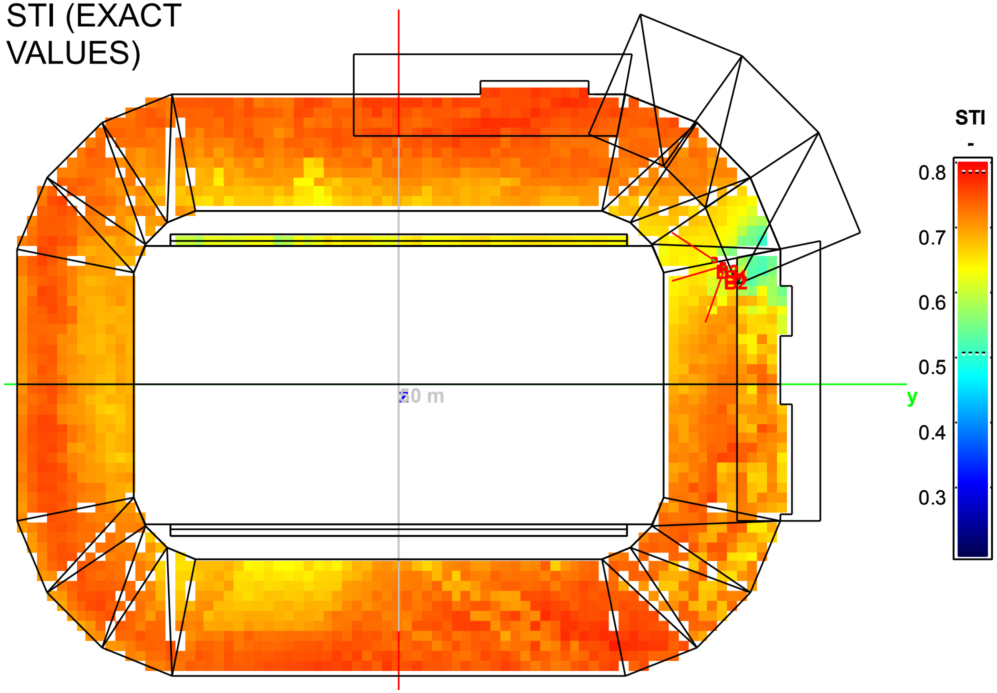
4kHz

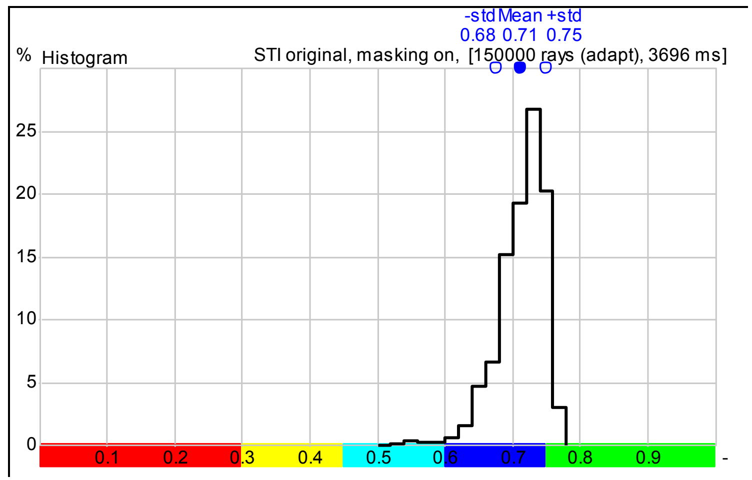


TENNIS COURT 2

SPEECH INTELLIGIBILITY (STI) SIMULATION WITH AUDIENCE PRESENT

STI (EXACT VALUES)



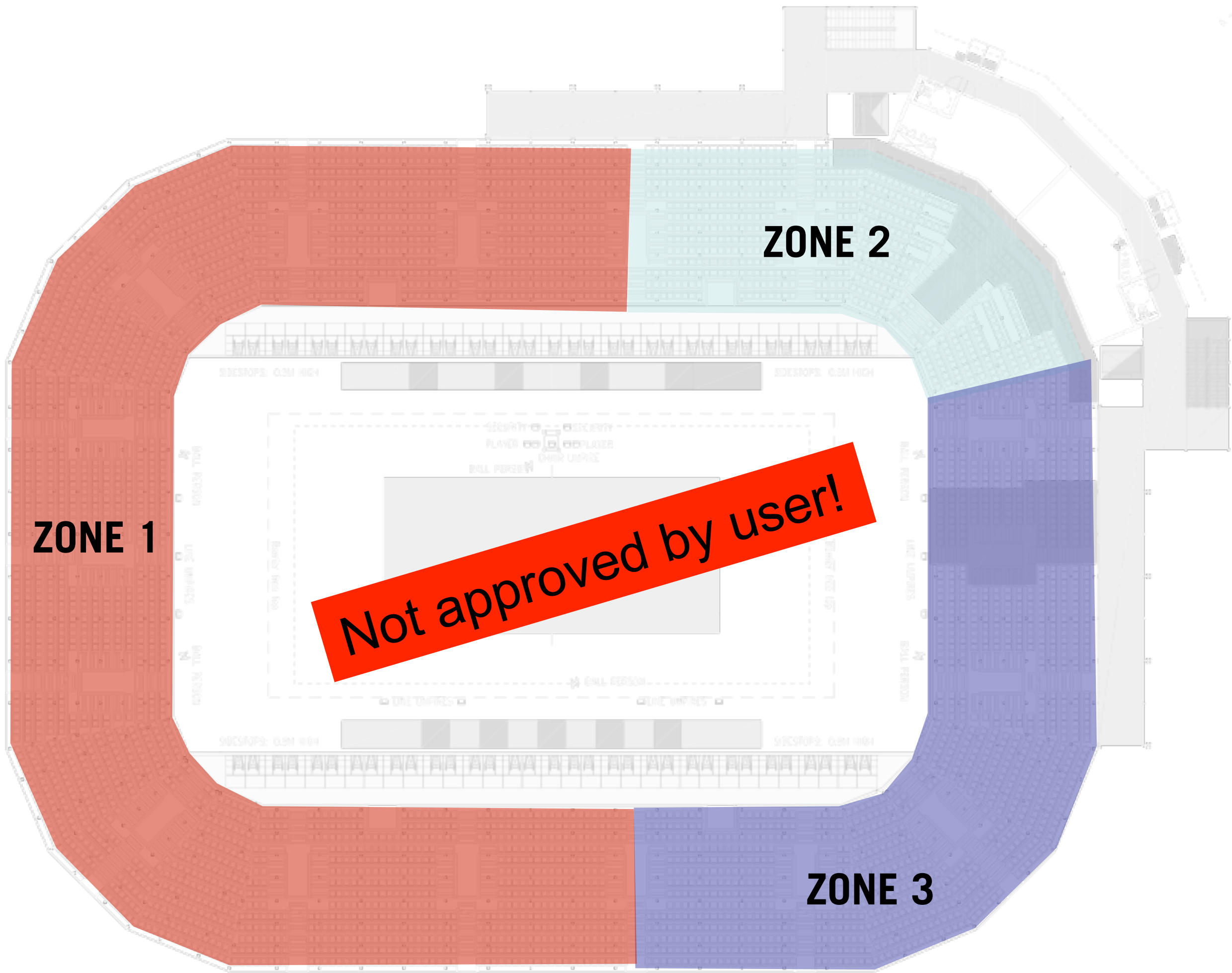


Averange STI of 0.71, Mean-Std = 0.68.
No seats in the simulated area are lower than STI 0.5

Background Noise: 90dB(A)
SPL on Audience: 100dB(A)

WSDG WALTERS-STORYK DESIGN GROUP

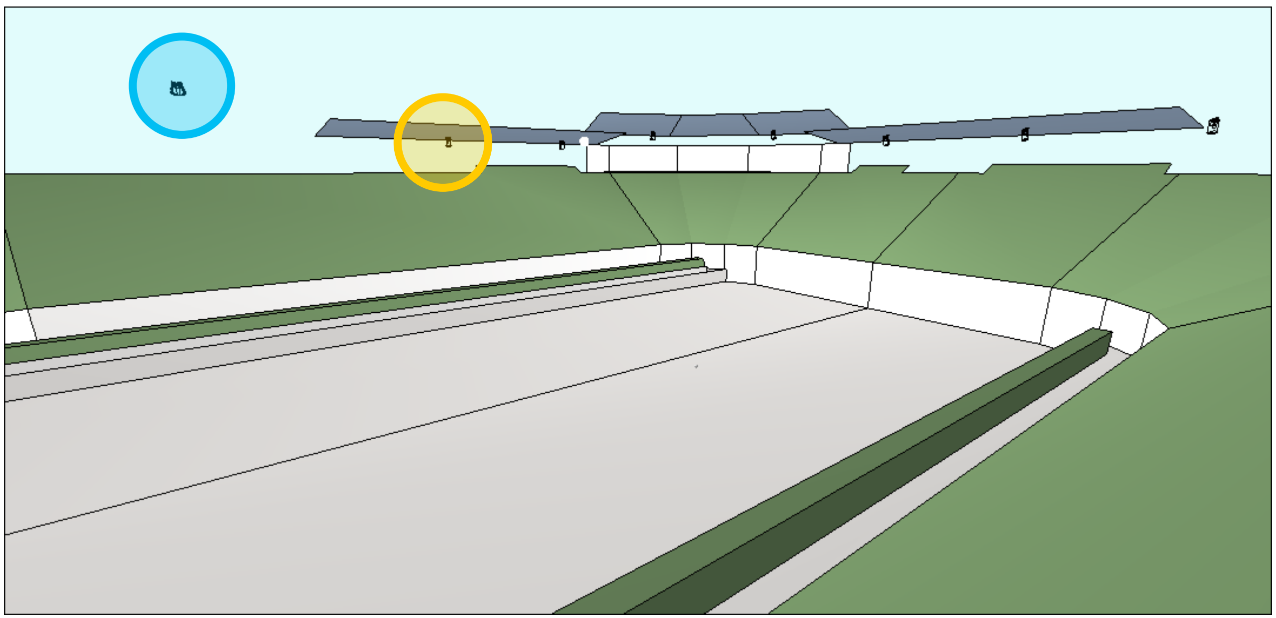
TENNIS COURT 2



TENNIS COURT 2

OPTION B

5x clusters with 2 speakers
7x 1 speaker



Clusters at lighting poles

Speakers at Roof Structure

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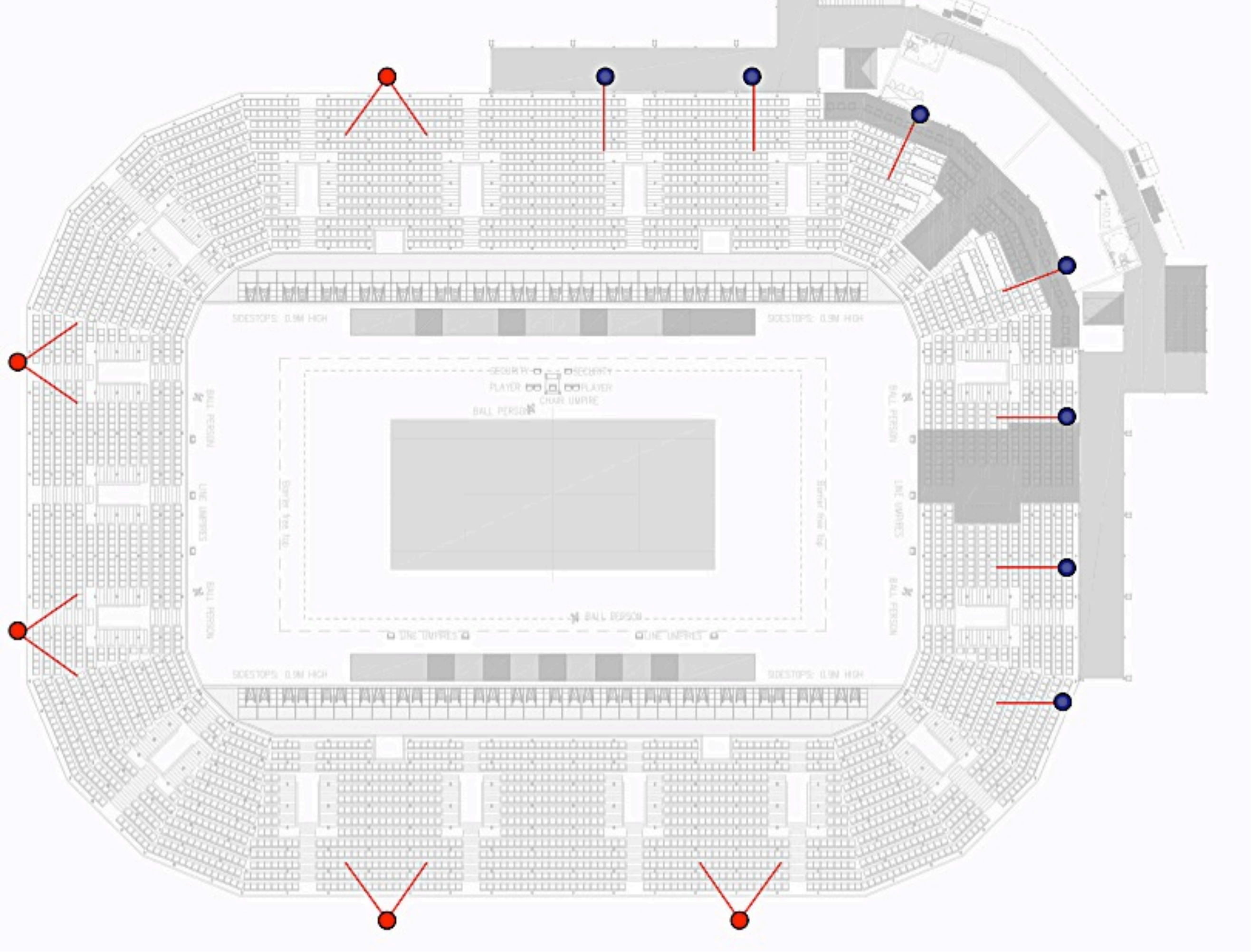
WALTERS-STORYK DESIGN GROUP

TENNIS COURT 2

OPTION B

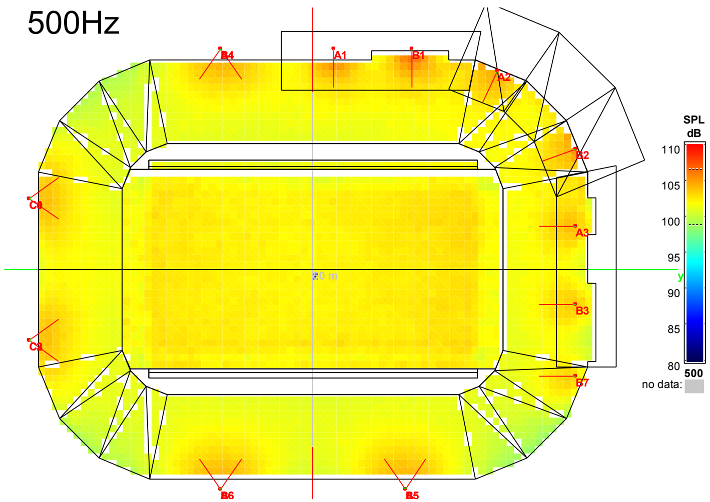


TENNIS COURT 2

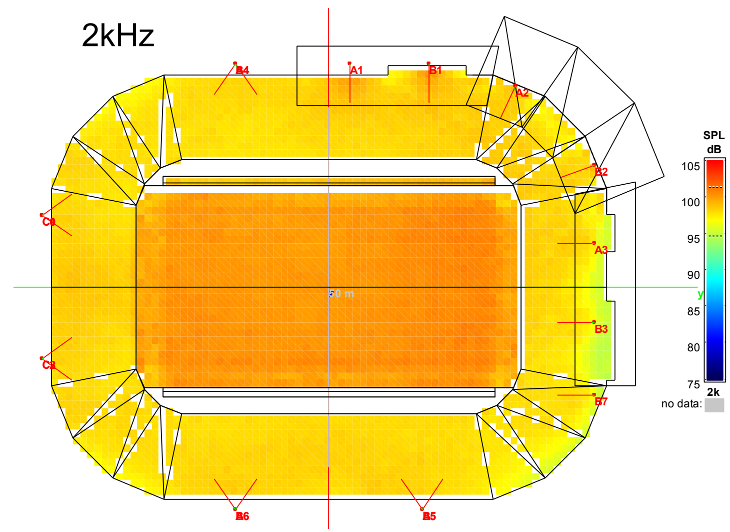
OPTION B

SOUND PRESSURE LEVEL (SPL) SIMULATION WITH AUDIENCE PRESENT

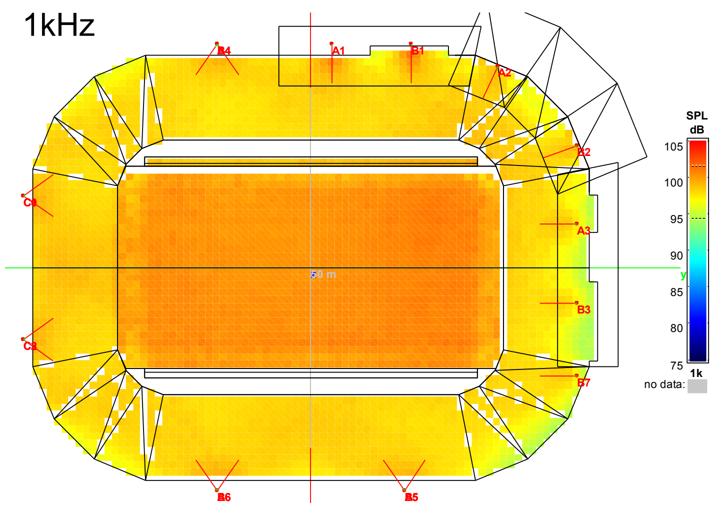
500Hz



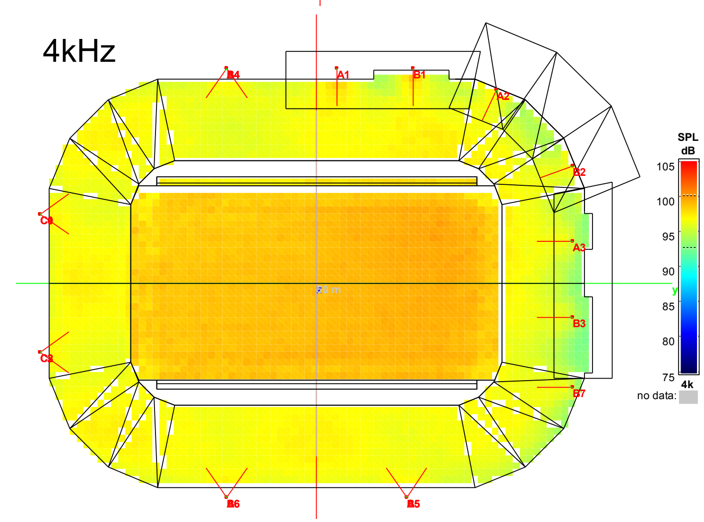
2kHz



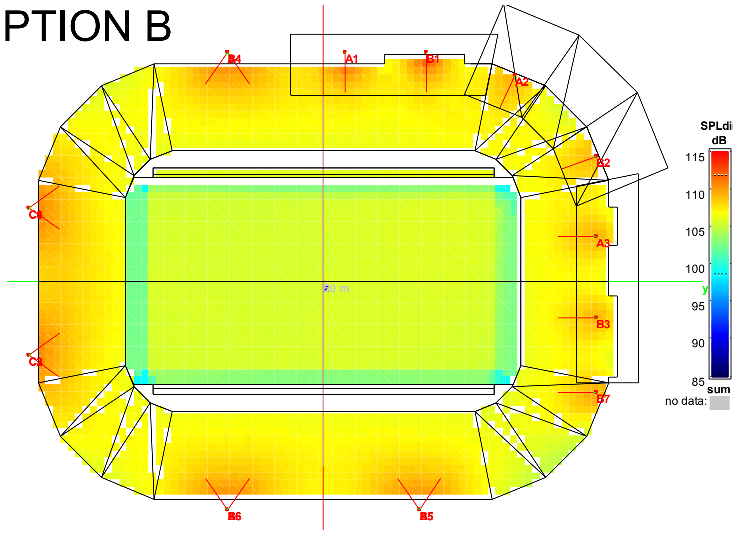
1kHz

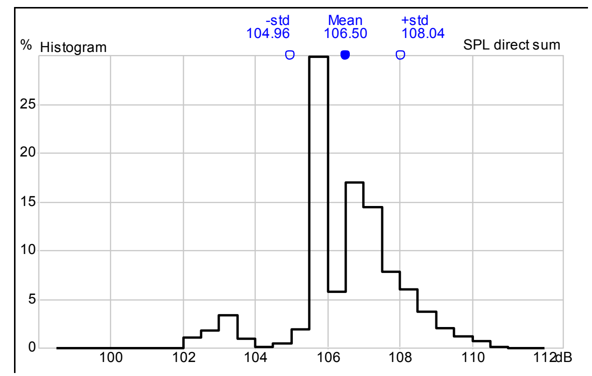


4kHz



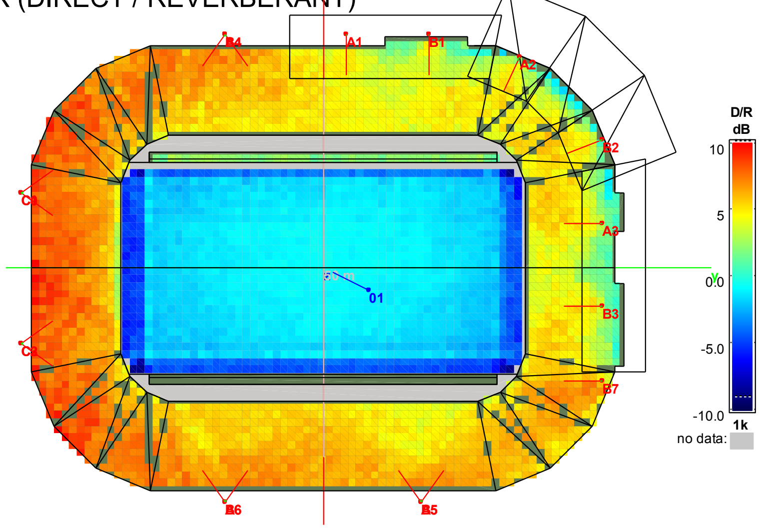
TENNIS COURT 2
OPTION B

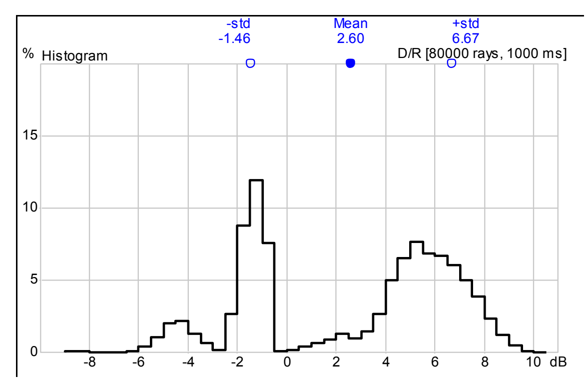




Uniform coverage with deviation of 1.5dB.
Average SPL of 106dB(C)

D/R (DIRECT / REVERBERANT)

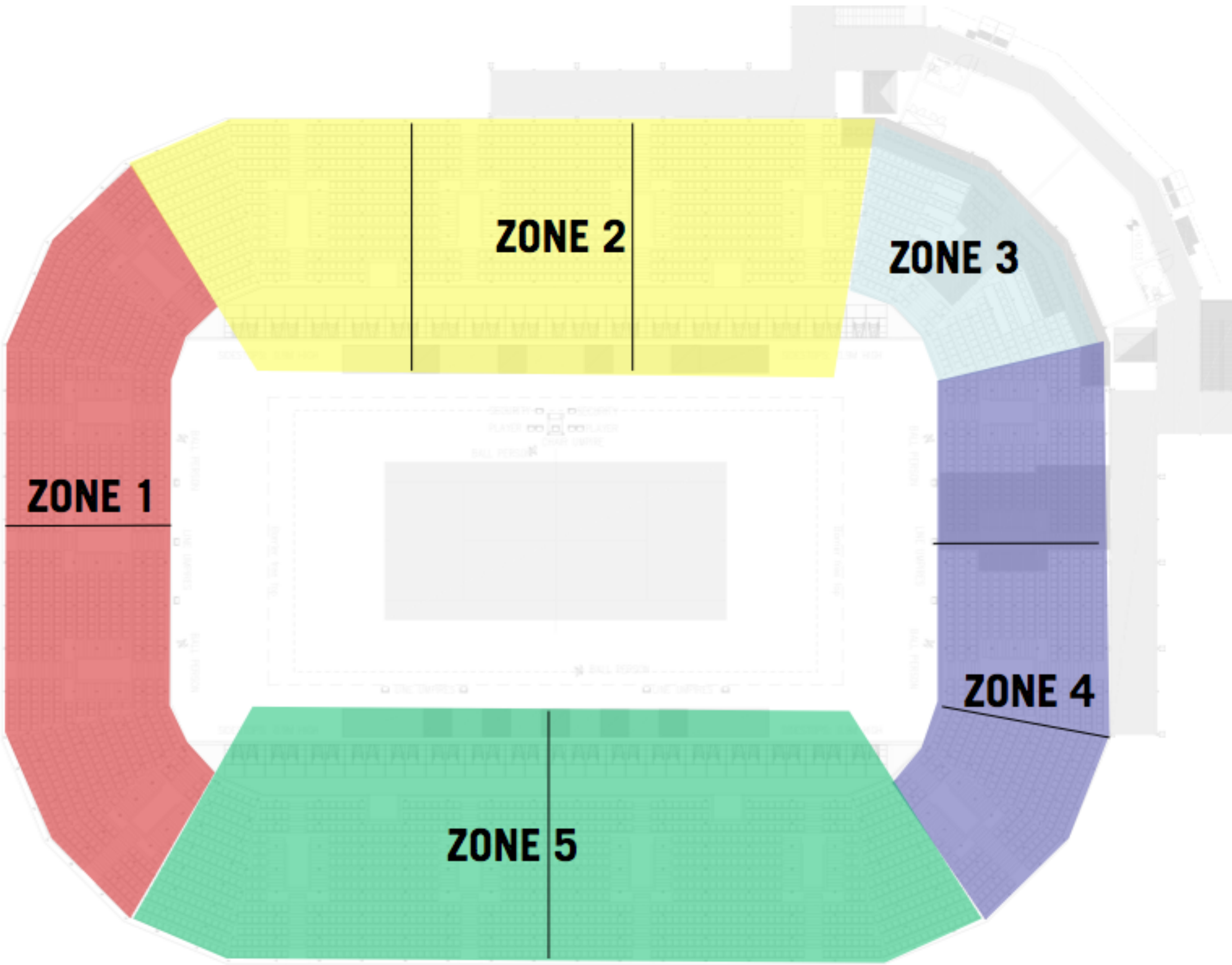




D/R relation is positive for the most part:
More direct sound at the listeners.

TENNIS COURT 2

OPTION B



SYSTEMS

DESIGN DEVELOPMENT

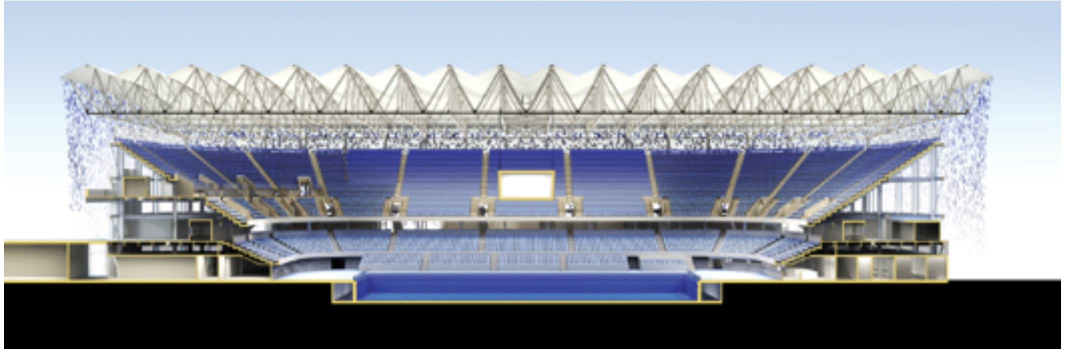
ARCHITECTURAL PLANS

MODELING

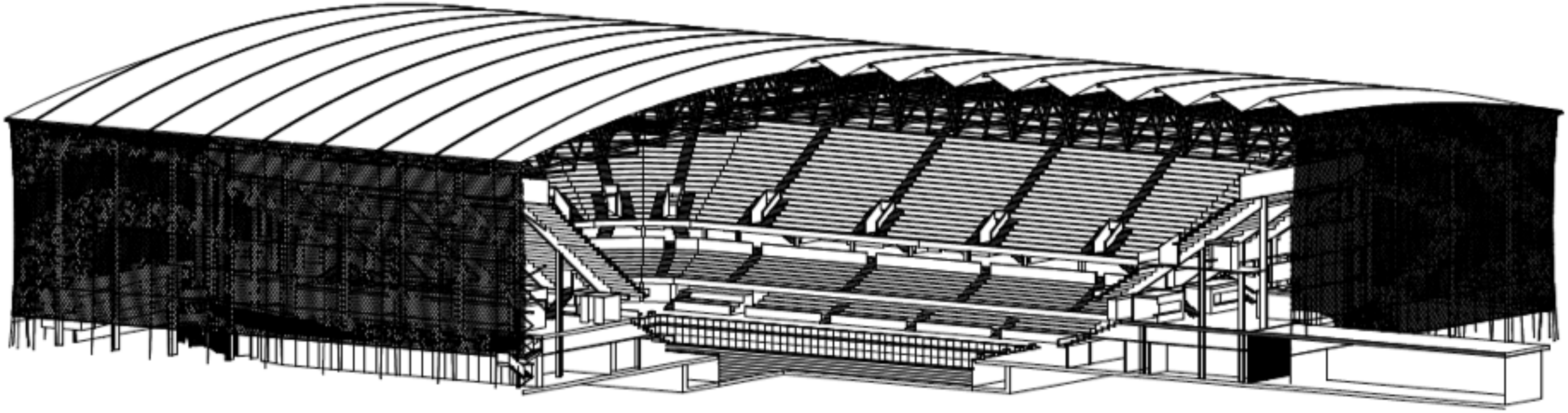
SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS



RIO 2016 - AQUATIC



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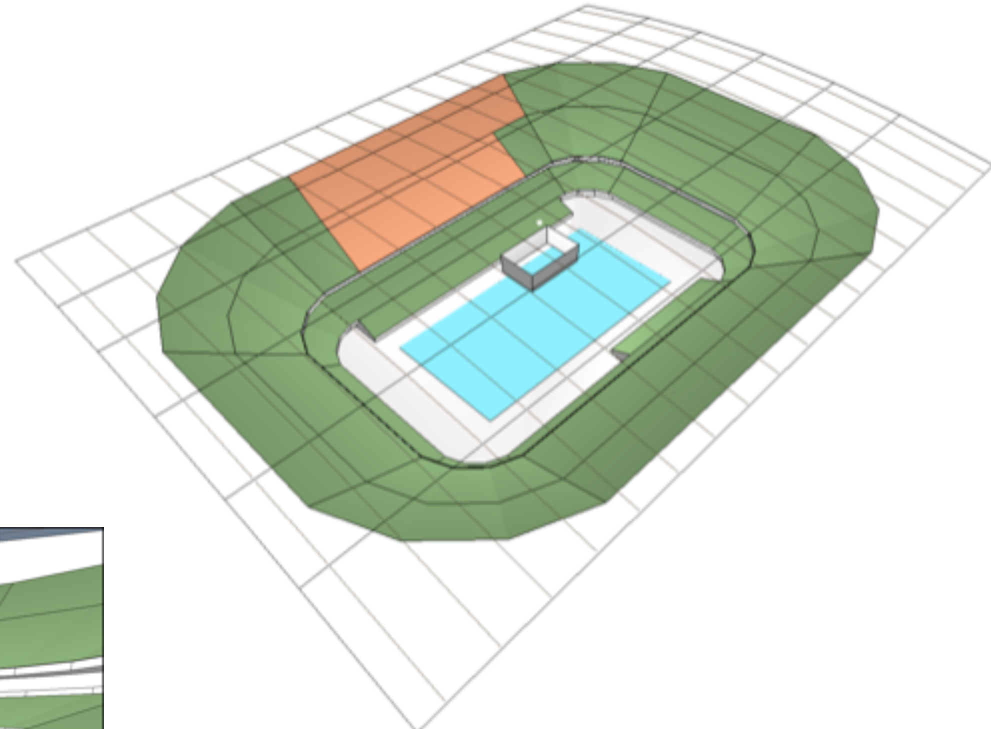
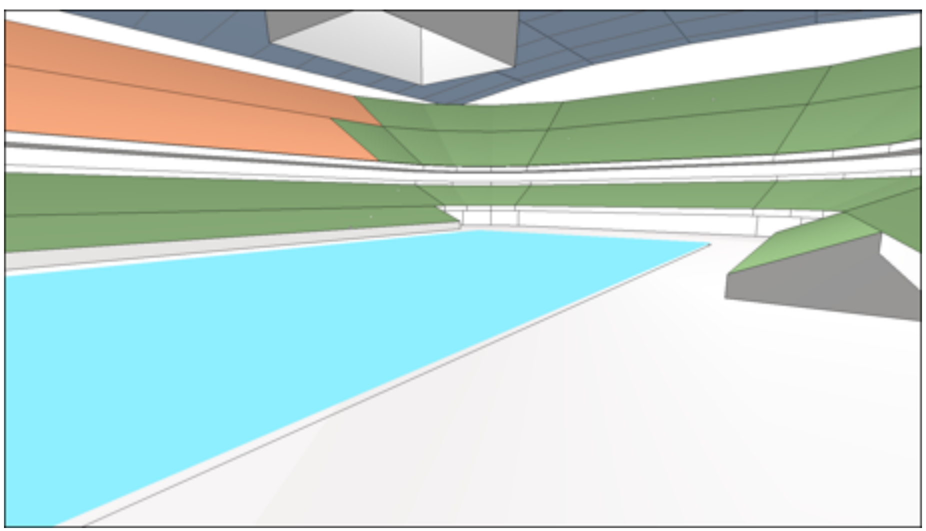
RESULTS





Three Dimensional Computermodel of stadium (CATT-Acoustic) as used for room- and electro-acoustical studies and design.

A few options…

- Point Source
- Distributed System (100V)
- Digitally Steered Line Source
- Line Array

Example...

ARCHITECTURAL PLANS

MODELING

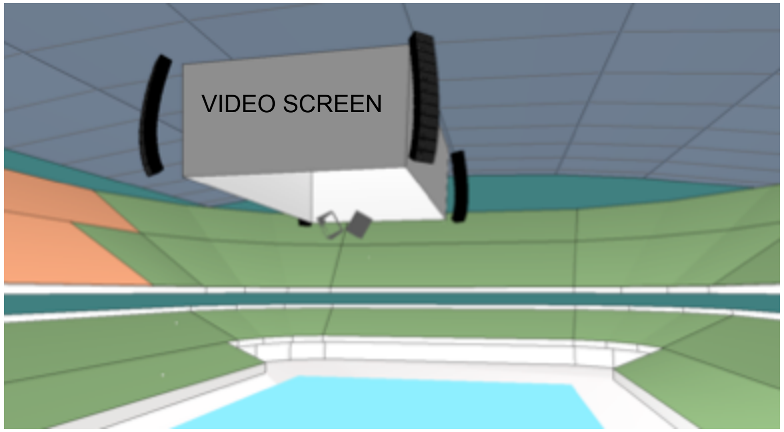
SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

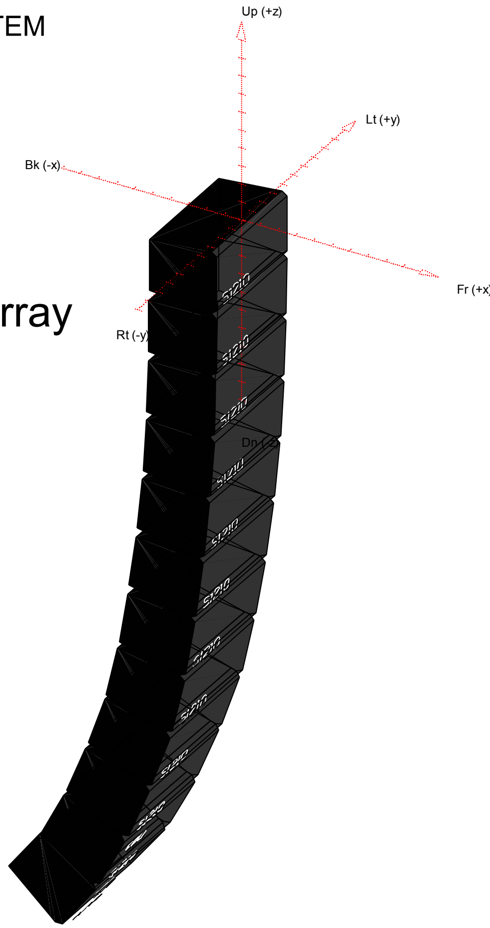
RESULTS

SUGGESTED SOUND REINFORCEMENT SYSTEM

4 Line Array Clusters
+ Point Source Downfill



Line Array



ARCHITECTURAL PLANS

MODELING

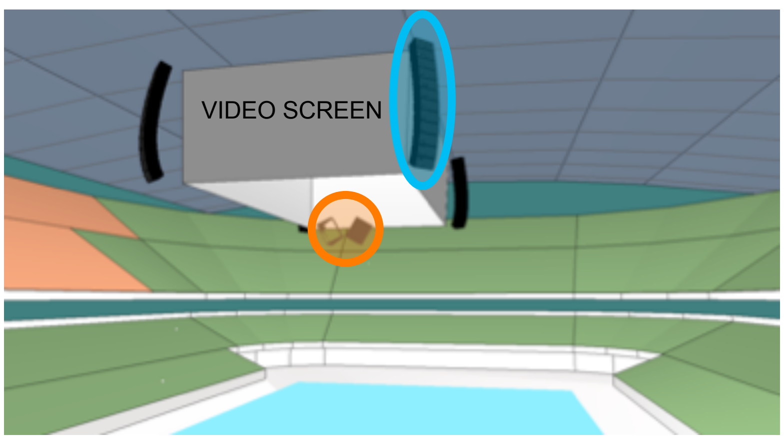
SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS

SUGGESTED SOUND REINFORCEMENT SYSTEM

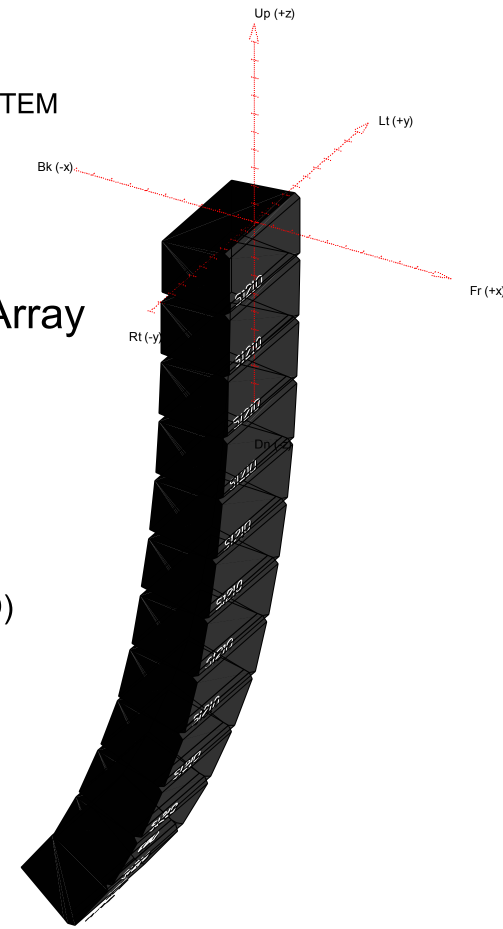
4 Line Array Clusters
+ Point Source Downfill



MAIN ARRAY

DOWNFILL

Line Array



Arrays:

Estimated weight
420kg

Size
4.25m x 0.8m x 1m (HxWxD)

SPL handling

Driver Configuration

Cost: ????

Coverage

.

.

.

.

Speaker selection – interactive process!

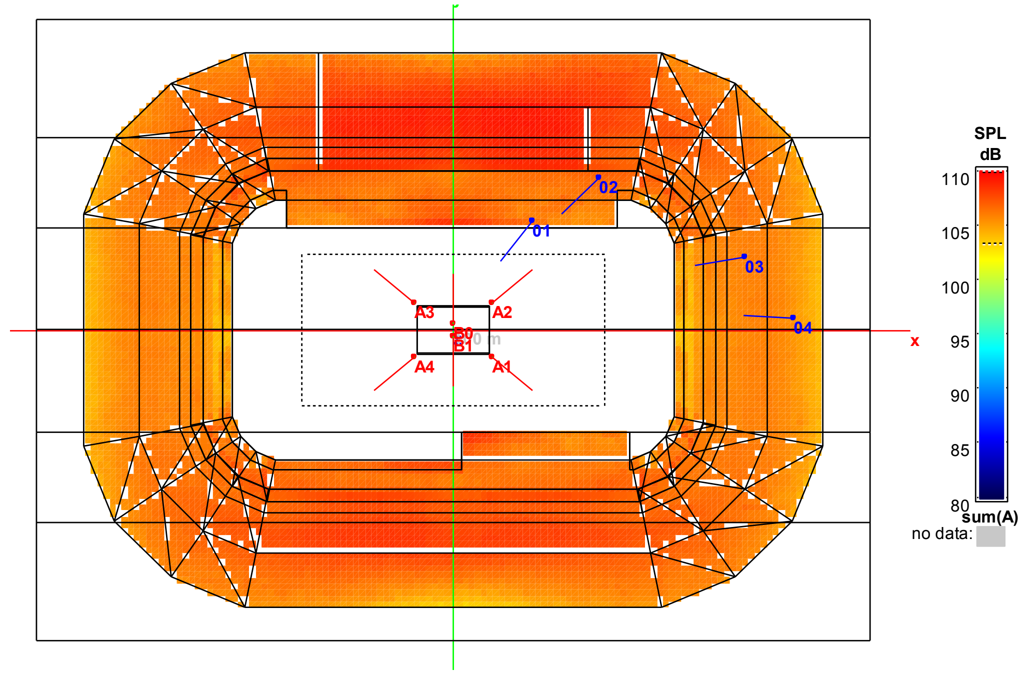
ARCHITECTURAL PLANS

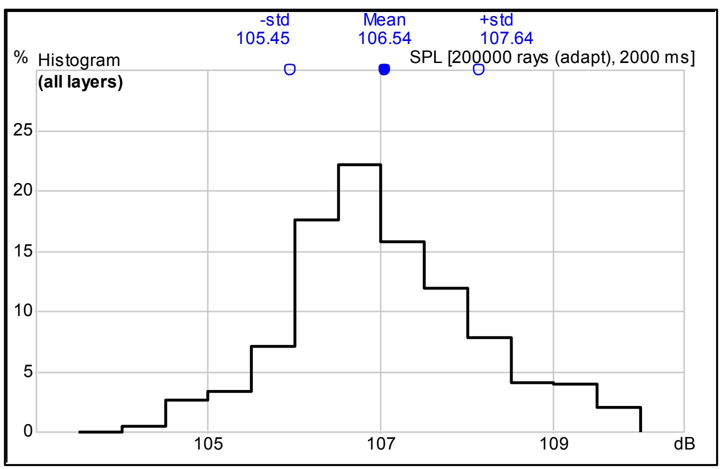
MODELING

SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS





Version A

SPL simulation using line array sources with additional downfills for the VIP areas.

The maximum SPL that can be achieved is 107dB(A) with a standard deviation of +/-1dB

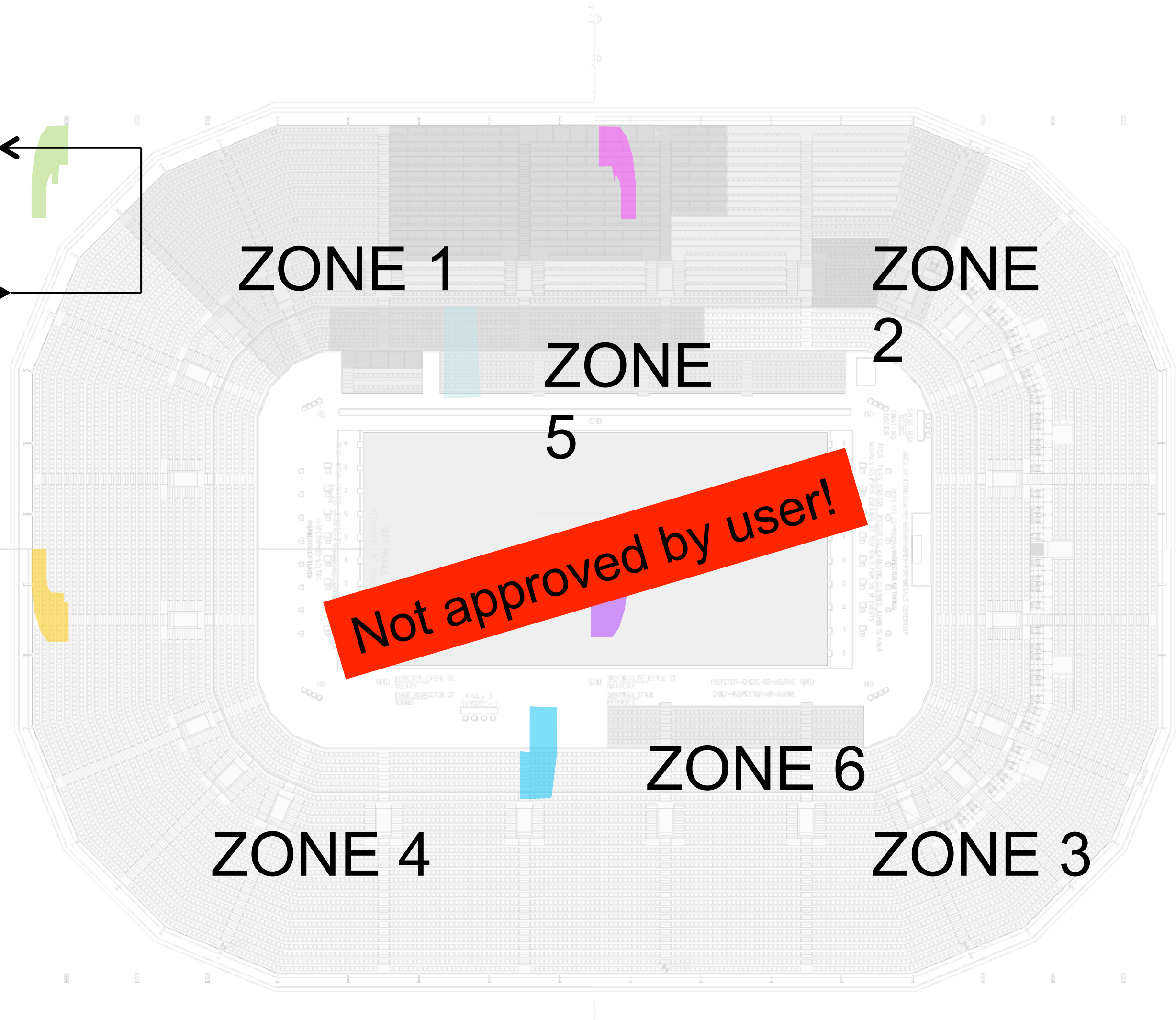
ARCHITECTURAL PLANS

MODELING

SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS



BEST ACOUSTICAL PERFORMANCE BUT…

ZONING CRITERIA NOT FULLFILLED!

ARCHITECTURAL PLANS

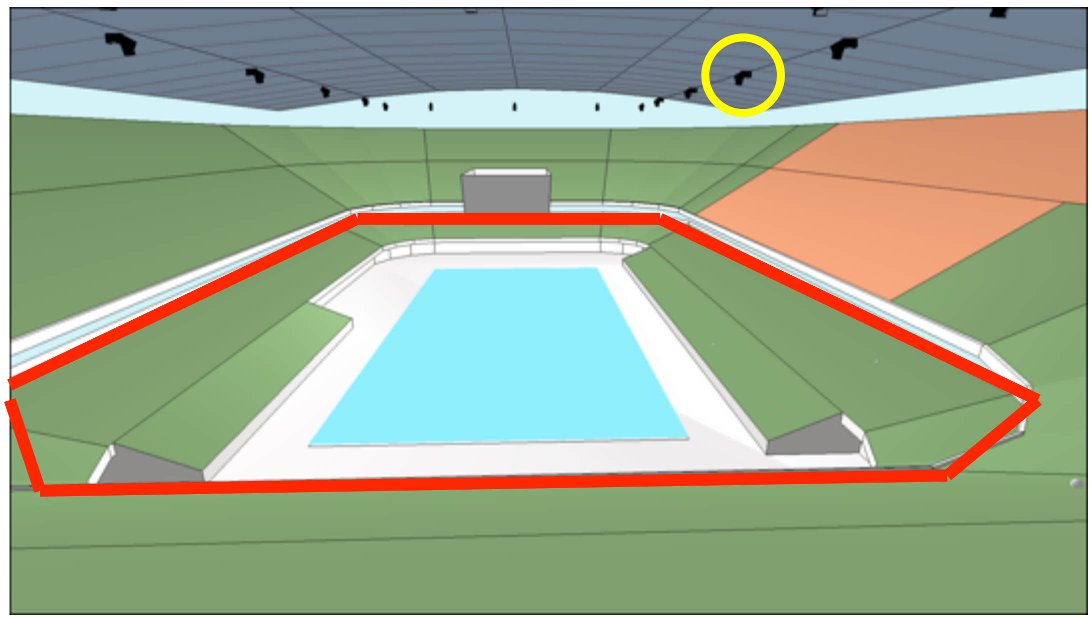
MODELING

SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS

REVISED SOUND REINFORCEMENT SYSTEM



Point Sources distributed at the roof

Fill speakers under balcony.

ARCHITECTURAL PLANS

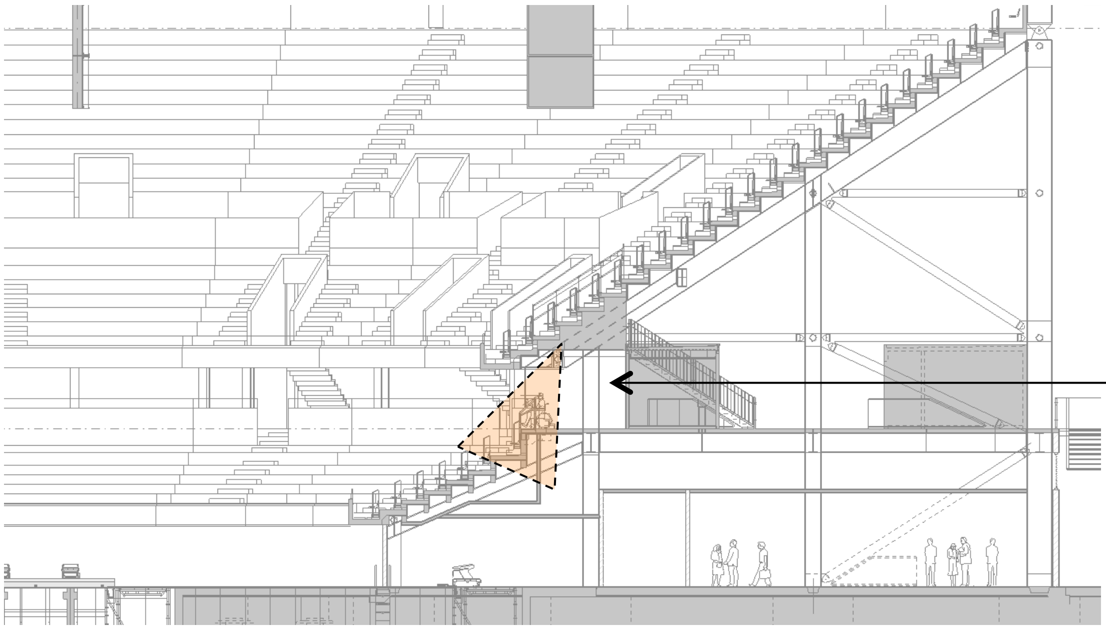
MODELING

SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS

REVISED SOUND REINFORCEMENT SYSTEM



Point Sources distributed at the roof

Fill speakers under balcony.

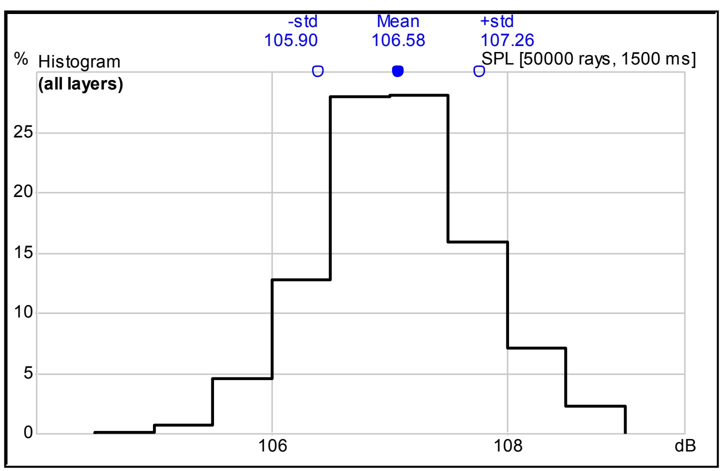
ARCHITECTURAL PLANS

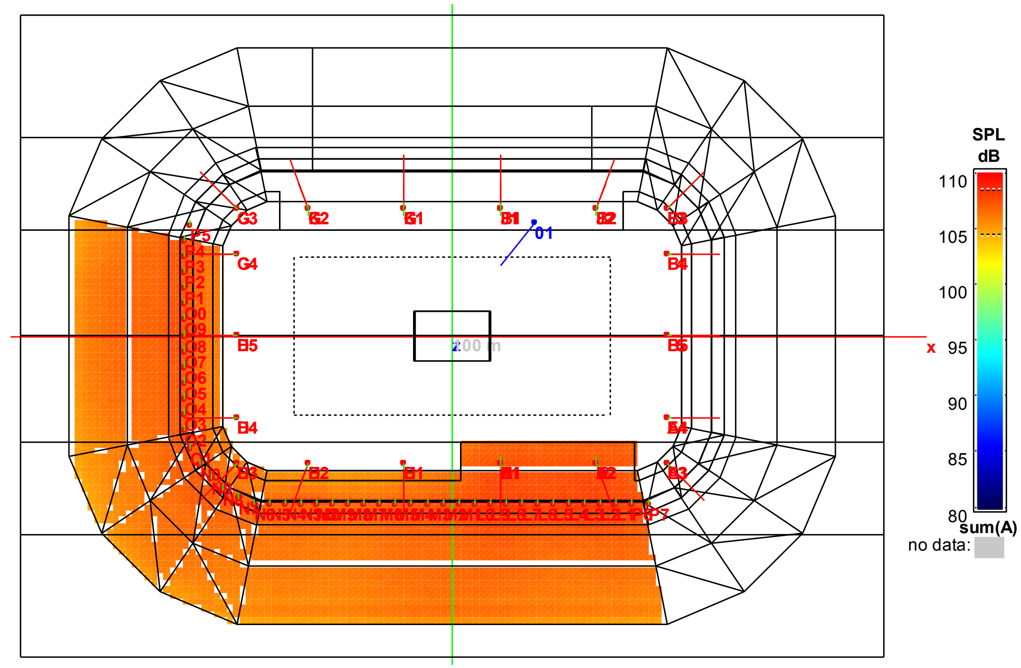
MODELING

SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS





Version B

SPL simulation using point sources with additional under balcony fills.

The maximum SPL that can be achieved is 107dB(A) with a standard deviation of +/-1dB

ATTENTION: Only partially simulated due to the simulation time needed with this huge number of souces – statistics are slightly distorted due to that fact.

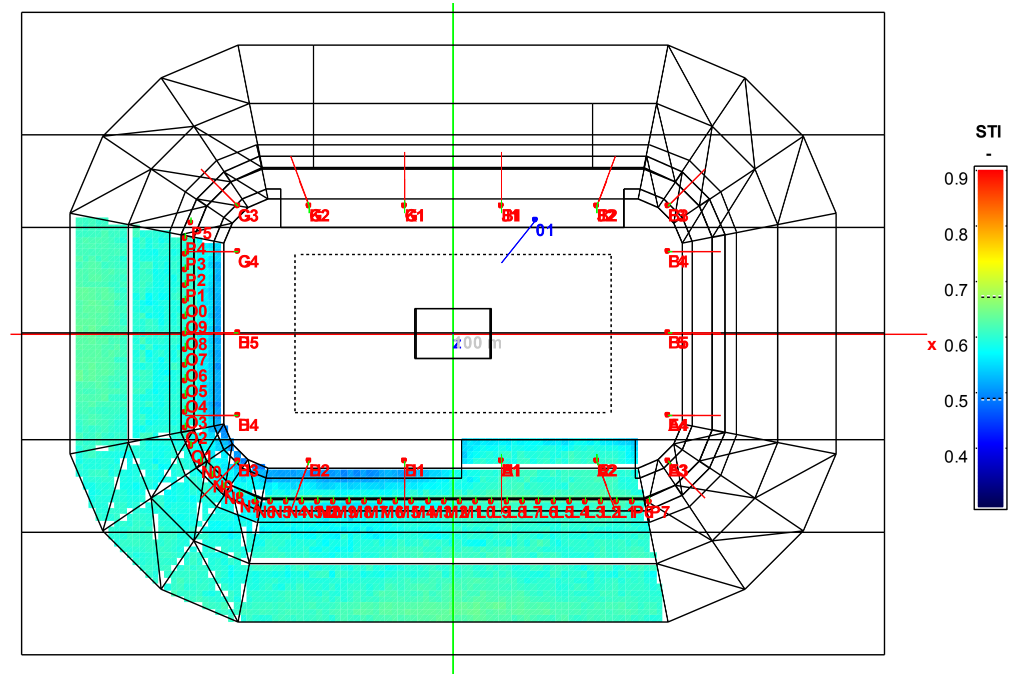
ARCHITECTURAL PLANS

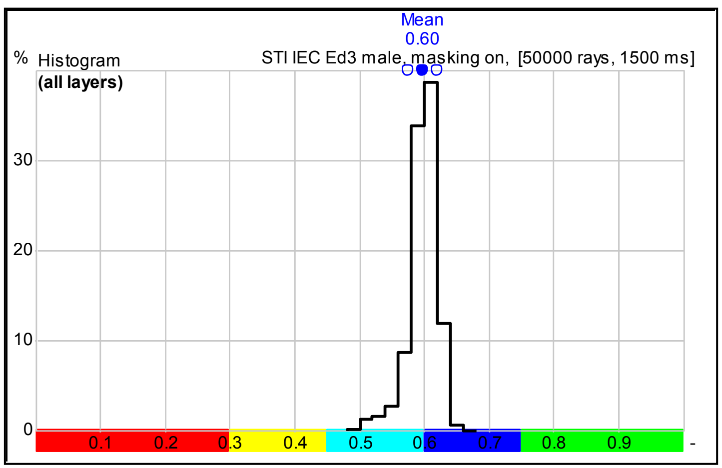
MODELING

SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS





Version B

STI Simulation

Mean STI: 0.598
Std. dev.: 0.023

Version A – Line Array

Mean STI: 0.634
Std. dev.: 0.028

ATTENTION: Only partially simulated due to the simulation time needed with this huge number of souces – statistics are slightly distorted due to that fact.

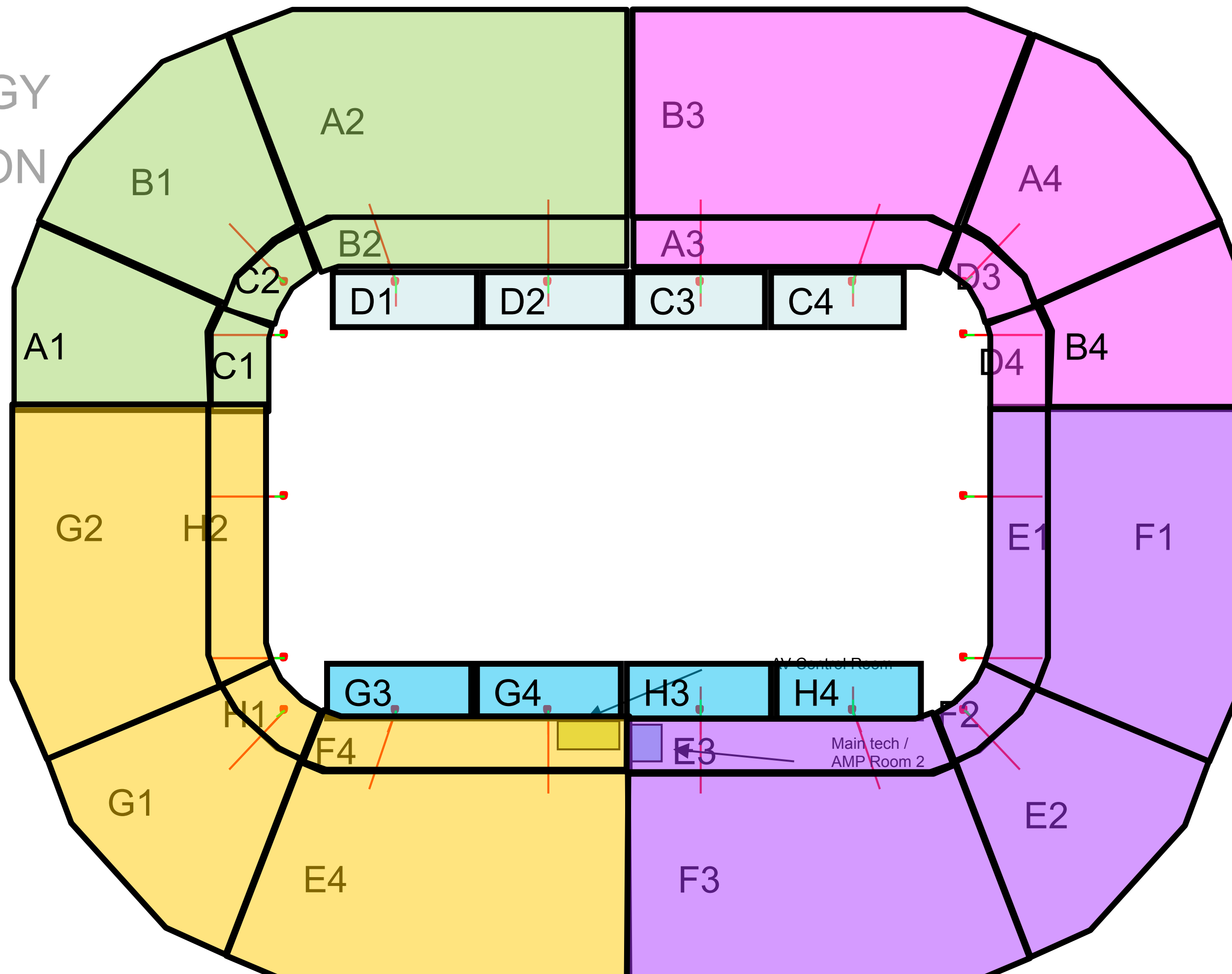
ARCHITECTURAL PLANS

MODELING

SYSTEM / TECHNOLOGY

EQUIPMENT SELECTION

RESULTS



GOOD ACOUSTICAL PERFORMANCE AND ZONING CRITERIA FULLFILLED!

X,# = Amplifier, Output

ARCHITECTURAL PLANS

MODELING

SYSTEM / TECHNOLOGY

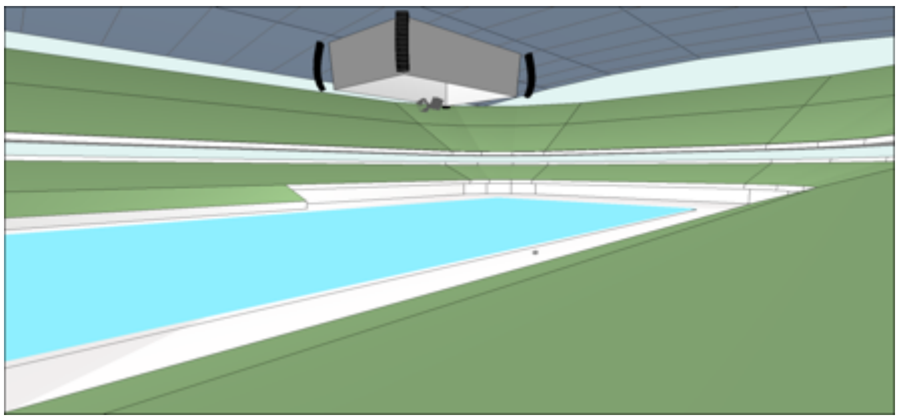
EQUIPMENT SELECTION

RESULTS

GOOD ACOUSTICAL PERFORMANCE AND ZONING CRITERIA FULLFILLED!

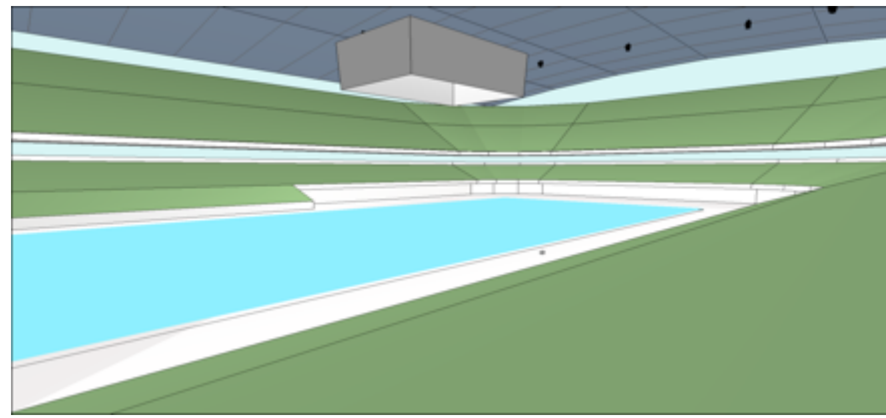
DOUBLE CHECK THE SUBJECTIVE PERFORMANCE USING AURALIZATION…

AURALIZATION EXAMPLE - AQUATIC



Line Array

PLAY STOP



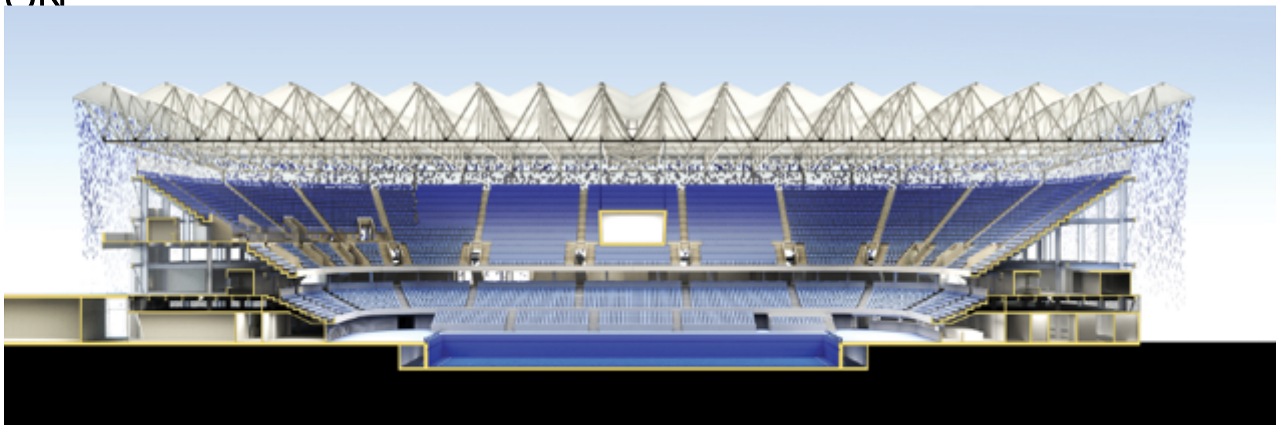
Point Source

PLAY STOP

SYSTEMS

DESIGN DEVELOPMENT

REVERBERATION



Aquatic Center

RT_{60} Simulation

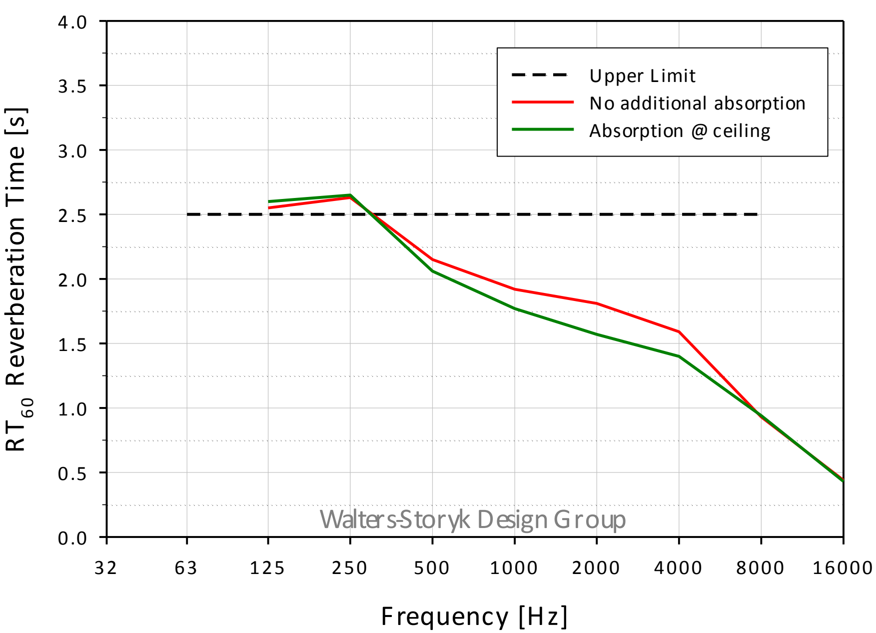


Tabela C11: Metas de Desempenho Preliminar de Audio/Video (PAVA

Espaço	Nível típico de funcionamento dB(A)	Nível máx. exigido dB(A)	STI (média - 1 desvio padrão)	Resposta de Frequência	Tempo de Reverberação T_{mf}(s)[1]
Áreas de Arquibancada da Arena	85 ±3	103	0.45	100Hz -12kHz ±5dB[2]	≤ 2.5

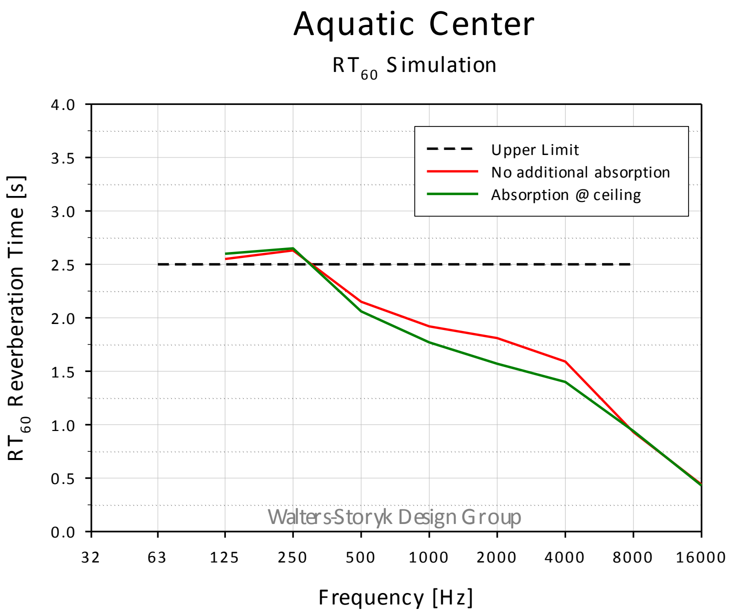
With the assumed (untreated) materialisation for the roof and an audience occupation of 100%, the RT_{60} times are mostly below the 2.5s threshold specified by the required standards.

Only at 125Hz and 250Hz the reverberation time is higher.

Adding mid-high frequency absorbers at the ceiling would bring down the reverberation time and increase Intelligibility.

Verify $ related!

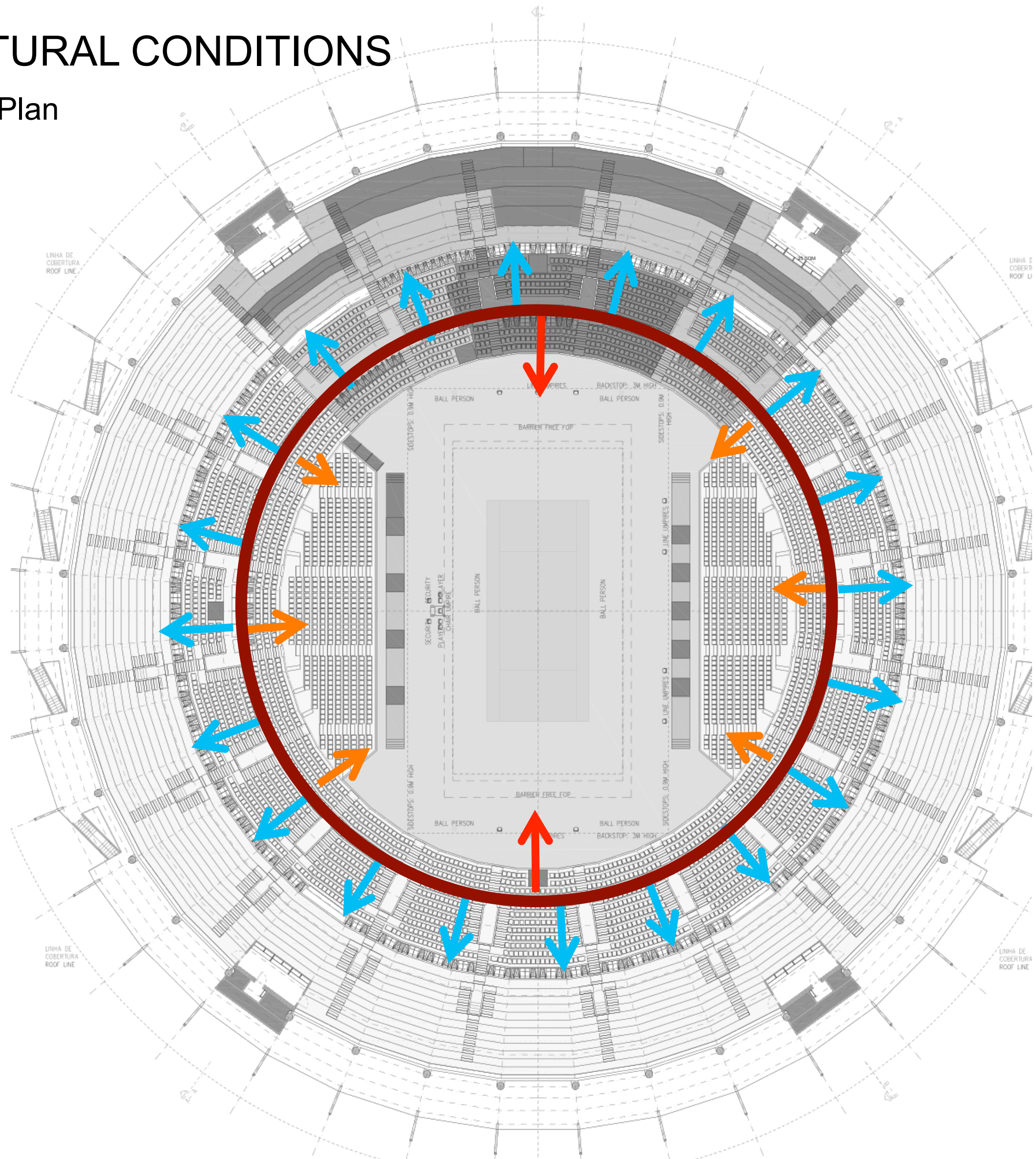
REVERBERATION



Stadia with occupied audience	*Simulated Reverberation Time RT60 in octave bands [s]*							
Stadium	*125*	*250*	*500*	*1k*	*2k*	*4k*	*8k*	*16k*
TEN01, Center Court	2,0	2,0	2,0	1,9	1,8	1,4	0,8	0,3
TEN02, Court 1 (5000)	1,1	1,2	1,2	1,2	1,2	1,1	0,7	0,3
TEN03, Court 2 (3000)	1,0	1,1	1,1	1,1	1,1	1,0	0,6	0,4
Maracanã Stadium	4,8	4,6	4,3	3,8	3,0	1,9	0,9	0,3
Mineirão - no treatment	6,8	5,7	4,4	3,6	3,1	1,3	1,0	0,4
Mineirão - absorptive	6,5	5,1	3,6	3,1	2,5	1,2	1,0	0,4

ARCHITECTURAL / STRUCTURAL CONDITIONS

RIO 2016 – Tennis 01 – Schematic Plan



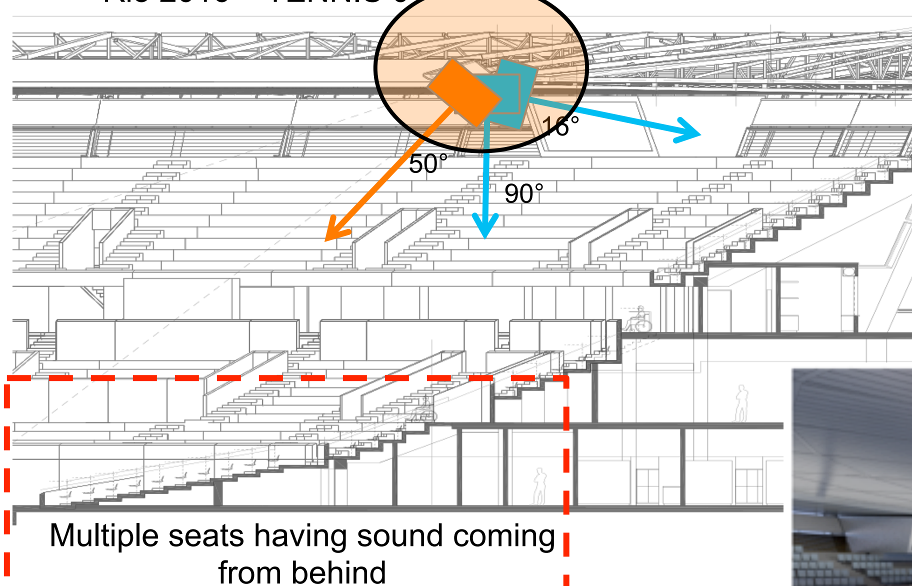
MAIN CLUSTERS

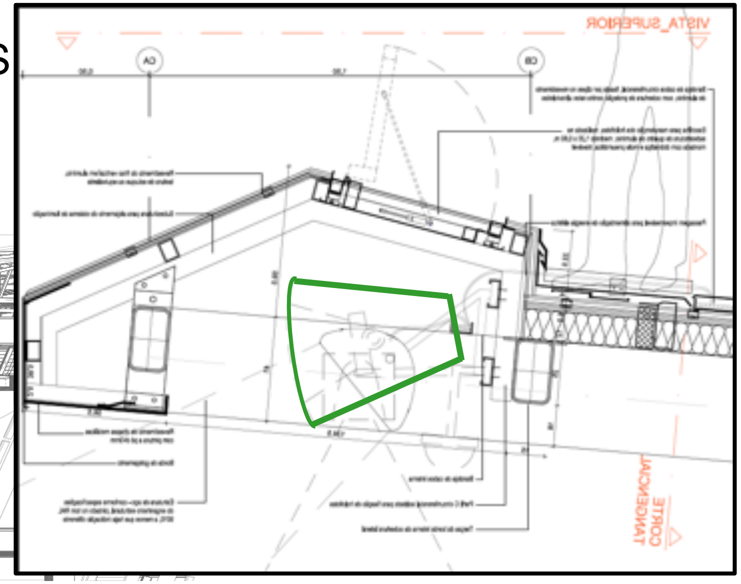
DOWN FILL

FIELD OF PLAY (FOP)

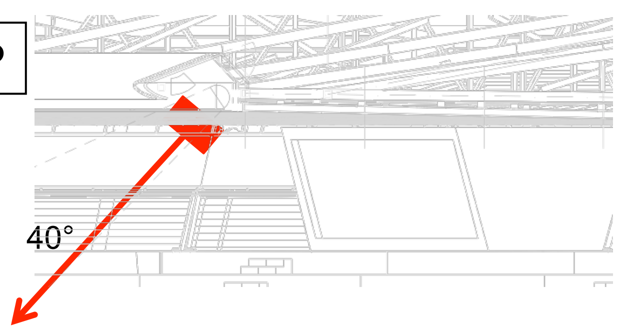
ARCHITECTURAL / STRUCTURAL CONDITIONS

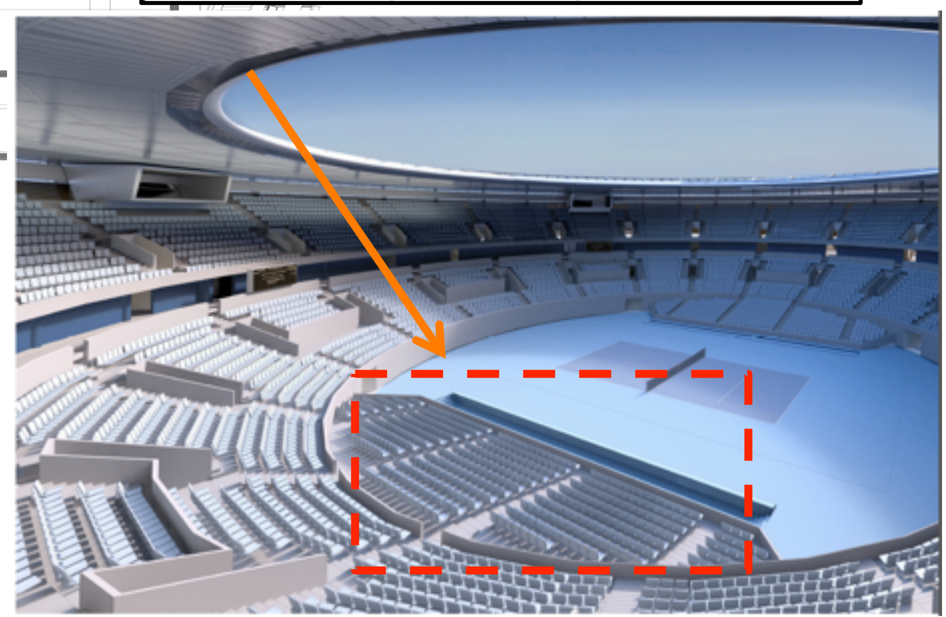
Rio 2016 – TENNIS 01



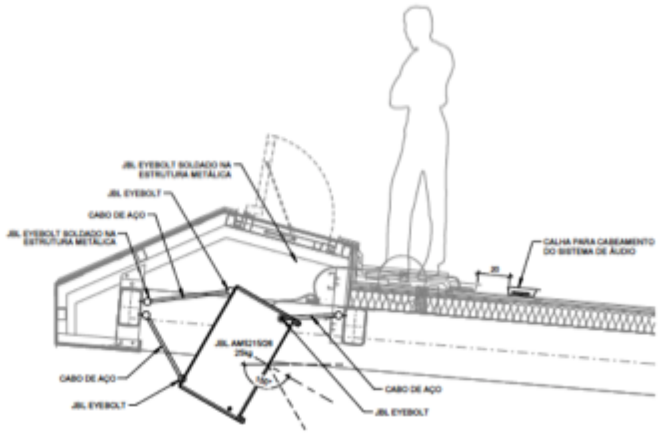


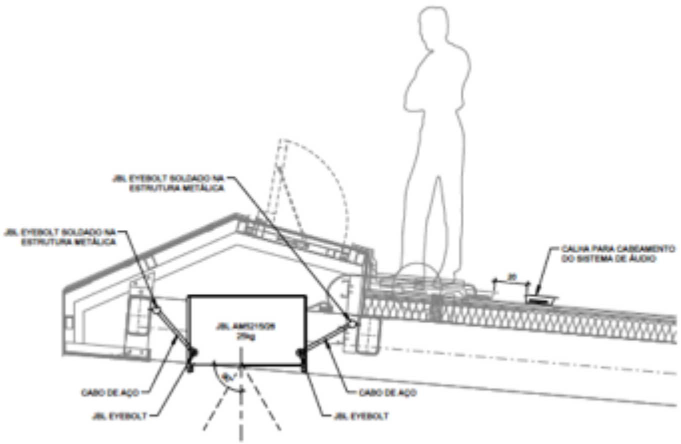
FOP

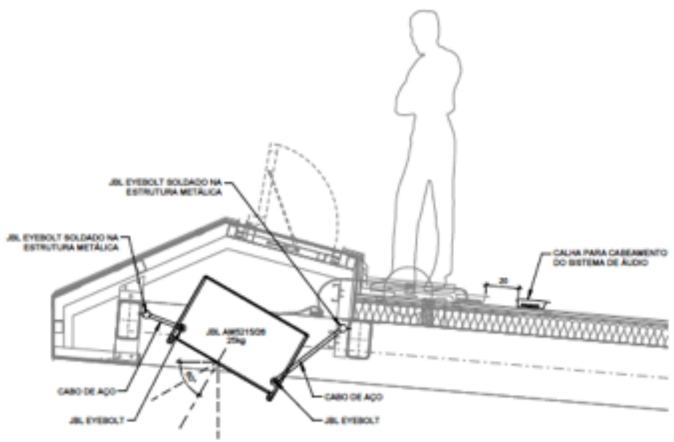


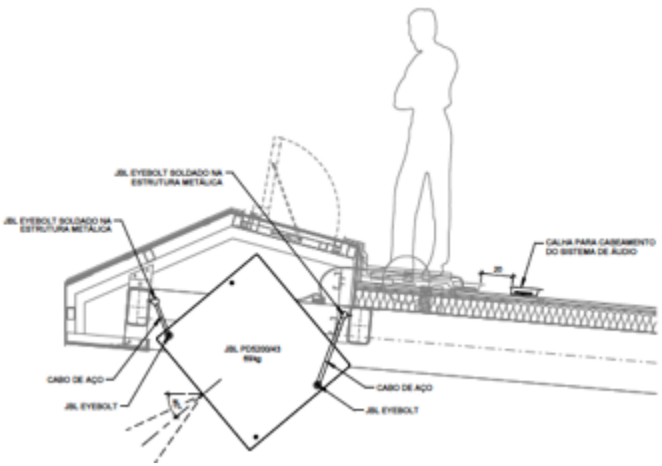


ARCHITECTURAL / STRUCTURAL CONDITIONS





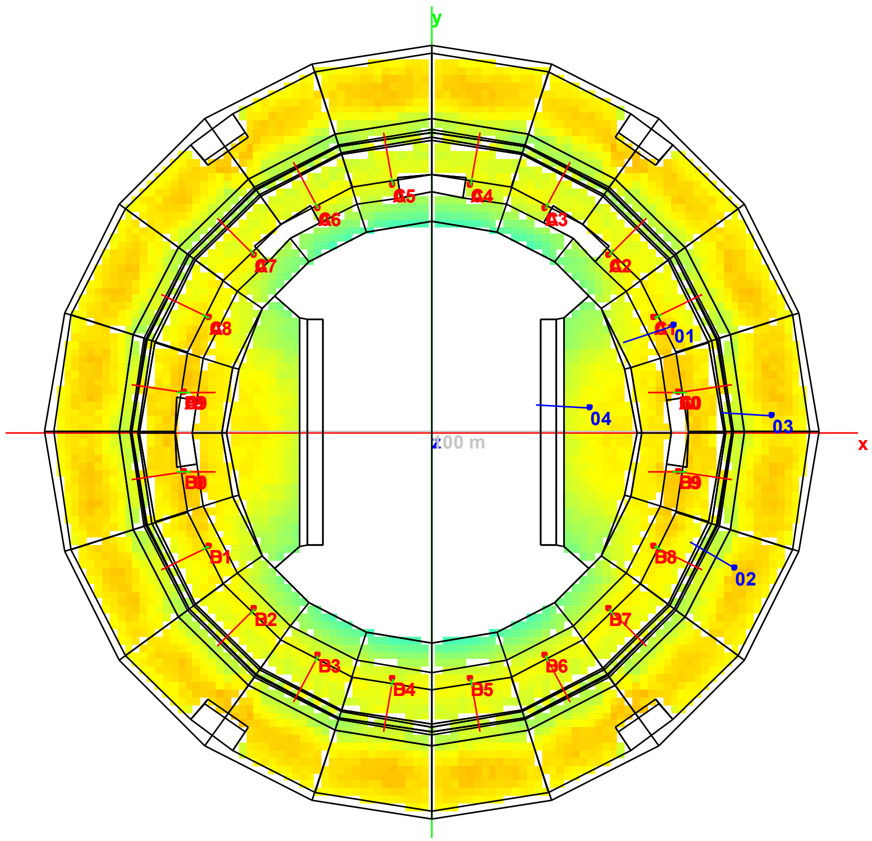


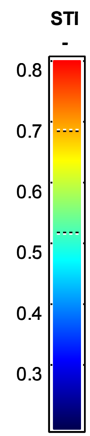


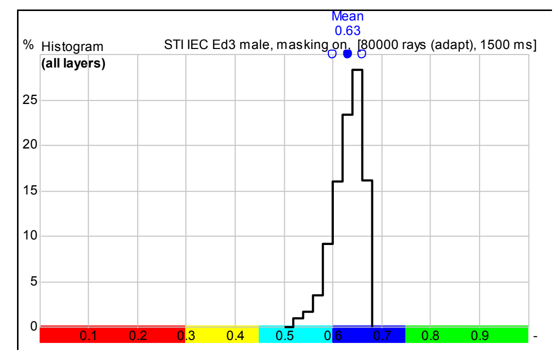
STI VALUES

RIO 2016 – TENNIS 01

STI (EXACT VALUES)





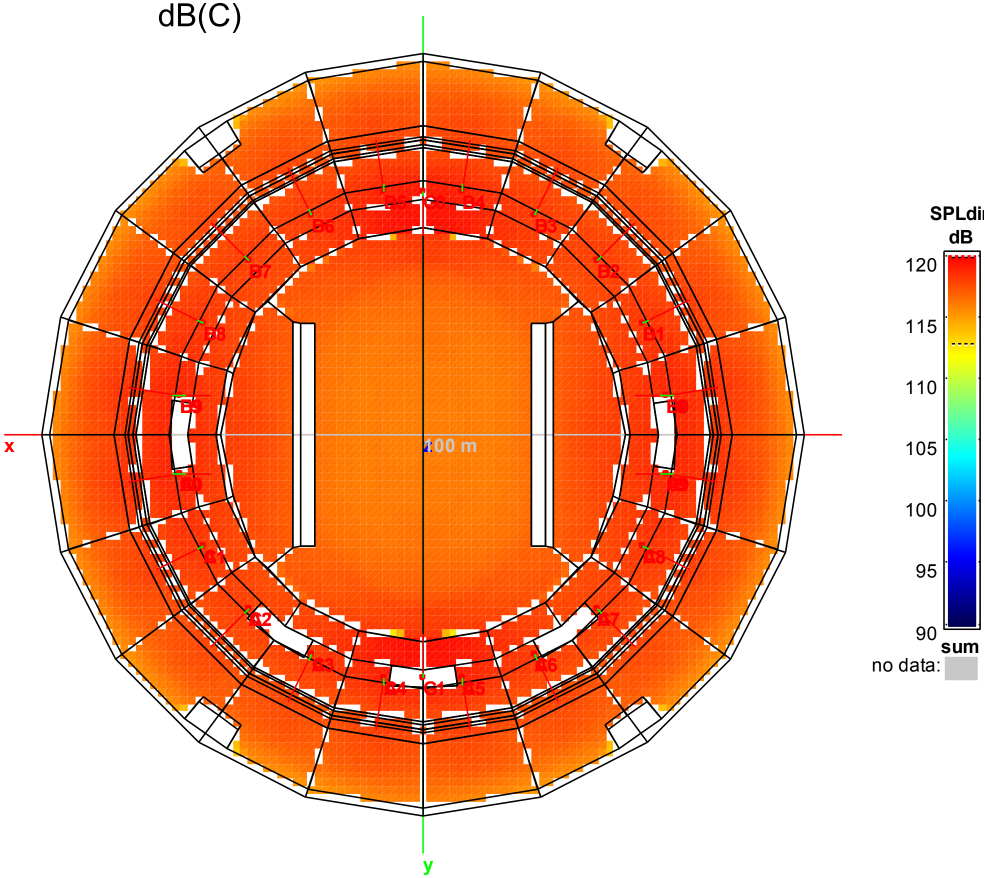


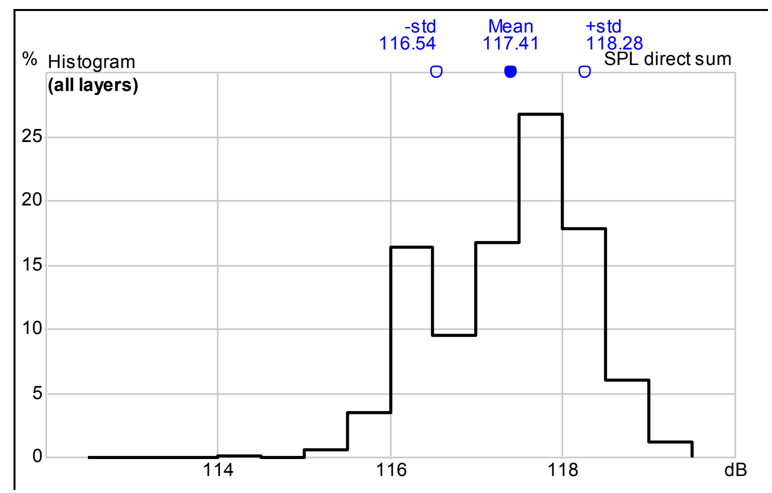
Averange STI of 0.63. Mean – Std = 0.6
No seats in the simulated area are lower than STI 0.5

STI
VALUES

RIO 2016 – TENNIS 01

dB(C)



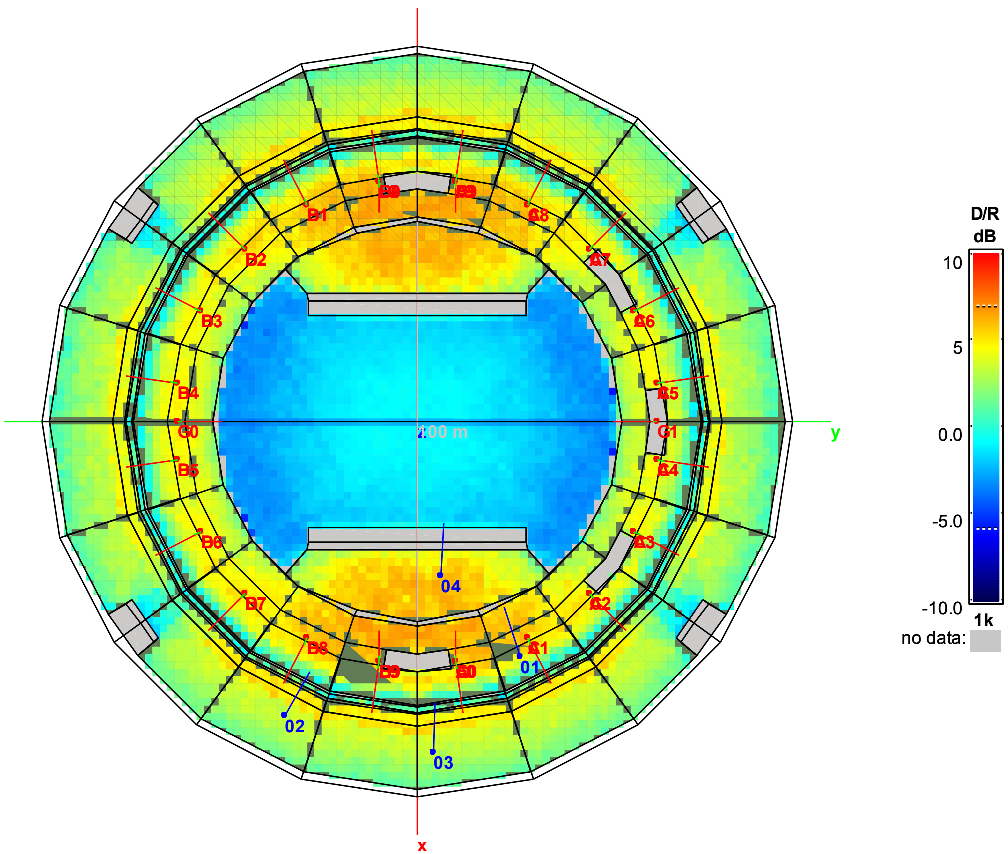


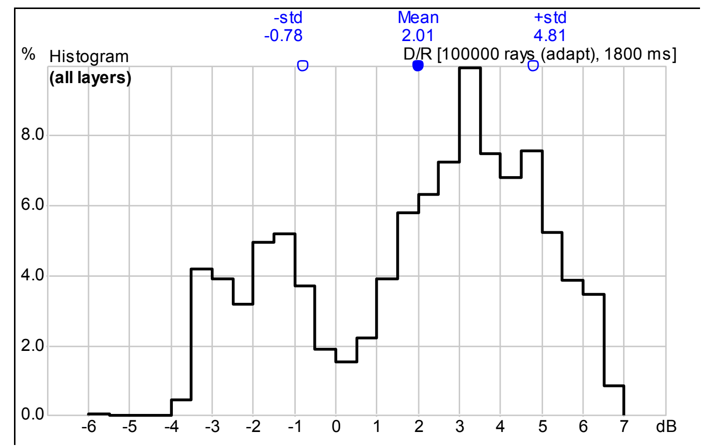
Uniform SPL coverage with 2.0dB deviation. Average SPL is 117dB(C)

STI VALUES

RIO 2016 – TENNIS 01

D/R DIRECT / REVERBERANT

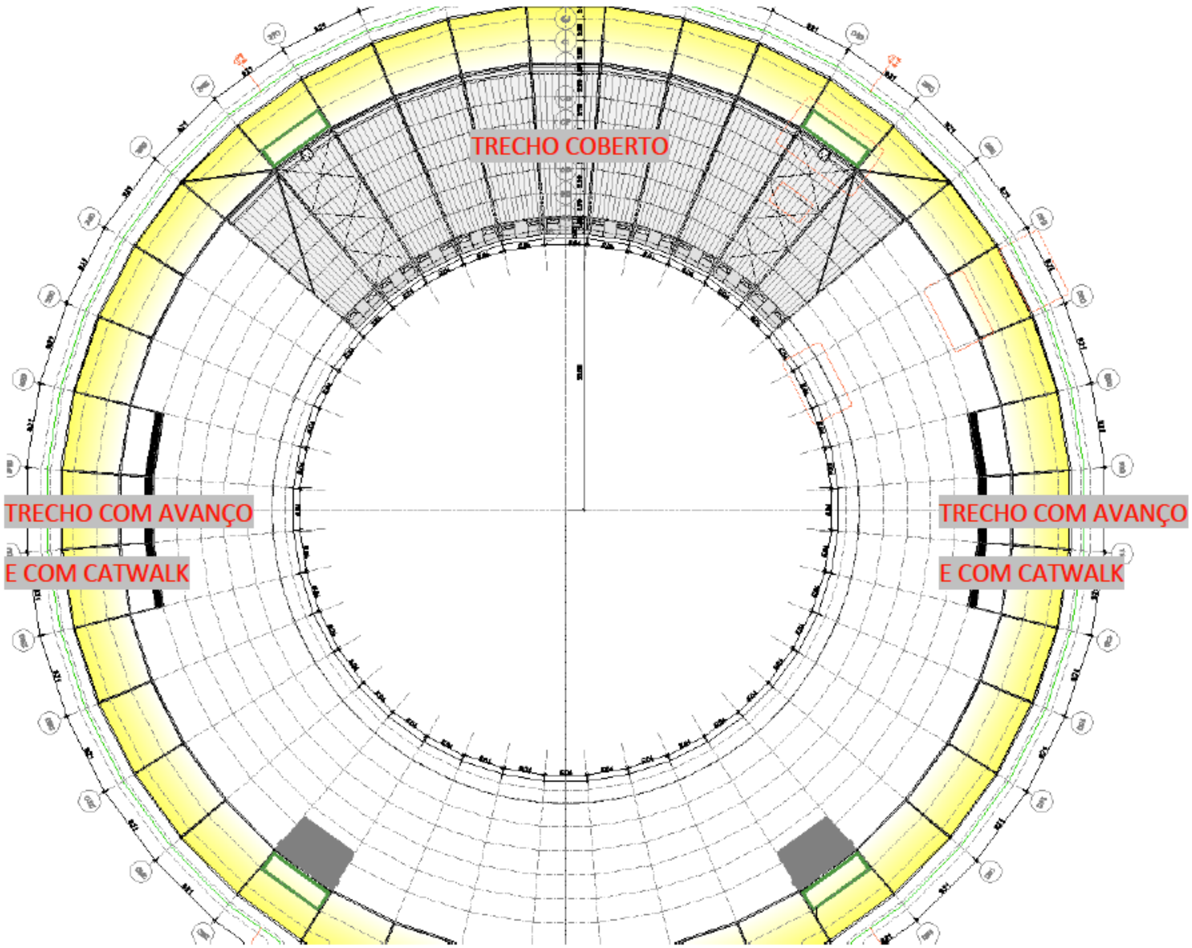




D/R is positive, specialy at the ranks.
More direct sound reaches the listening positions compared to the reflected sound in the Arena.

STI
VALUES
RIO 2016 – TENNIS 01

Things Change!
new architecture



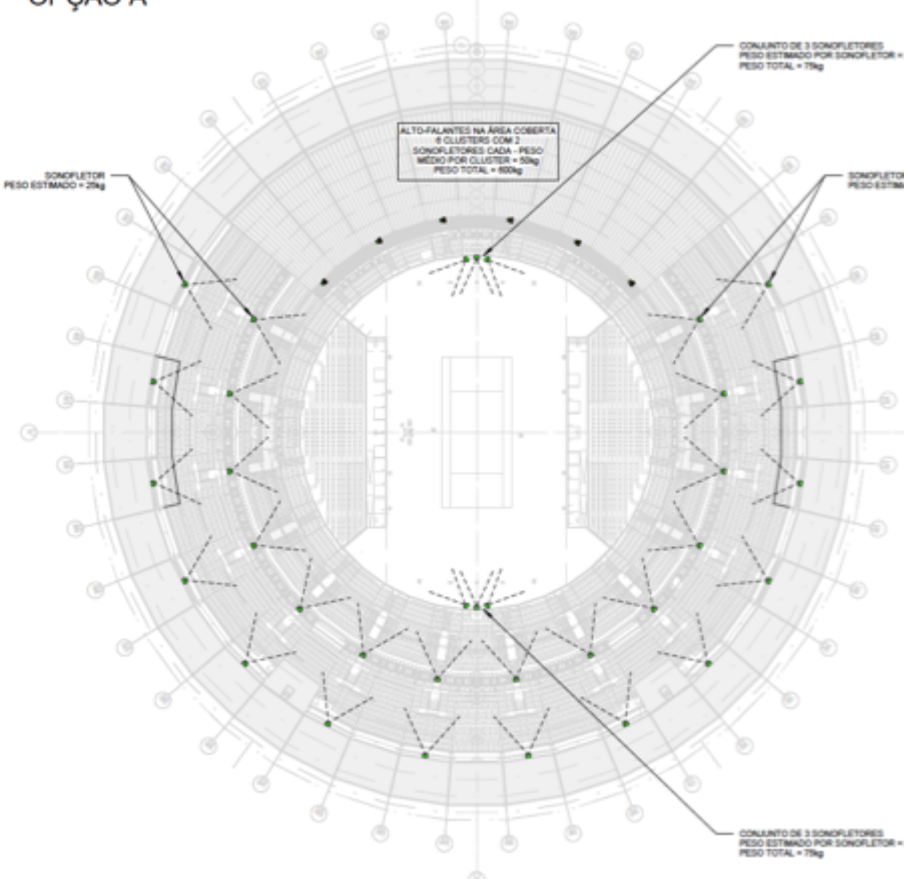
SYSTEMS

DESIGN DEVELOPMENT

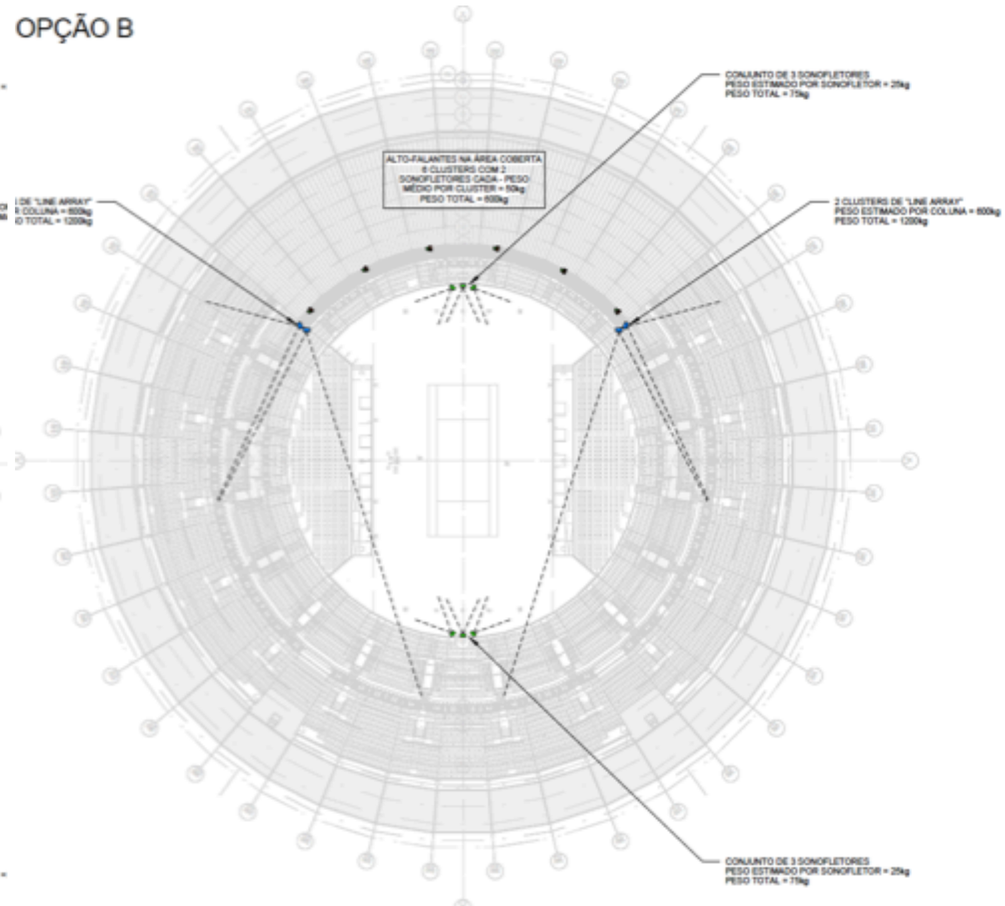
STI
VALUES
RIO 2016 – TENNIS 01

<u>Things Change!</u>
<u>a few weeks ago.....</u>

OPÇÃO A



OPÇÃO B



SYSTEMS

TOPOLOGY

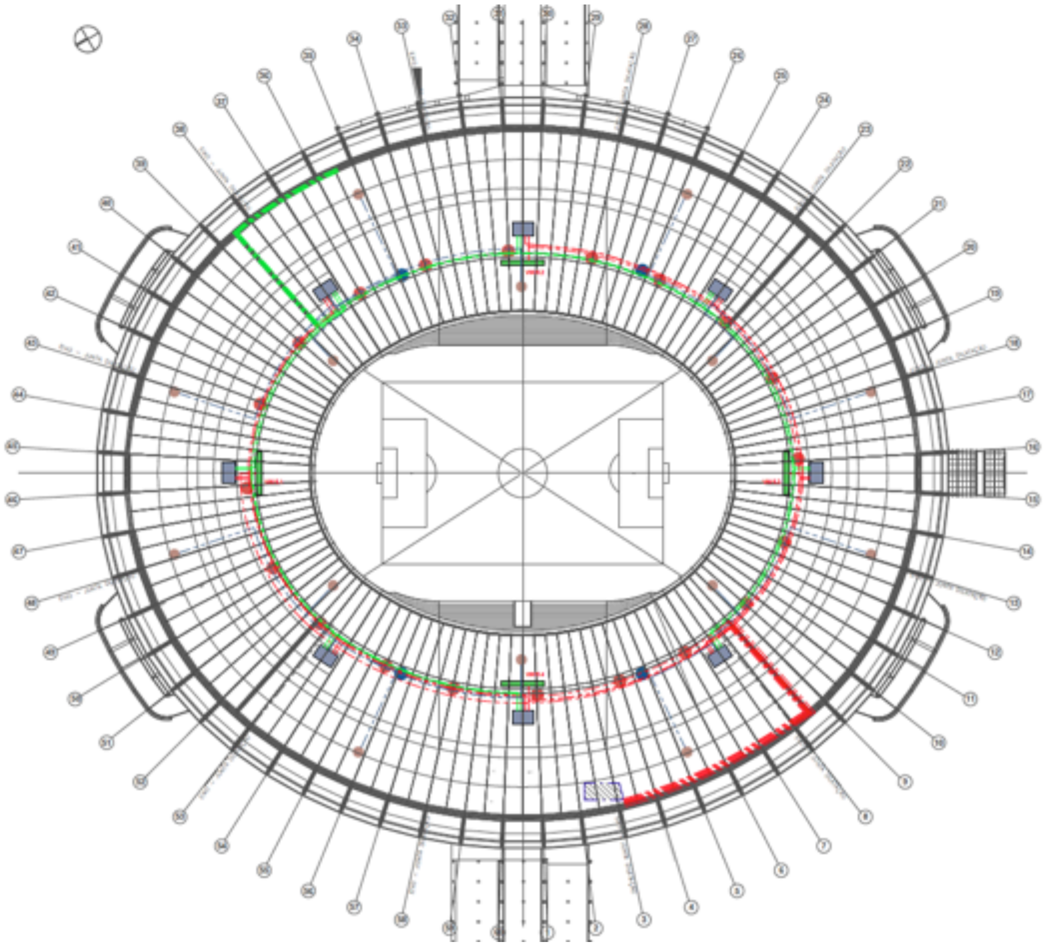
AFTER ELECTROACOUSTICS HAS BEEN DEFINED...

START INTERACTION WITH ARCHITECTURAL PROGRAM…AND OTHER DISCIPLINES

- AMP ROOMS
- DISTRIBUTION PATH
- TECHNICAL ROOMS
- CONTROL ROOM

MARACANÃ
ROOF PLAN

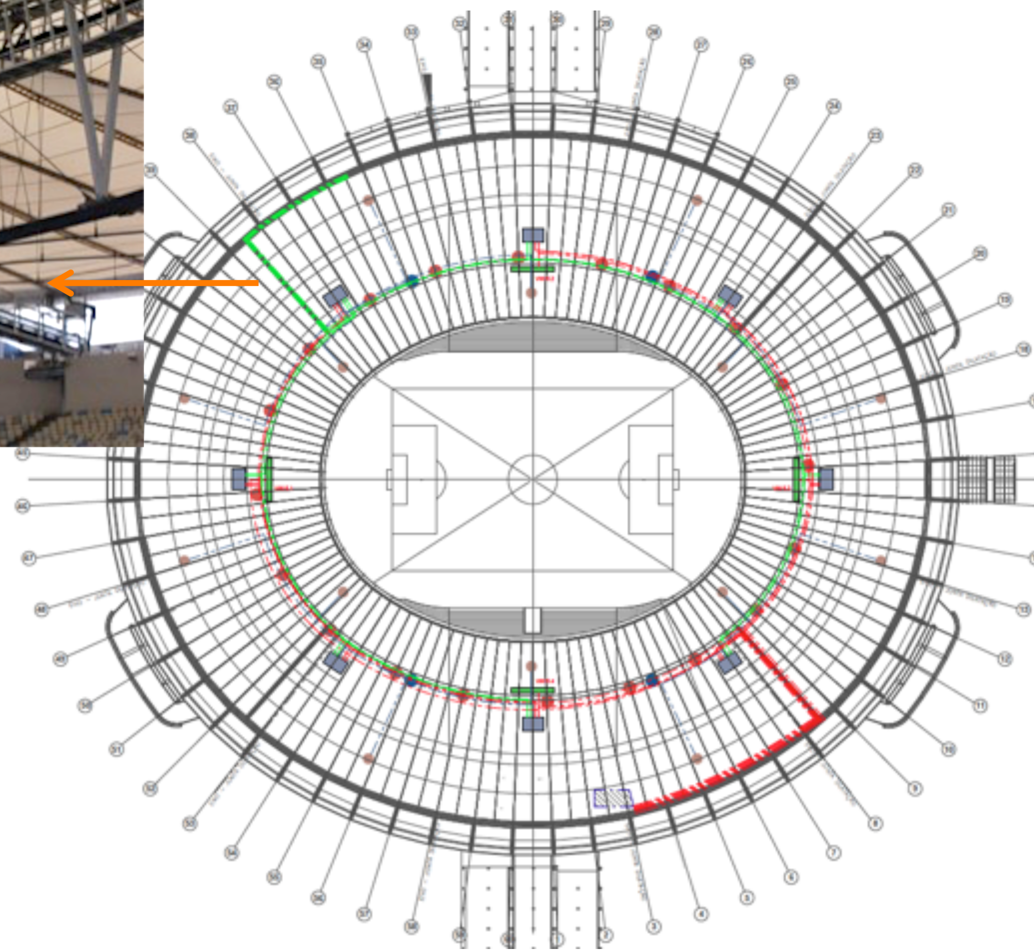
SPEAKER LOCATION



SYSTEMS

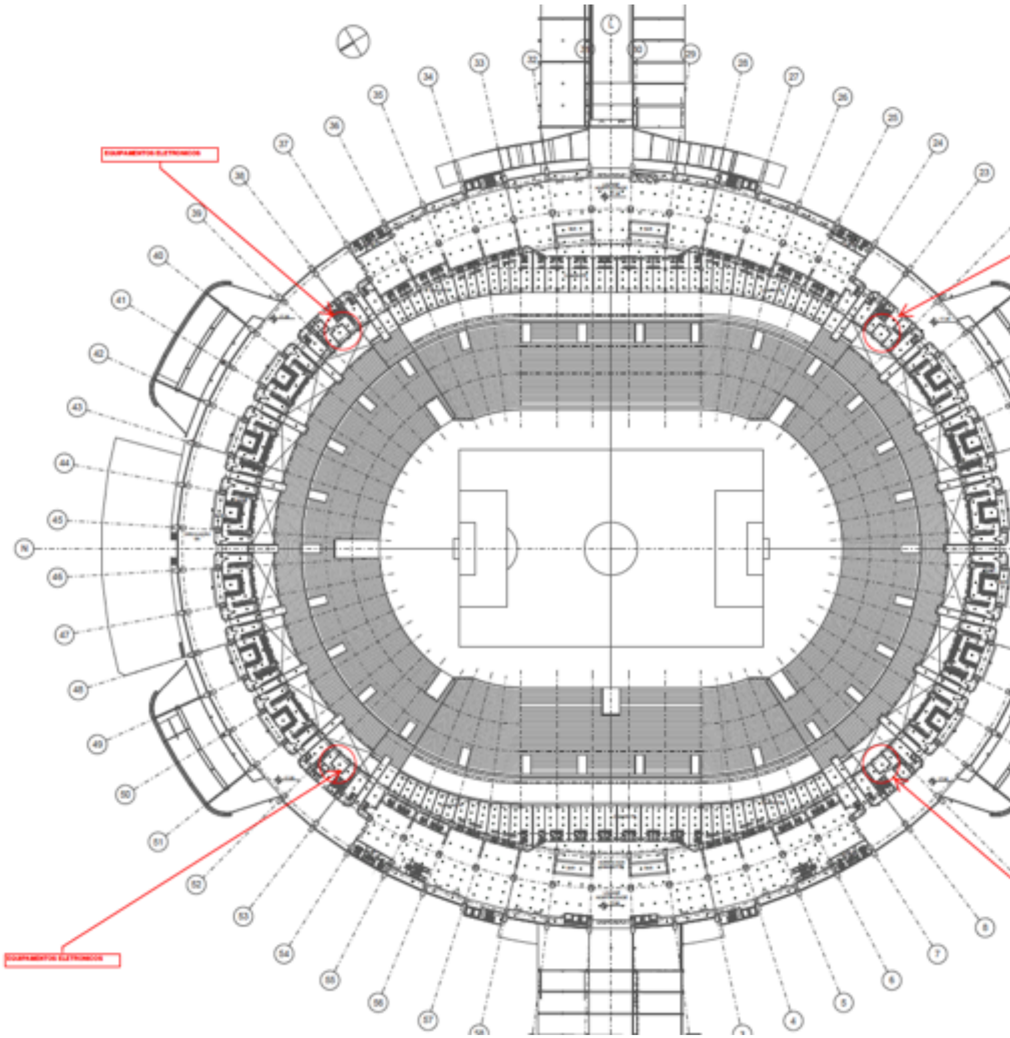
TOPOLOGY

MARACANÃ
ROOF PLAN



DISTRIBUTION PATH

MARACANÃ
TECHNICAL ROOMS

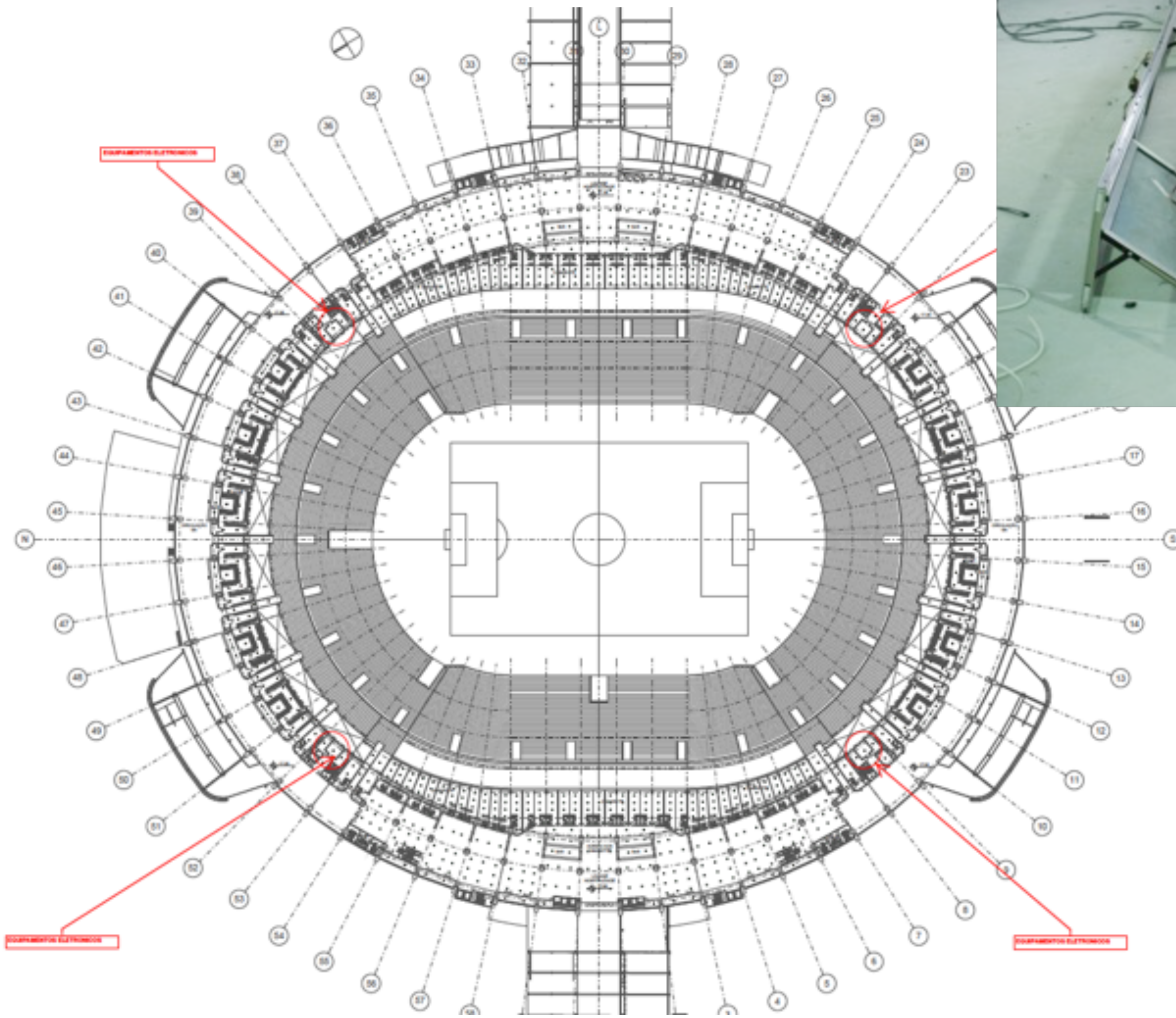


4.000 ceiling speakers!

SYSTEMS

TOPOLOGY

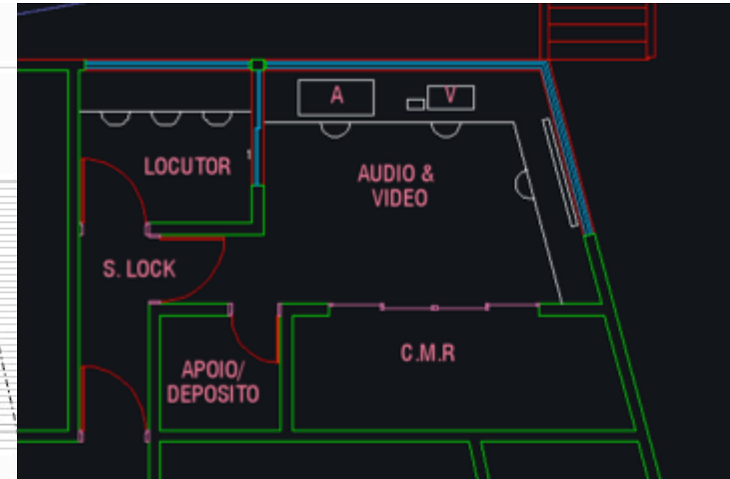
MARACANÃ
TECHNICAL ROOMS



ETHERNET BACKBONE ON FIBER REQUIRED DUE TO LARGE DISTANCES.

SELECTION OF SUITABLE AUDIO DISTRIBUTION NETWORK.

MARACANÃ
CONTROL ROOM DETAIL

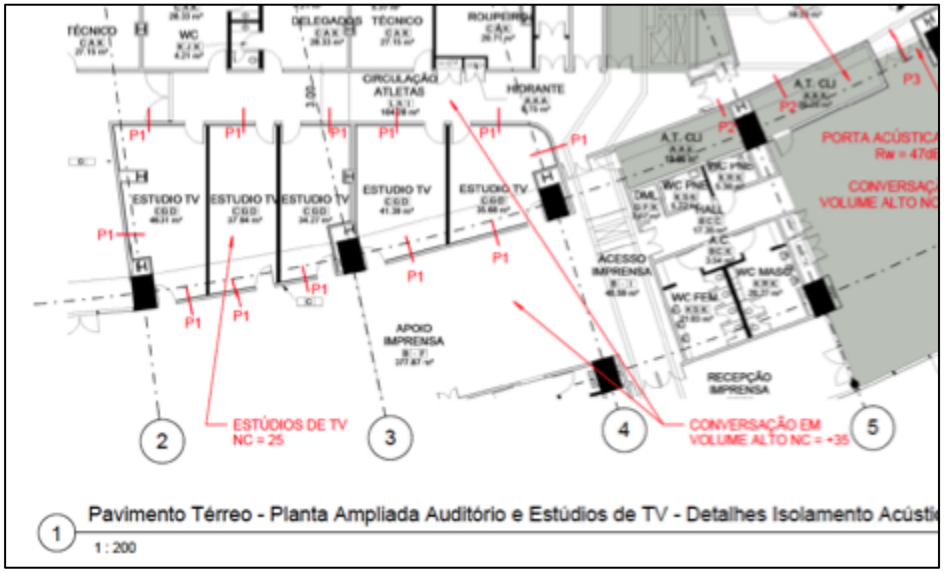


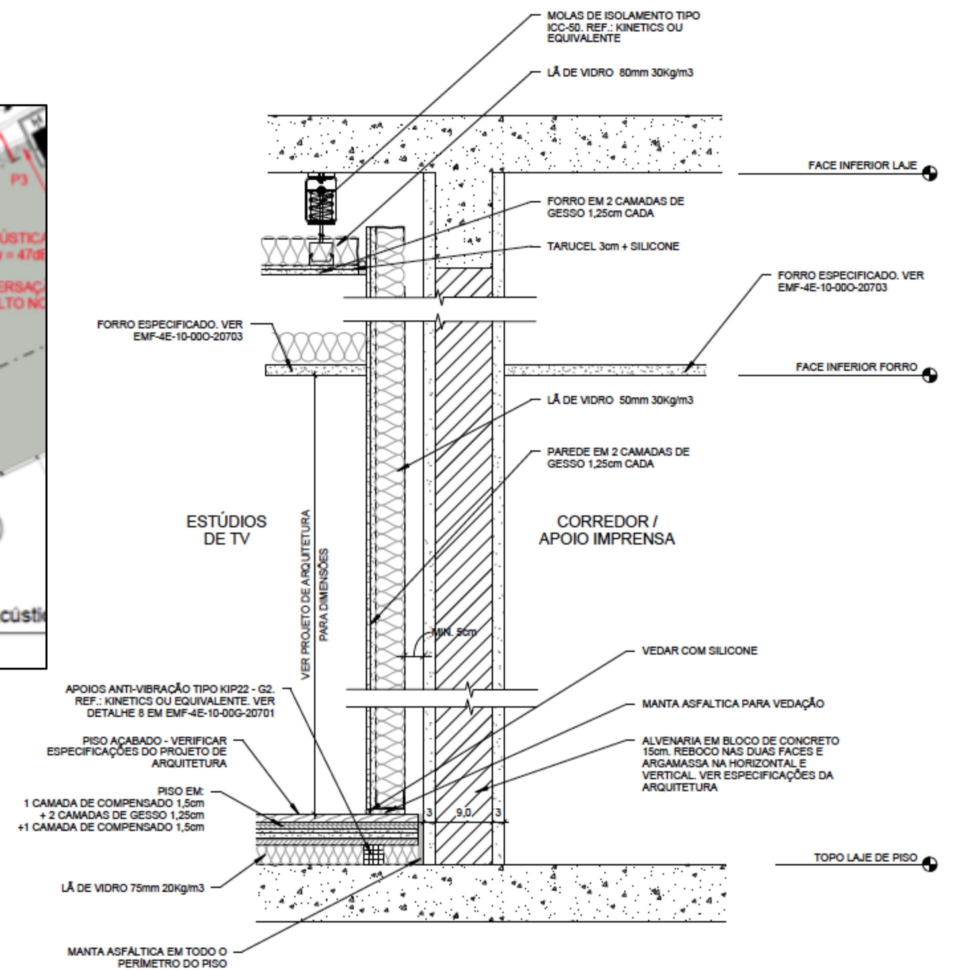
- ACOUSTICAL REQUIREMENTS
- SPACE REQUIREMENTS
- VIEW TO THE FIELD

SYSTEMS

TOPOLOGY

MARACANÃ
ACOUSTICAL REQUIREMENTS





3 Partição Tipo 1
1 : 10

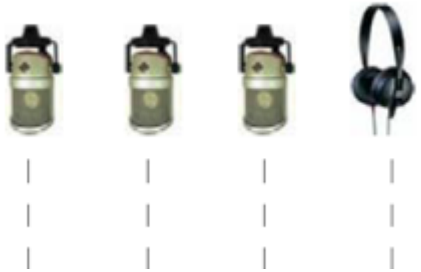
NOTA:
PARA PENETRAÇÕES DE DUTOS DE AR CONDICIONADO, ELETRODUTOS, ELETROCALHAS E SPRINKLERS EM PARTIÇÕES ACÚSTICAS VER DETALHES TÍPICOS EM EMF-4E-10-00G-20701

PROGRAM SOURCES:

ANNOUNCER / MEDIA CONTENT

PAGING / SECURITY MESSAGES

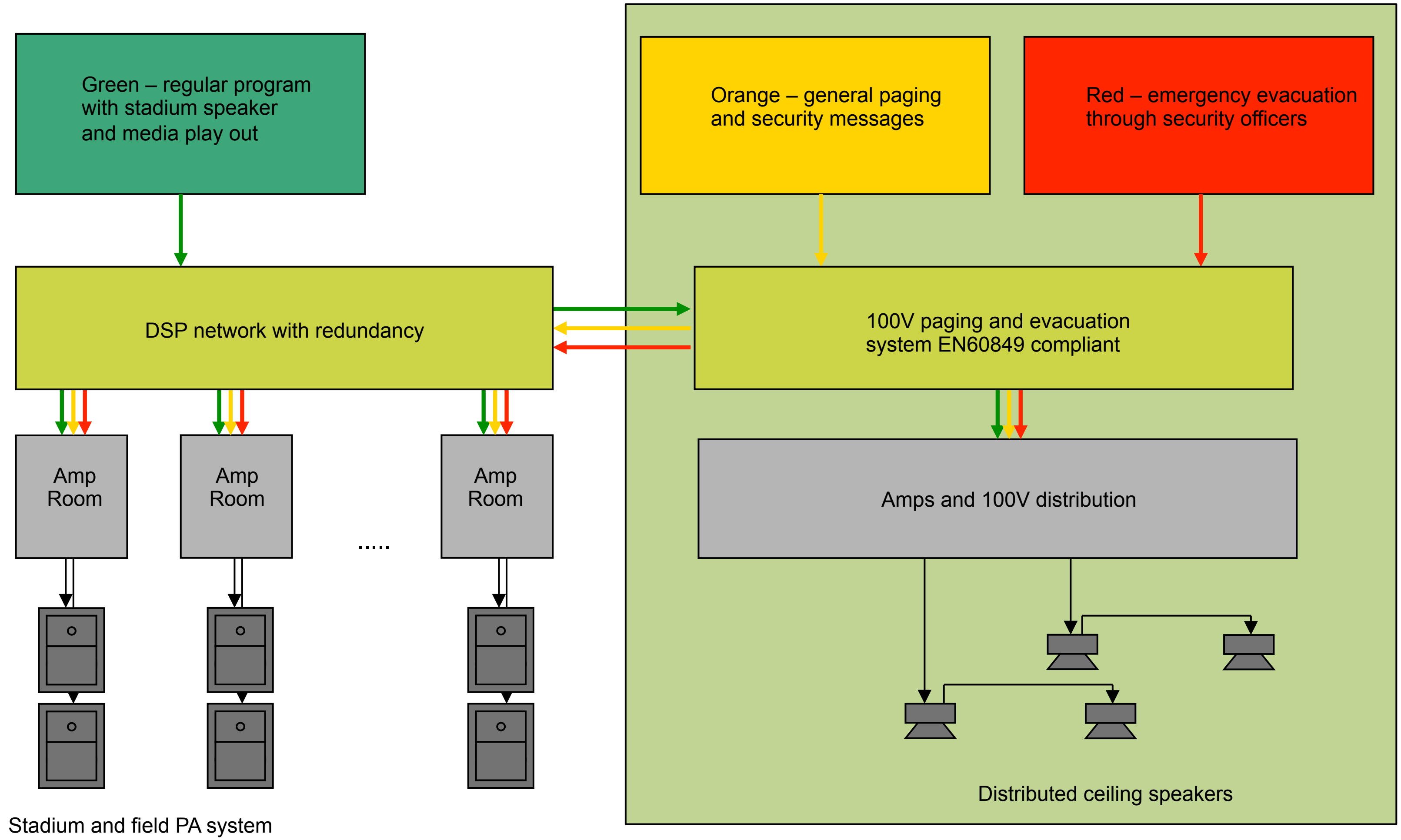
EMERGENCY EVACUATION



SYSTEMS

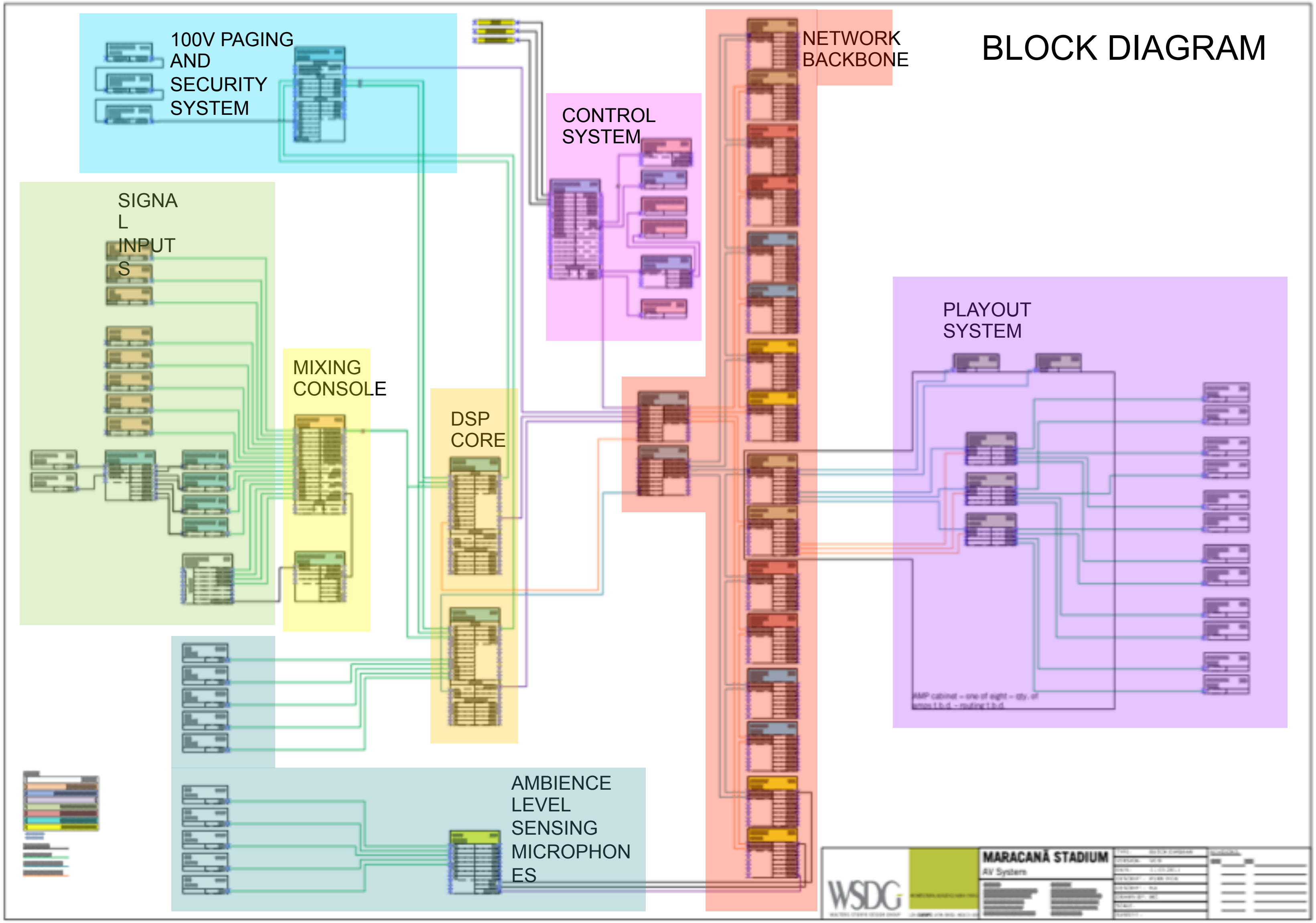
SIGNAL MANAGEMENT

SCHEMATIC DIAGRAM



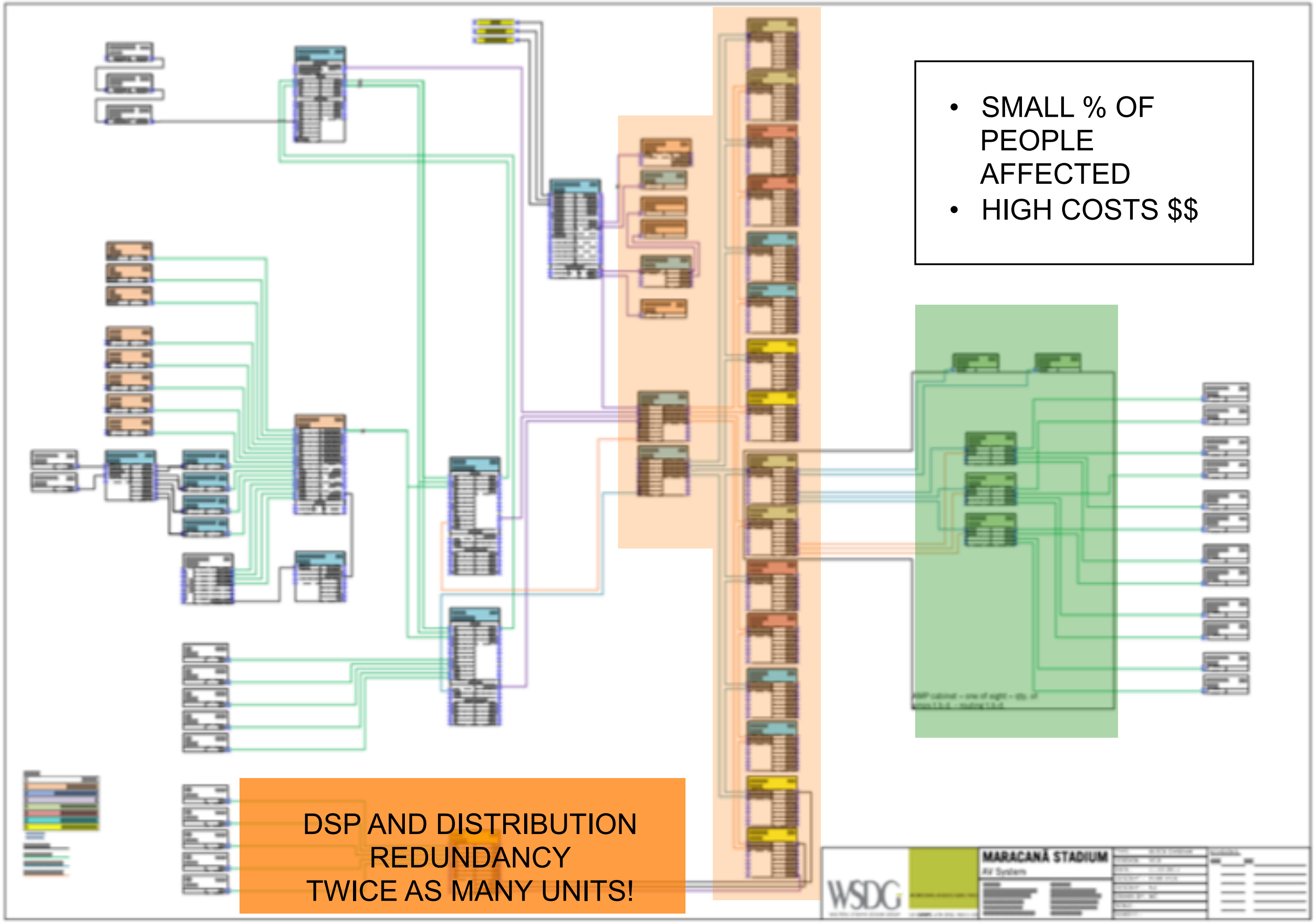
SYSTEMS

SIGNAL MANAGEMENT



REDUNDANCY

MARACANÃ – BLOCK DIAGRAM



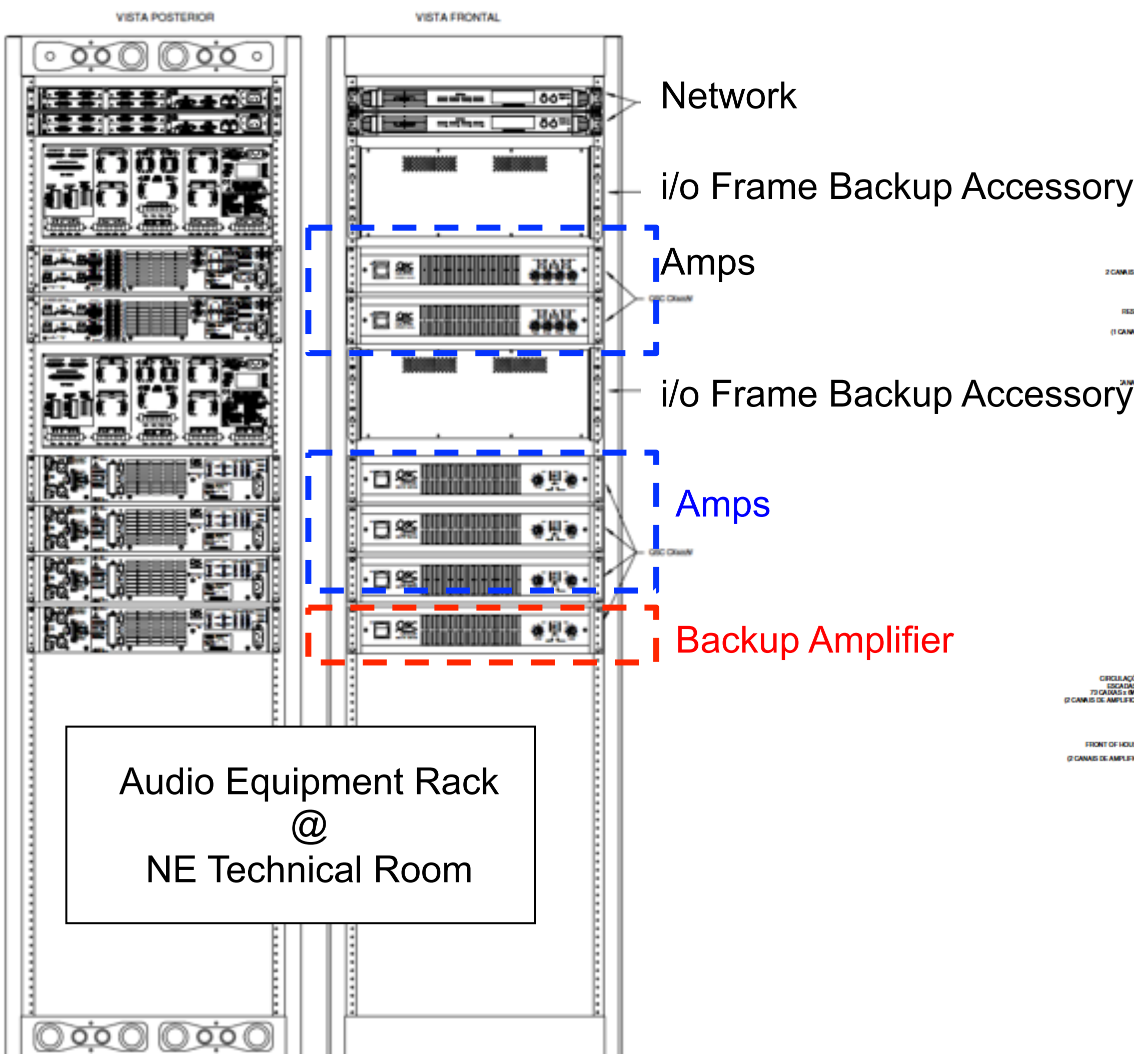
- SMALL % OF PEOPLE AFFECTED
- HIGH COSTS $$

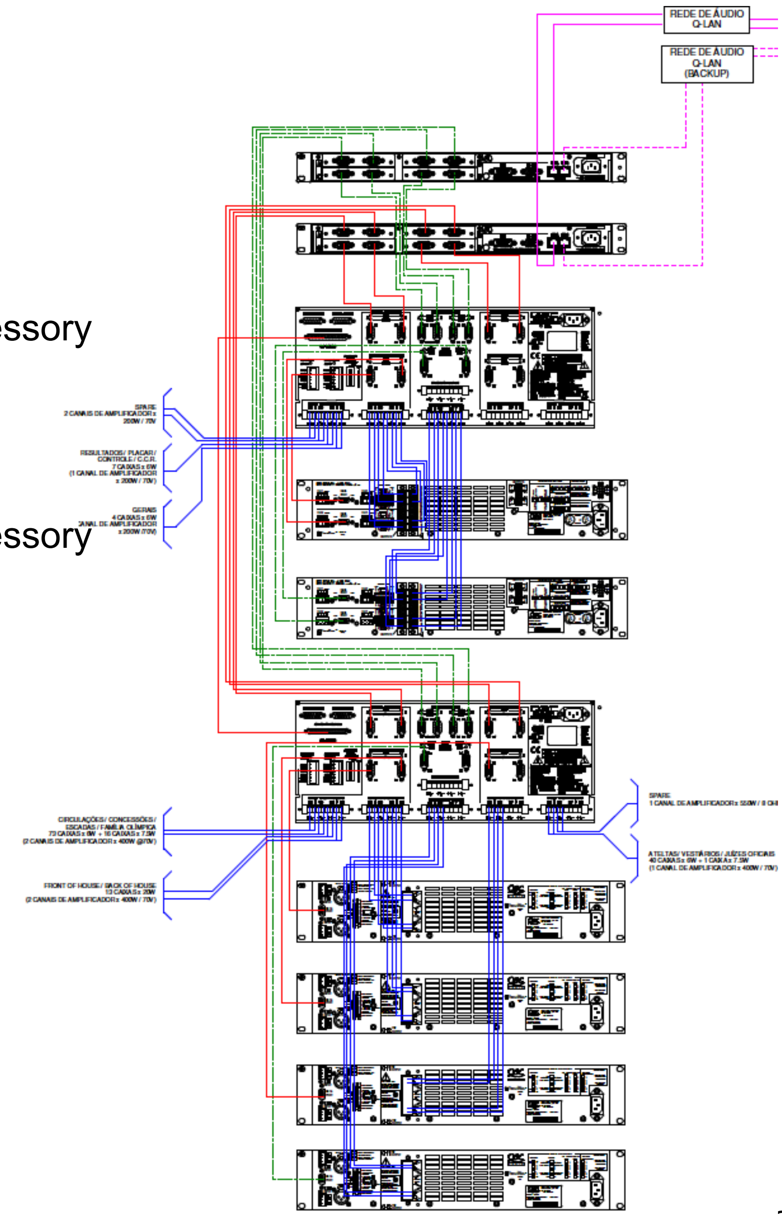
SYSTEMS

REQUIREMENTS - USE

REDUNDANCY

RIO 2016 Tennis and Aquatic Arenas



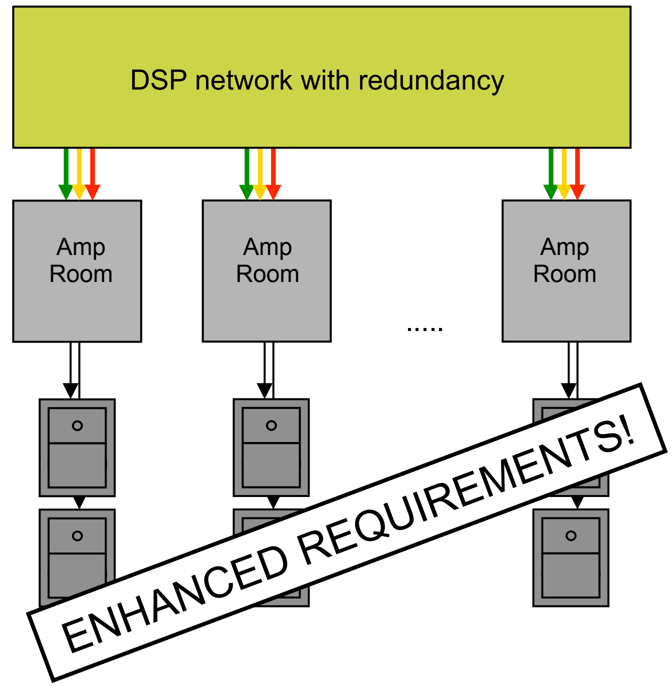


SECURITY

VOICE ALARM

COMPLIANCE TO REGULATIONS !

- EN 60849
- EN 54
- NFPA 72



- AMPLIFIER SUPERVISION
- LOAD MONITORING
- AUDIO NETWORK STATUS
- FAULT REPORTING

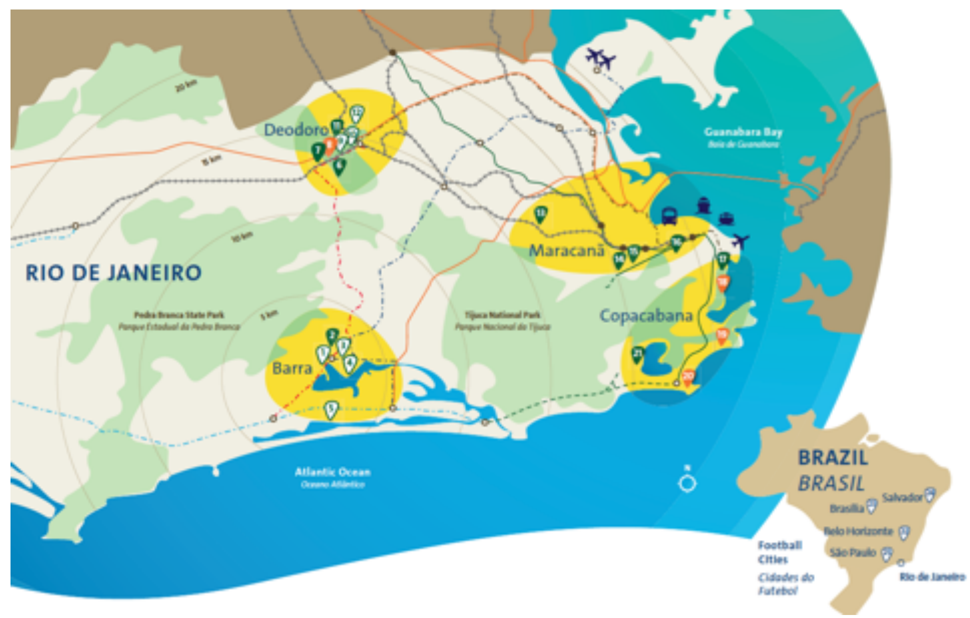
SYSTEM CONFIGURATION NEEDS COORDINATION WITH SECURITY PROCEDURES!

SYSTEMS

REGULATIONS

SECURITY

- AMPLIFIER SUPERVISION
- LOAD MONITORING
- AUDIO NETWORK STATUS
- FAULT REPORTING



STI SIMULATIONS

MARACANÃ STADIUM

SIMULATION STUDIES

POINT SOURCE x LINE ARRAY

MARACANÃ STADIUM
SOUND PRESSURE LEVELS (SPL)

Measured SPL Levels at football game:
Inside Stadium in Audience Area **94dB(A)** **110dB(C)**

The Speech intelligibility (STI) will not suffer if the SPL of the sound system is 6dB higher than the ambience noise.

Required SPL for Soundsystem in Audience Area **105dB(A)** **119dB(C)**

SYSTEMS

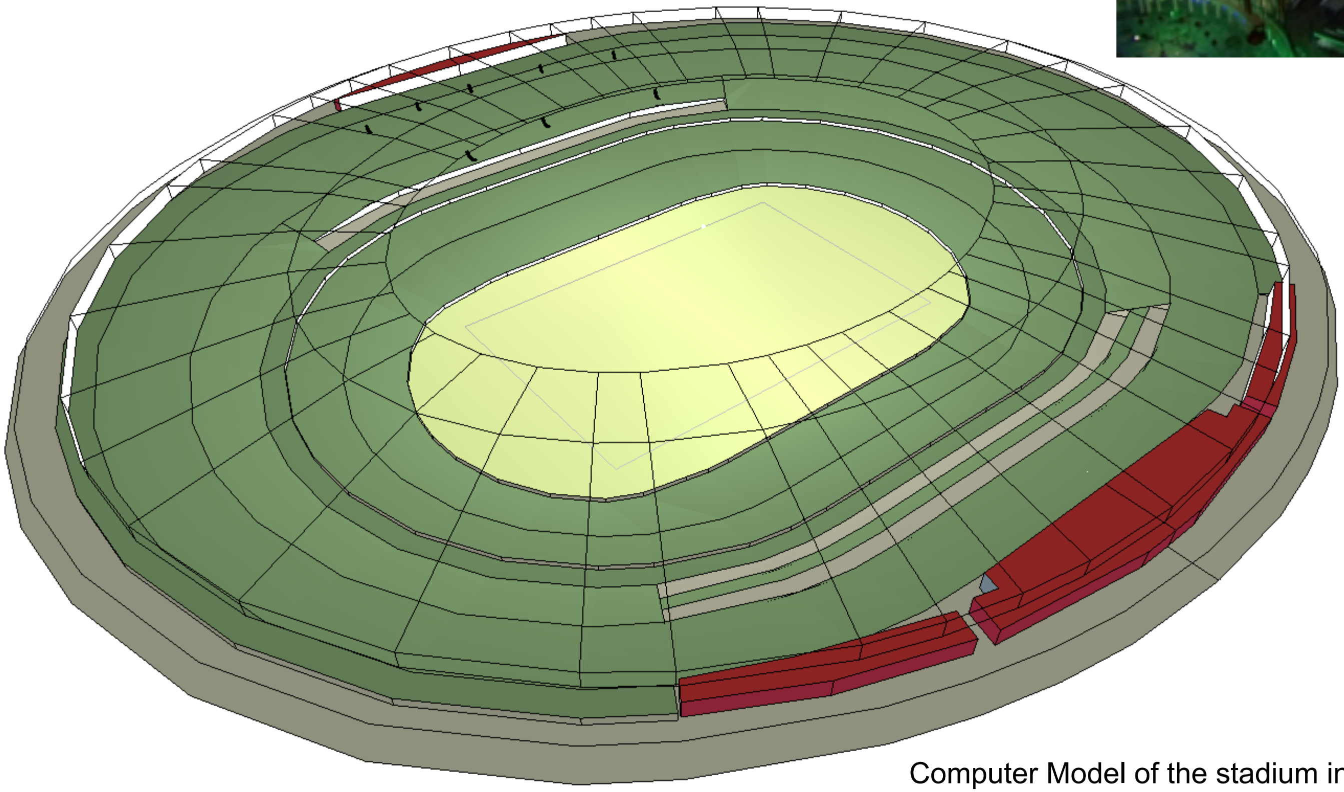
REQUIREMENTS - USE

STI SIMULATIONS

MARACANÃ STADIUM

SIMULATION STUDIES

POINT SOURCE x LINE ARRAY



Computer Model of the stadium including new roof

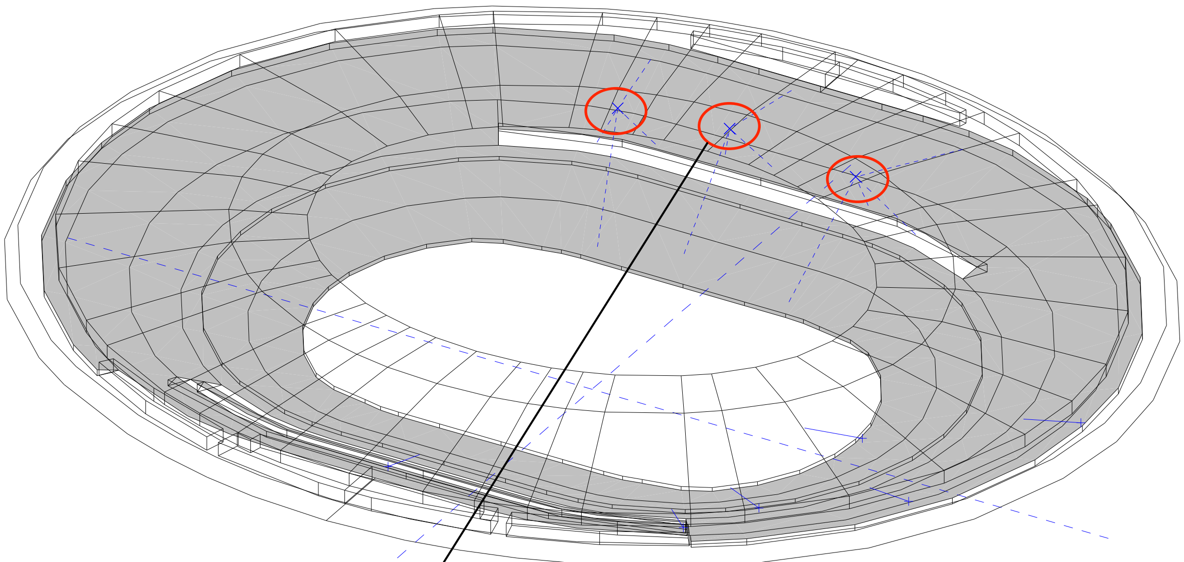
SYSTEMS

REQUIREMENTS - USE

STI SIMULATIONS

SYSTEM A – DEVELOPMENT

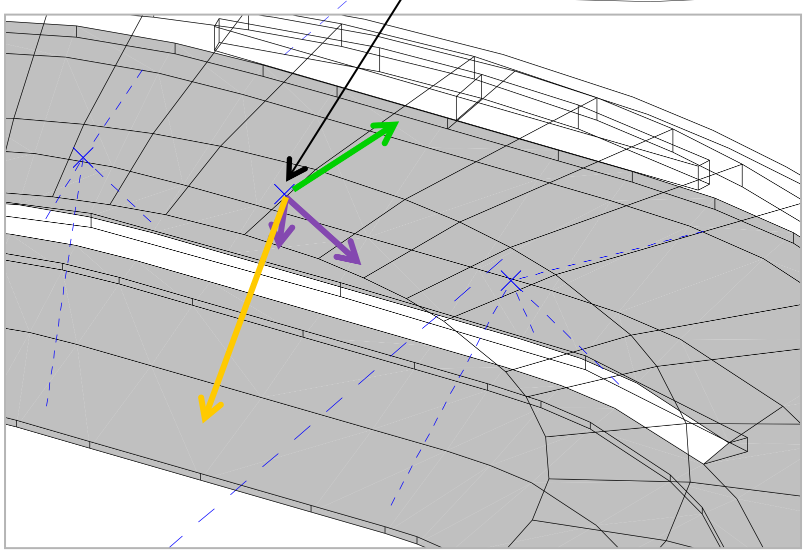
PA System mounted at the catwalk position consisting of point sources.



Three Clusters consisting of four speakers each:

1. Lower Ranks
2. Middle Ranks left
3. Middle Ranks right
4. Upper Ranks

Cluster one and two are closer together than cluster two and three in order to determine the coverage and therefore the necessary distance between clusters horizontally.



1. **Lower Ranks**
2. **Middle Ranks left**
3. **Middle Ranks right**
4. **Upper Ranks**

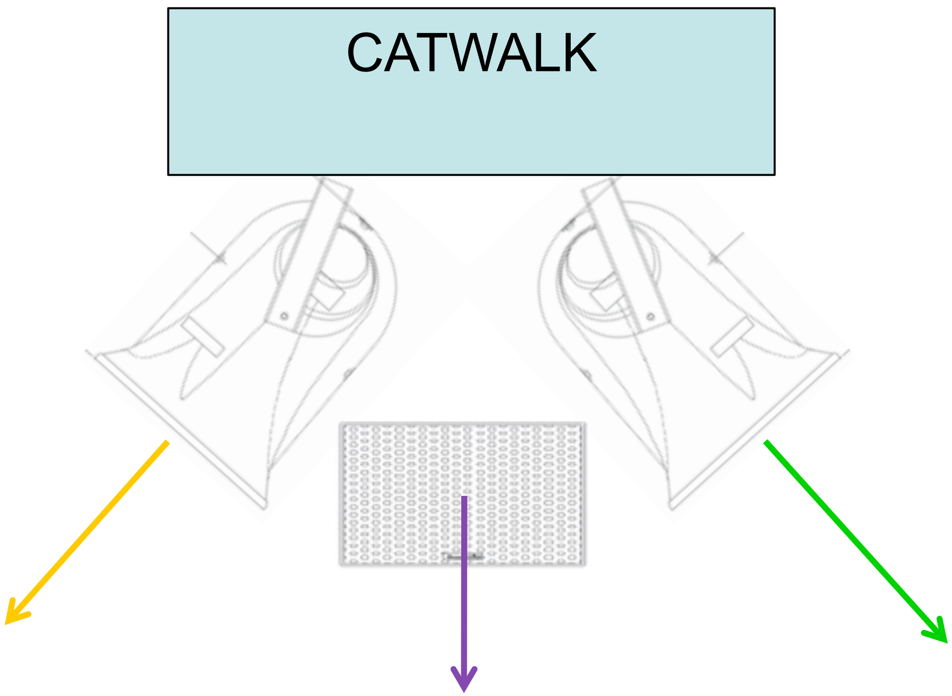
SYSTEMS

REQUIREMENTS - USE

STI SIMULATIONS

SYSTEM A – CLUSTER DESIGN

PA System mounted at the catwalk position consisting of point sources.



Section – schematic
Example for one Cluster

Each Cluster:

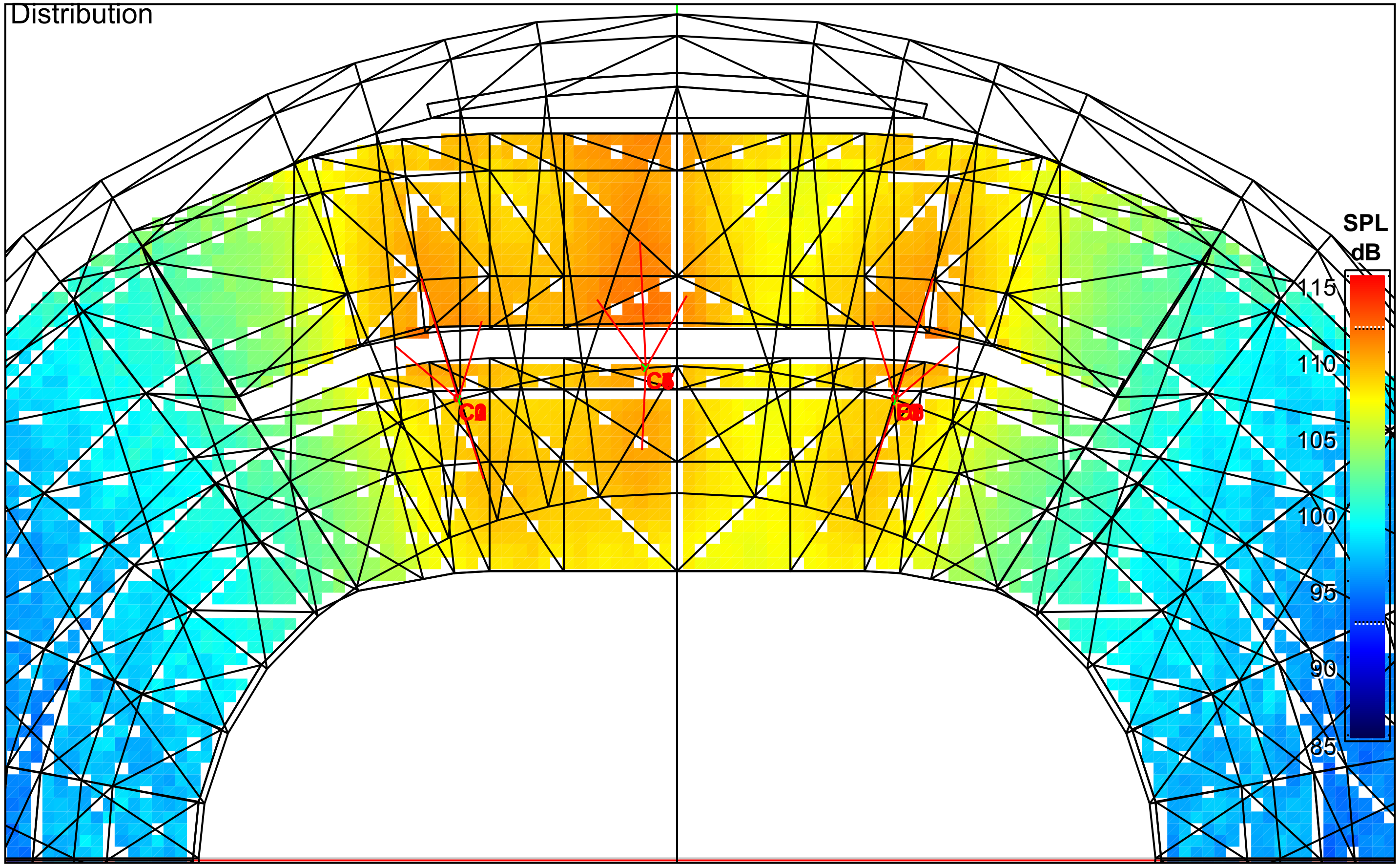
2x Long Throw
(lower and upper ranks)

2x Short Throw
(middle left and right ranks)

STI SIMULATIONS

SYSTEM A – SIMULATION RESULTS

SPL – Sound Pressure Level Distribution



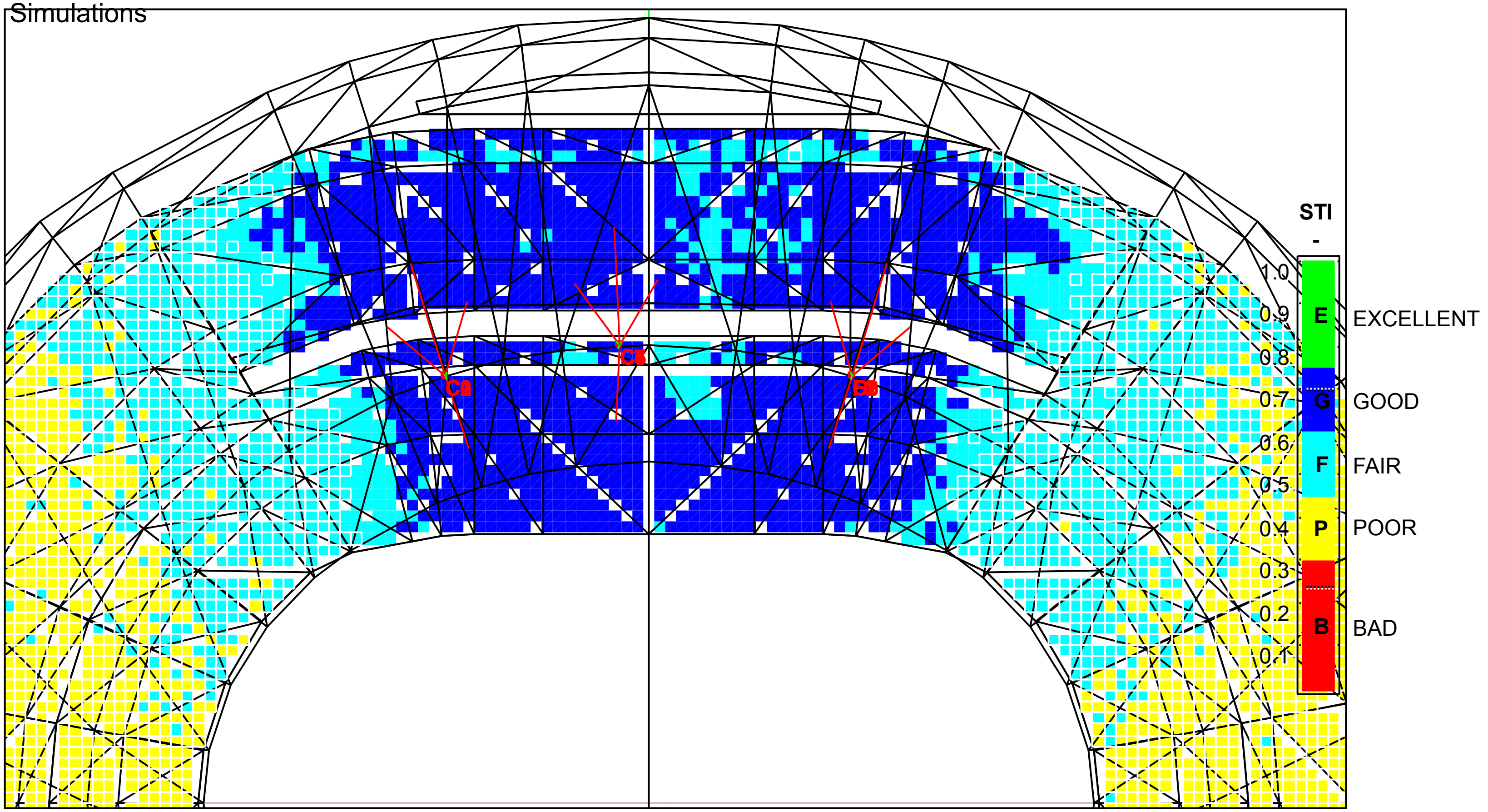
The SPL coverage along the ranks is quite equal, somewhat better for the left arrangement of clusters (closer together). In the right arrangement, the level-drop between the clusters is too big (4dB).

The simulated total SPL on the audience area is around 110dB(A).

STI SIMULATIONS

SYSTEM A – DEVELOPMENT

STI – Speech Intelligibility Simulations



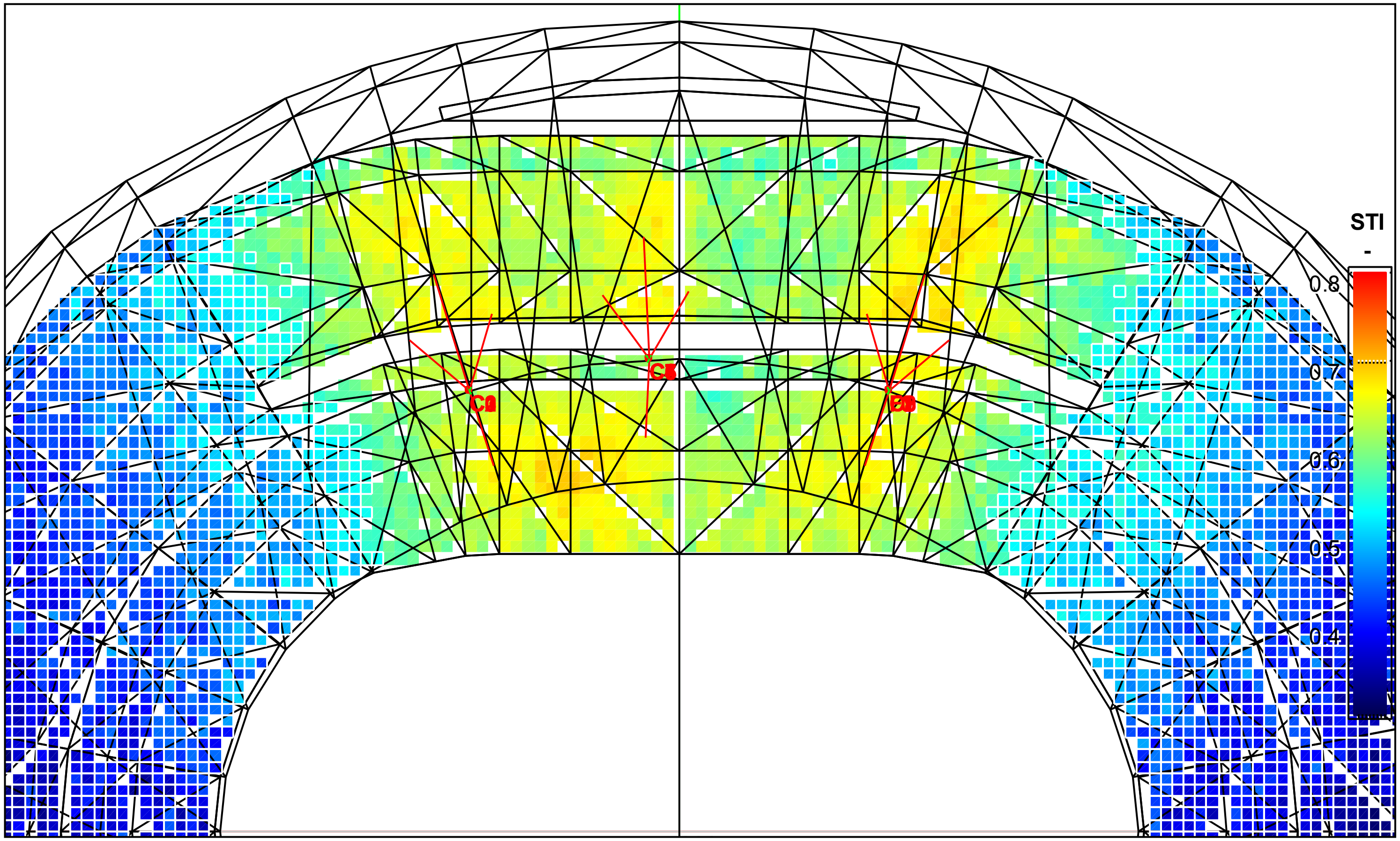
The STI Simulations show that the coverage of the left arrangement (cluster closer together) is better than with the right arrangement (clusters further appart) → less light blue areas (STI between 0.45 and 0.6).

As soon as the full system is active (all speakers, including field speakers), the absolute STI values will be lower than simulated here, using only three clusters.

STI SIMULATIONS

SYSTEM A – DEVELOPMENT

STI – Speech Intelligibility Simulations - Detailed



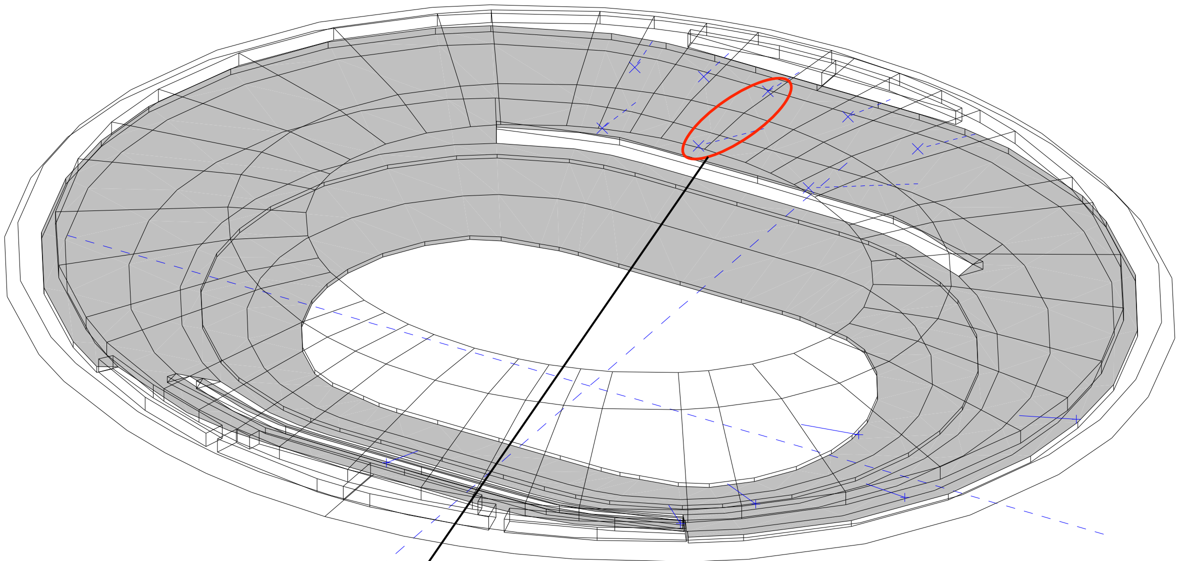
The STI Simulations show that the coverage of the left arrangement (cluster closer together) is better than with the right arrangement (clusters further appart) → less light blue areas (STI between 0.45 and 0.6).

As soon as the full system is active (all speakers, including field speakers), the absolute STI values will be lower than simulated here, using only three clusters.

STI SIMULATIONS

SYSTEM B – DEVELOPMENT

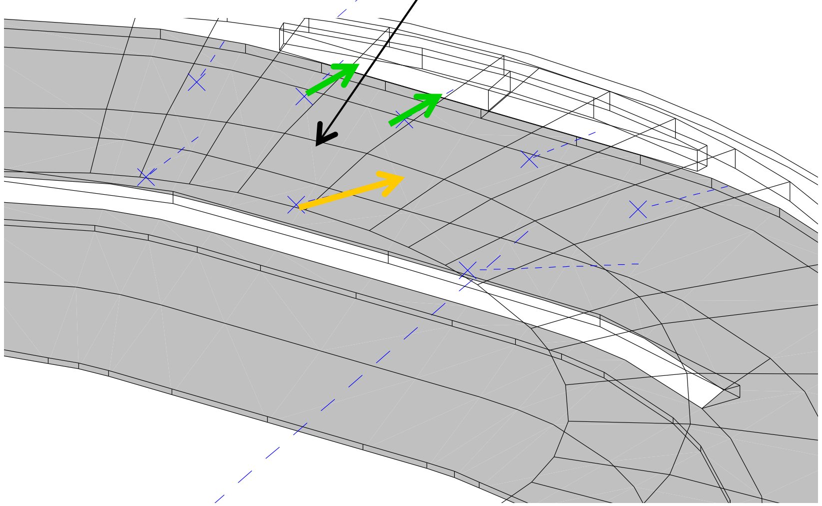
Line Array Solution – Mounted towards the outer rim of the roof



Two Main Clusters of Line Arrays

1. Lower and Middle Ranks
2. Upper Ranks

The Clusters on the left side are closer together horizontally than the ones on the right side in order to determine the correct horizontal distance needed for optimal coverage

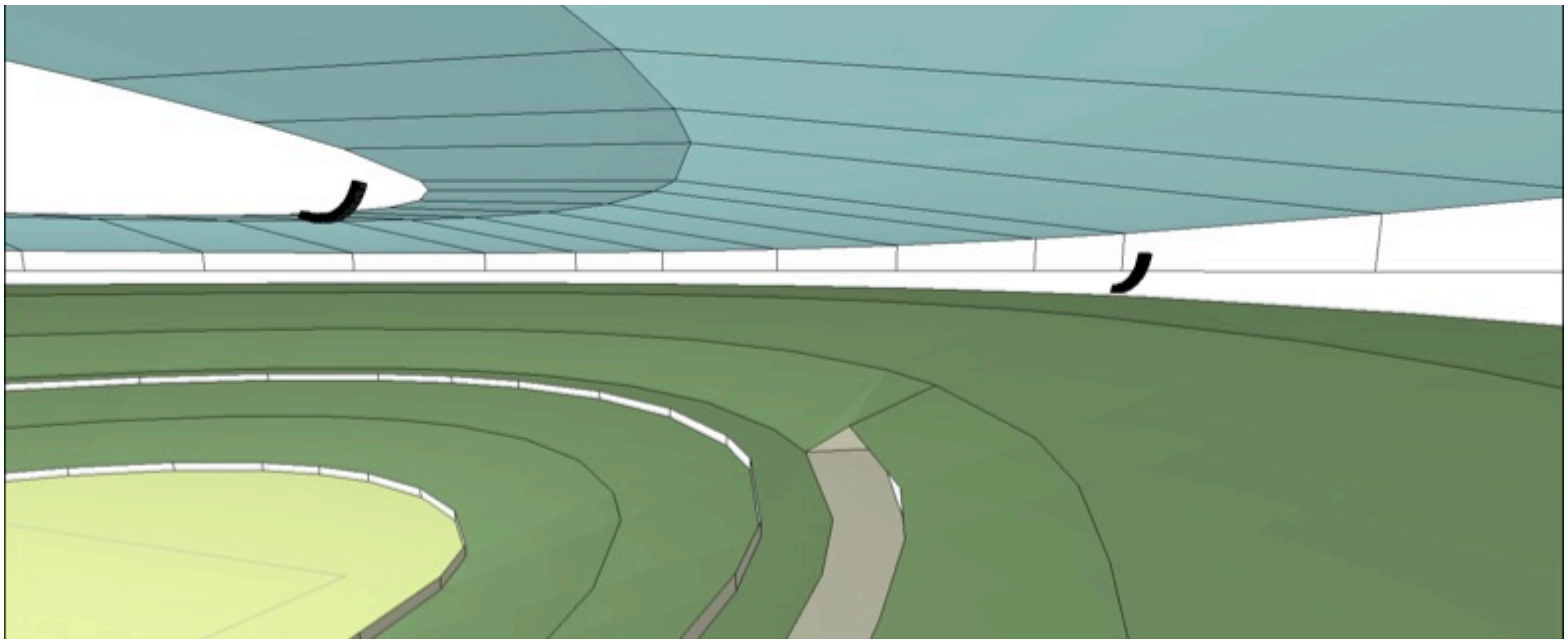


1. Lower and Middle Ranks
2. Upper Ranks

STI SIMULATIONS

SYSTEM B – DEVELOPMENT

Line Array Solution – Mounted towards the outer rim of the roof



Main Cluster for lower and middle ranks – consisting of 12 Boxes each, covering 90° vertically.

Delay Cluster for upper ranks consisting of 8 Boxes each, covering 80° vertically.

This cluster can be replaced by a standard point source instead of a line array source.

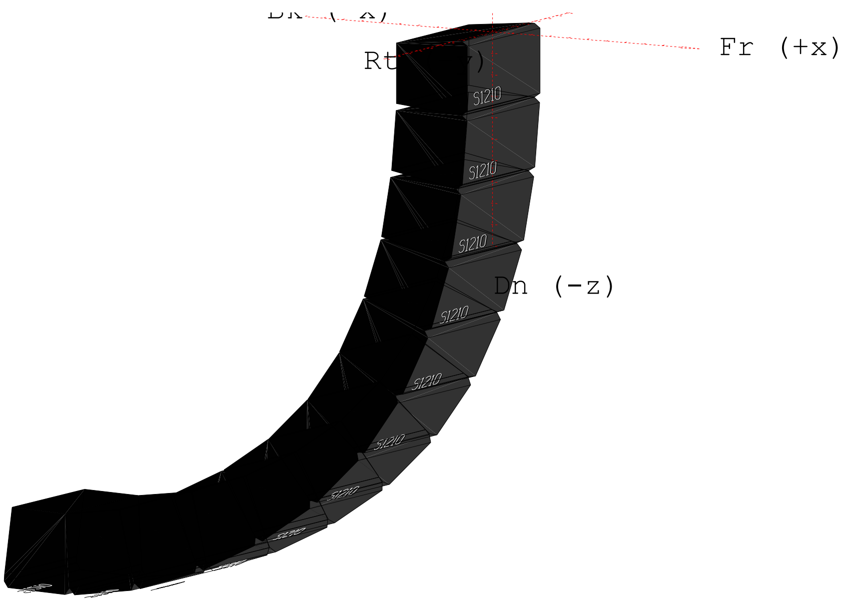
SYSTEMS

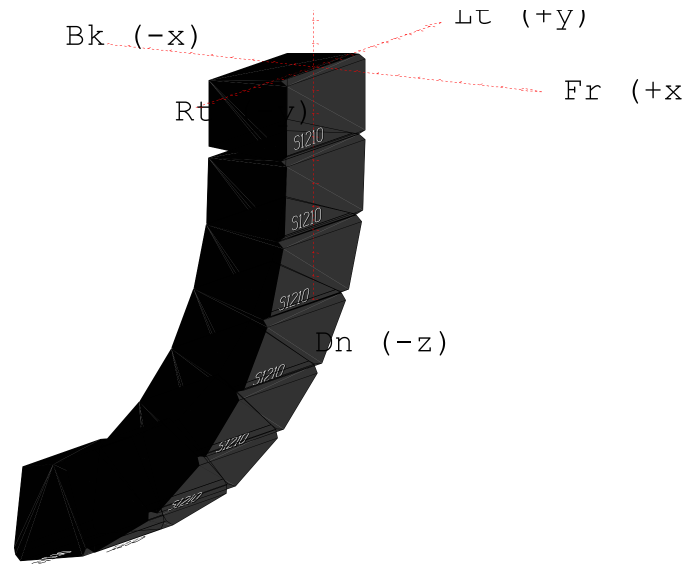
REQUIREMENTS - USE

STI SIMULATIONS

SYSTEM B – DEVELOPMENT

Line Array Solution – Mounted towards the outer rim of the roof





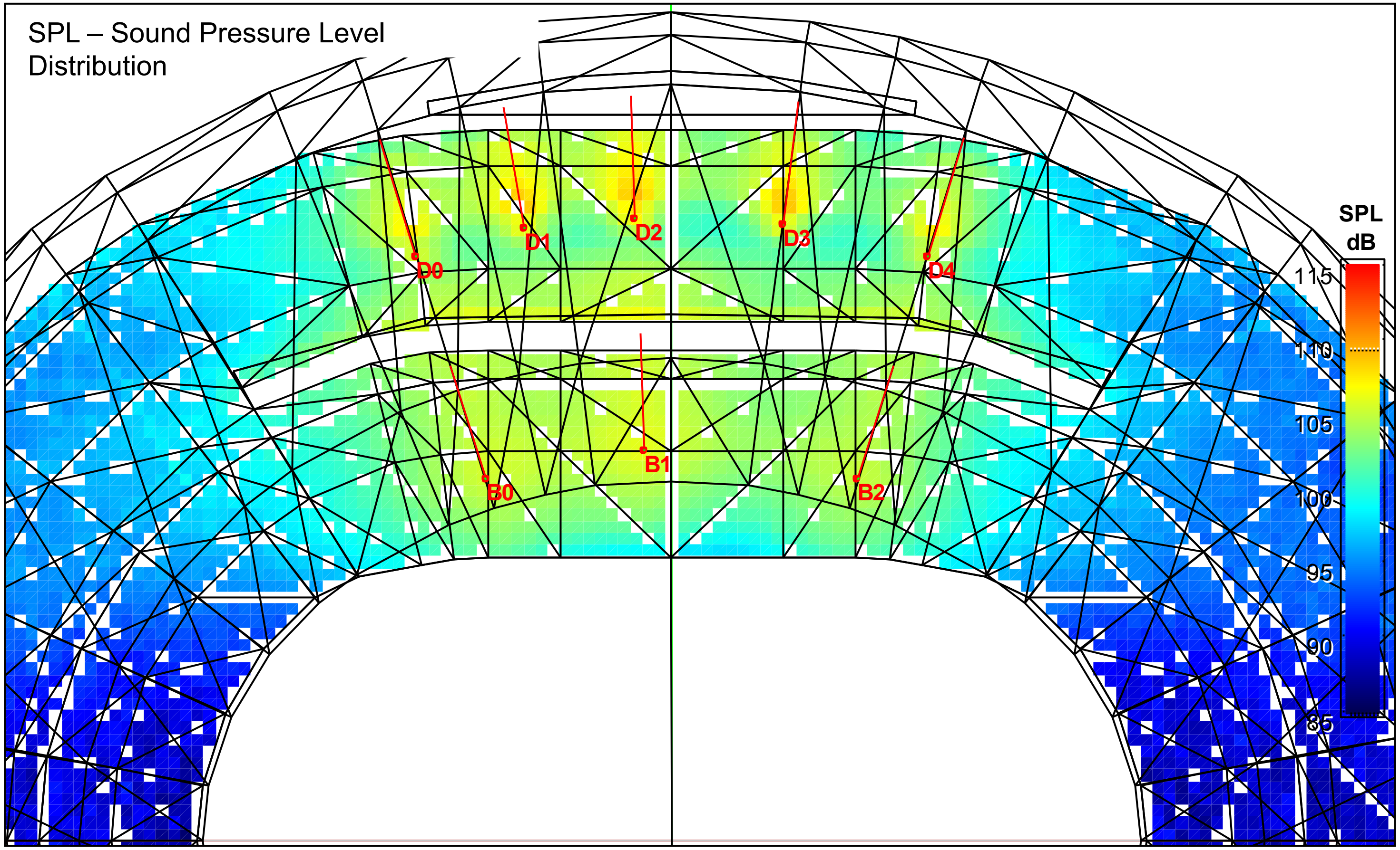
Main Cluster for lower and middle ranks – consisting of 12 Boxes each, covering 90° vertically

Delay Cluster for upper ranks consisting of 8 Boxes each, covering 80° vertically.

This cluster can be replaced by a standard point source instead of a line array source.

STI SIMULATIONS

SYSTEM B – DEVELOPMENT

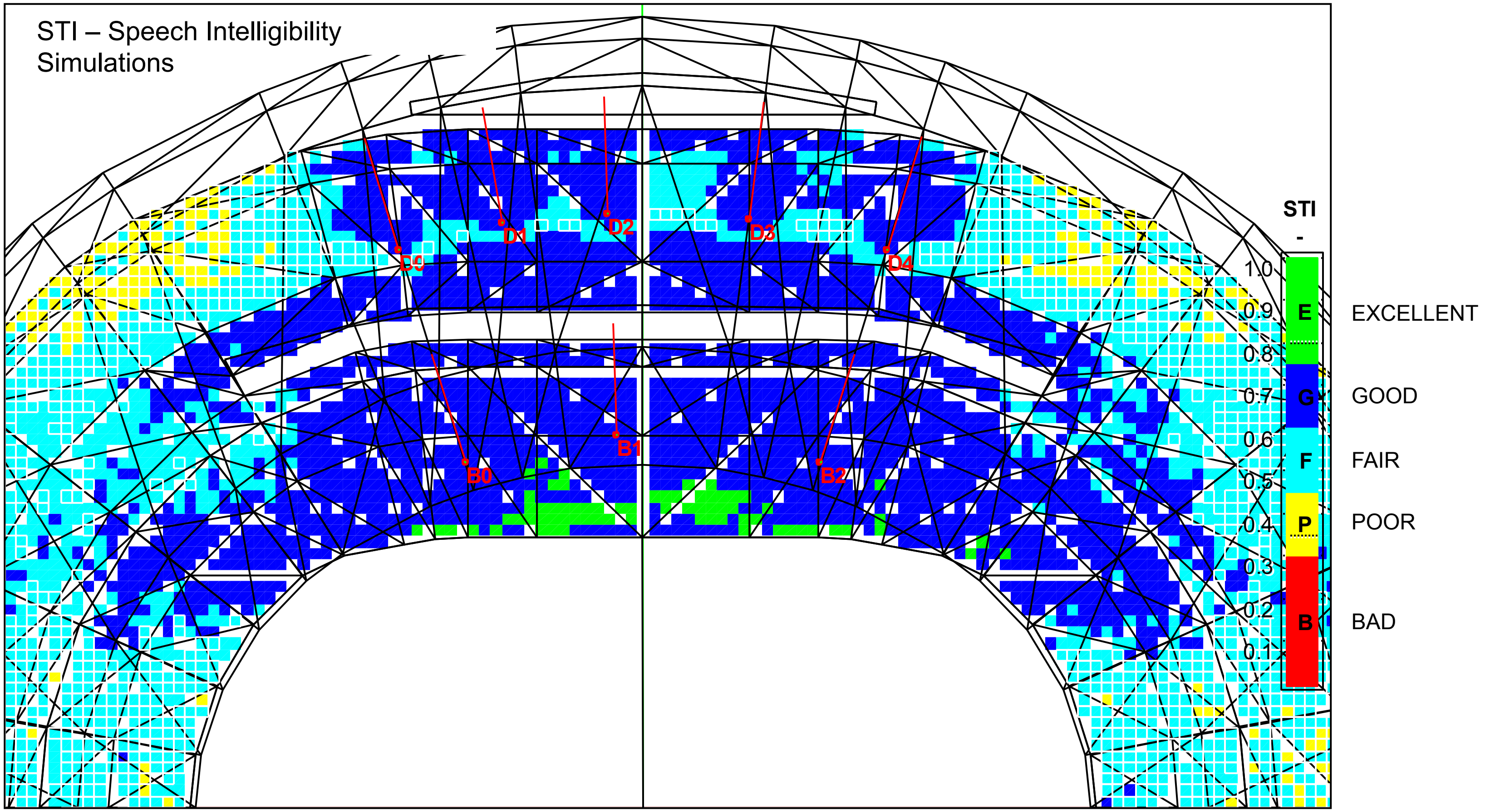


The SPL coverage of the main system along the lower and middle ranks is quite equal (B0-B2). The left arrangement with closer spaced Clusters performs better than the right one.
The Delay Systems ("D0-D4" in the graph above) are not optimal for the task – the SPL distribution is to narrow, especially in the right arrangement with more horizontal space between the clusters

The simulated total SPL on the audience area is around 107dB(A).

STI SIMULATIONS

SYSTEM B – DEVELOPMENT

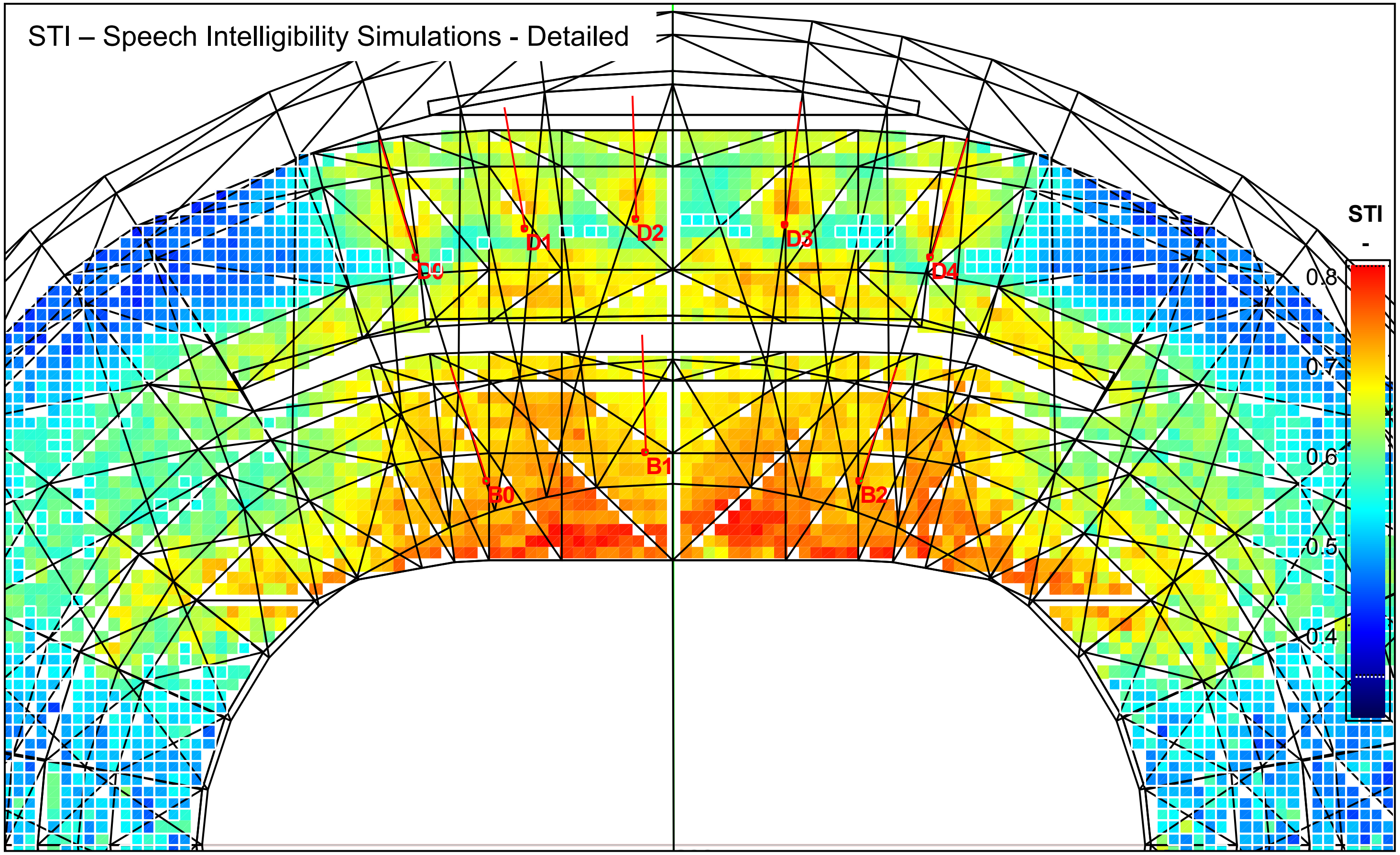


Very good coverage of the lower and middle ranks by the main system (B0-B2) – even the right arrangement with clusters further apart (horizontally) performes excellent.
The delay configuration does not perform equally well, too many blue areas where the STI lies between 0.45 and 0.6.

As soon as the full system is active (all speakers, including field speakers), the absolute STI values will be lower than simulated here, using only three clusters.

STI SIMULATIONS

SYSTEM B – DEVELOPMENT



Very good coverage of the lower and middle ranks by the main system (B0-B2) – even the right arrangement with clusters further apart (horizontally) performs excellent.
The delay configuration does not perform equally well, a different system will have to be defined.

As soon as the full system is active (all speakers, including field speakers), the absolute STI values will be lower than simulated here, using only three clusters.

STI SIMULATIONS

SUMMARY

System A, the point source approach, performs well in terms of SPL distribution and Speech intelligibility. The clusters should be mounted in the configuration where they are closer together horizontally in order to cover the audience area evenly.

The downsides of System A are the localisation of the sources for the lower ranks (sources are behind audience) as well as the somewhat less concentrated direct sound energy on the audience area.

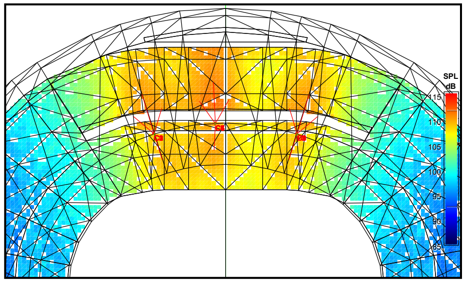
System B, the line source approach, performes very good in terms of Speech Intelligibility and direct sound energy on the audience area. The main clusters could be mounted in the configuration, where they are further apart from each other horizontally.

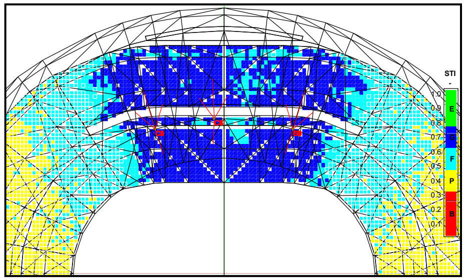
The downsides of System B are the delay lines (should be changed, possibly into point sources) and the maximum SPL on the audience area → choosing a more powerful main system would be an option here.

SPL [dB(A)]

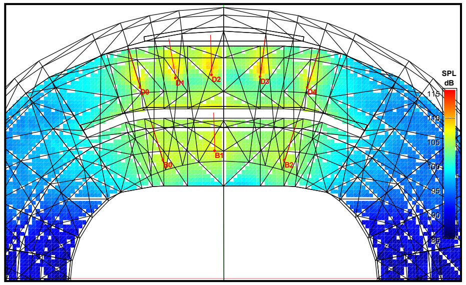
STI [%]

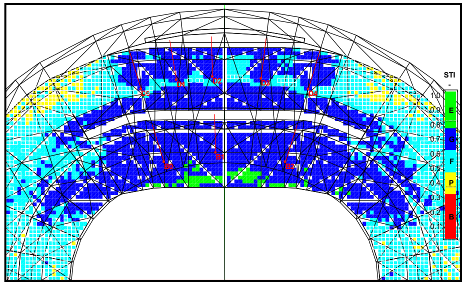
A





B





SYSTEMS

REQUIREMENTS - USE

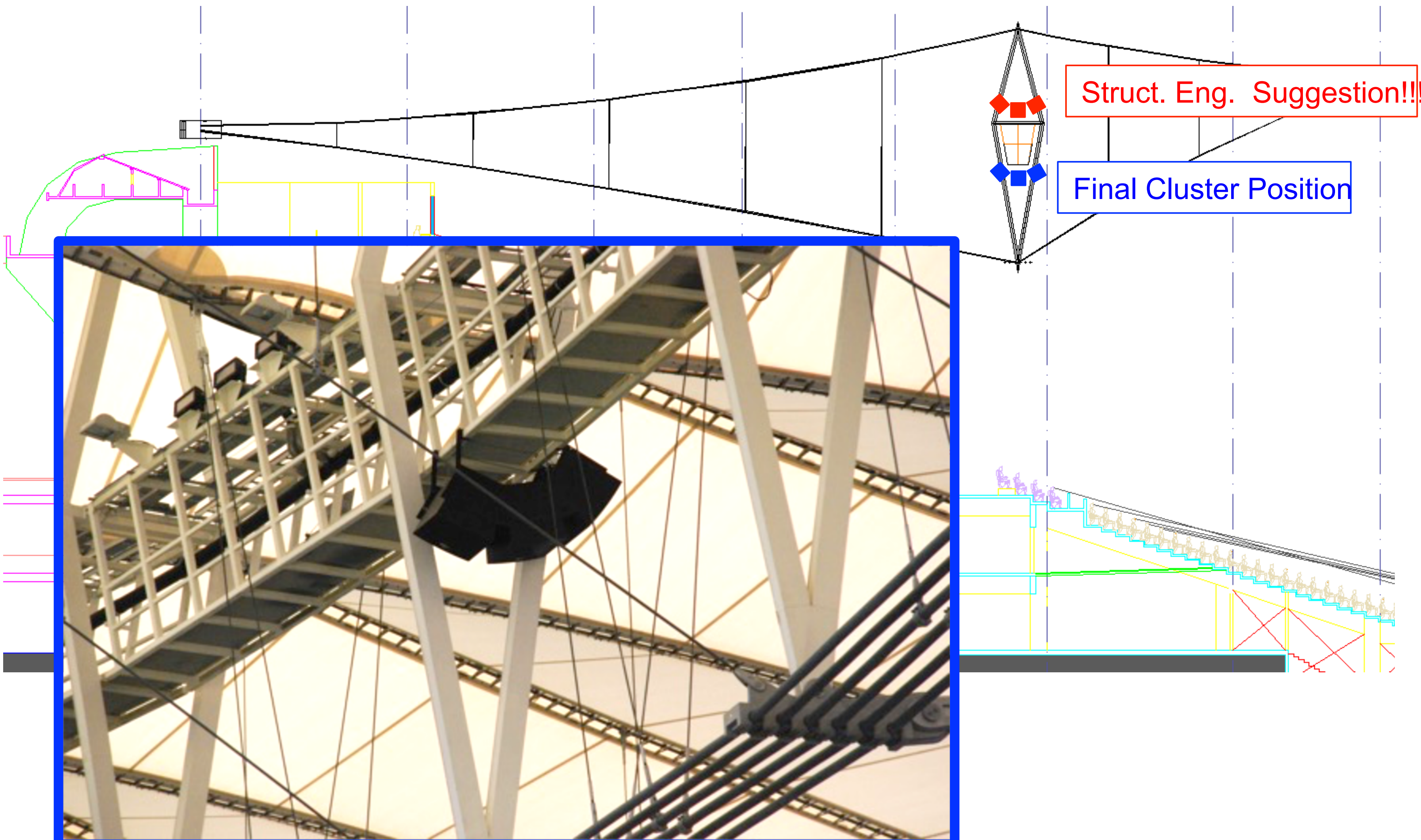
STI SIMULATIONS

SUMMARY

System A, the point source approach, performs well in terms of SPL distribution and Speech intelligibility. The clusters should be mounted in the configuration where they are closer together horizontally in order to cover the audience area evenly.

The downsides of System A are the localisation of the sources for the lower ranks (sources are behind audience) as well as the somewhat less concentrated direct sound energy on the audience area.

ARCHITECTURAL / STRUCTURAL CONDITIONS



STI SIMULATIONS

MINEIRÃO STADIUM

SIMULATION STUDIES

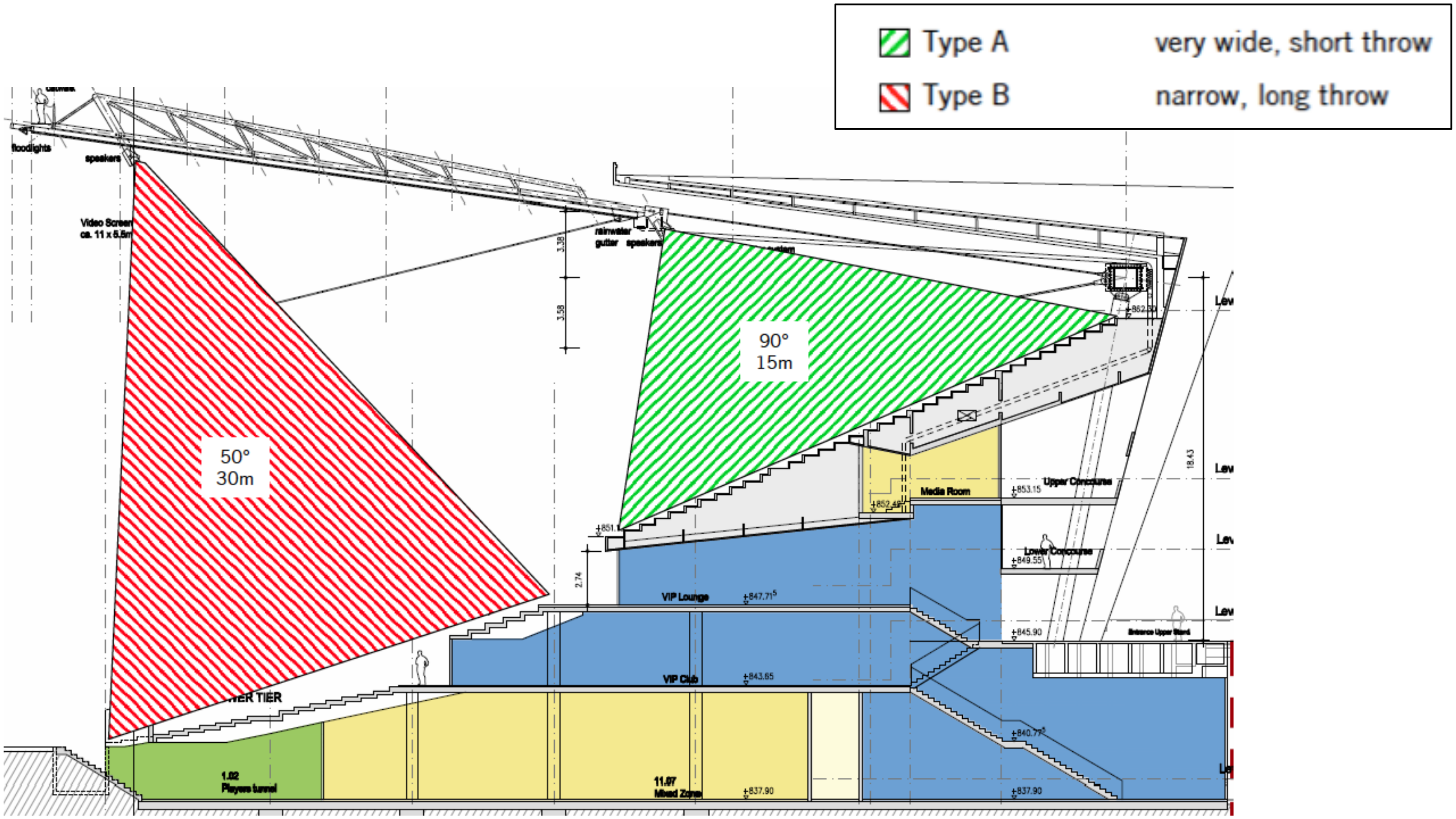
SYSTEMS

REQUIREMENTS - USE

STI SIMULATIONS

MINEIRÃO STADIUM

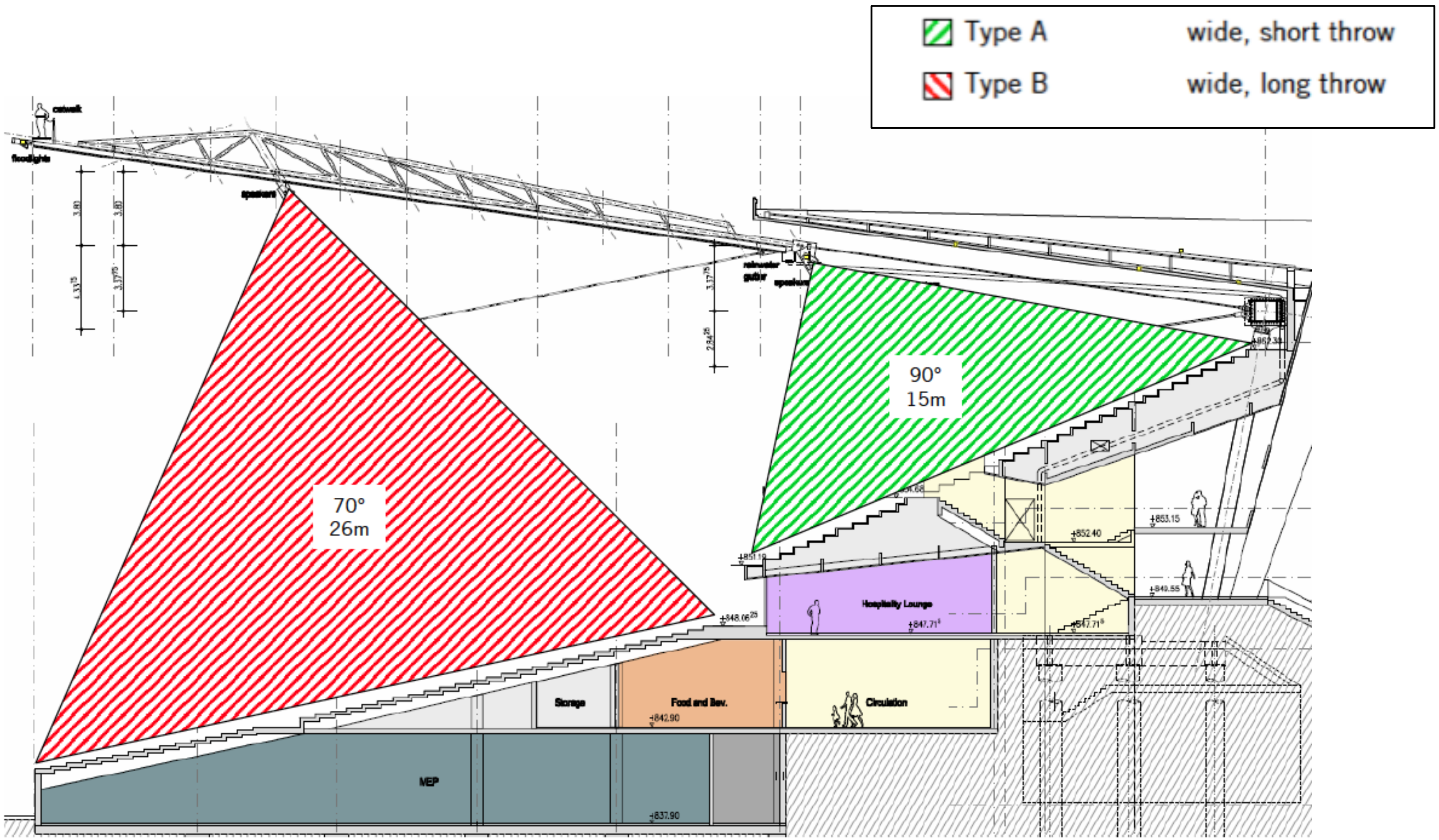
SIMULATION STUDIES - POINT SOURCE x LINE ARRAY



STI SIMULATIONS

MINEIRÃO STADIUM

SIMULATION STUDIES - POINT SOURCE x LINE ARRAY



SYSTEMS

REQUIREMENTS - USE

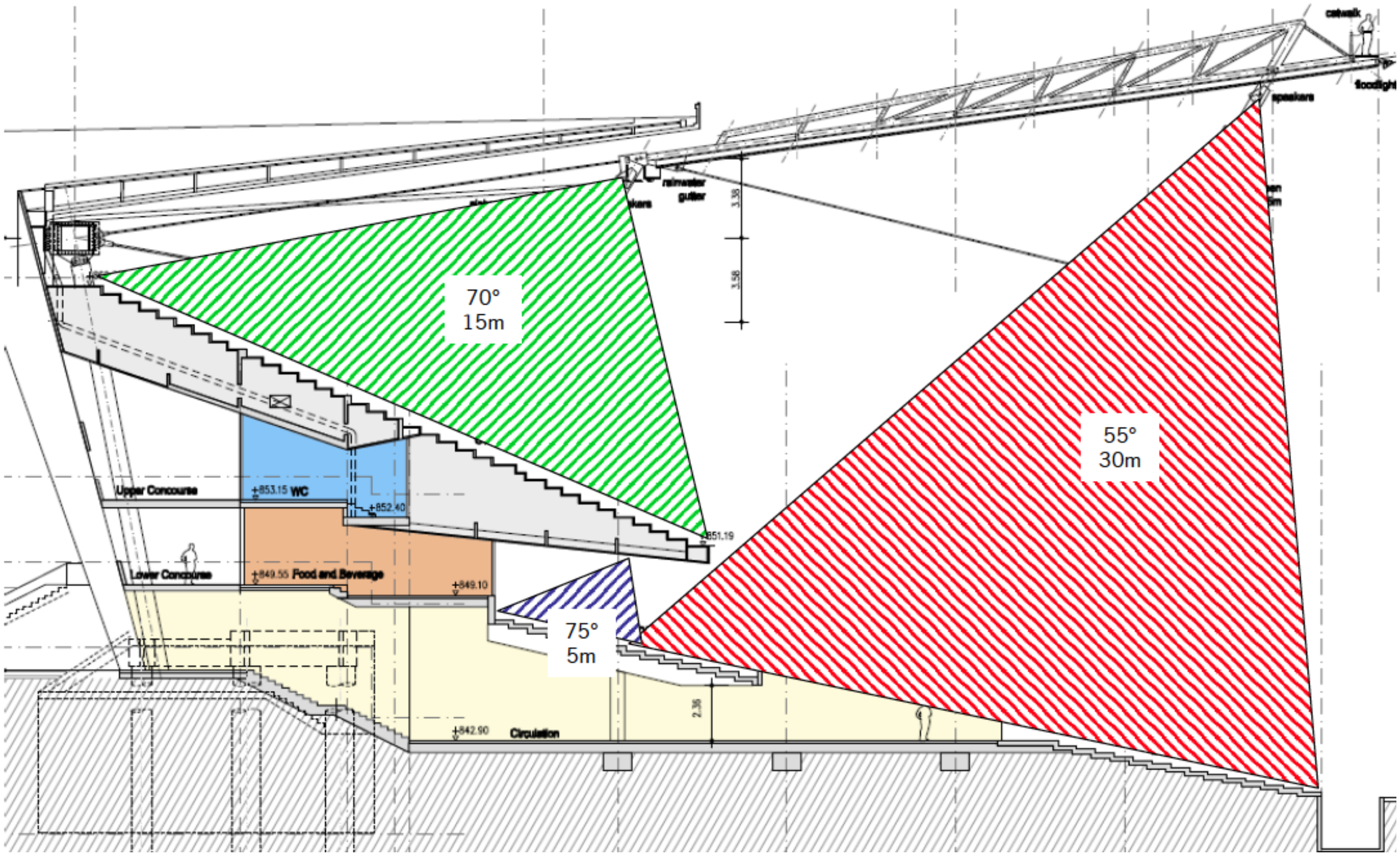
WSDG
WALTERS-STORYK DESIGN GROUP

STI SIMULATIONS

MINEIRÃO STADIUM

SIMULATION STUDIES - POINT SOURCE x LINE ARRAY

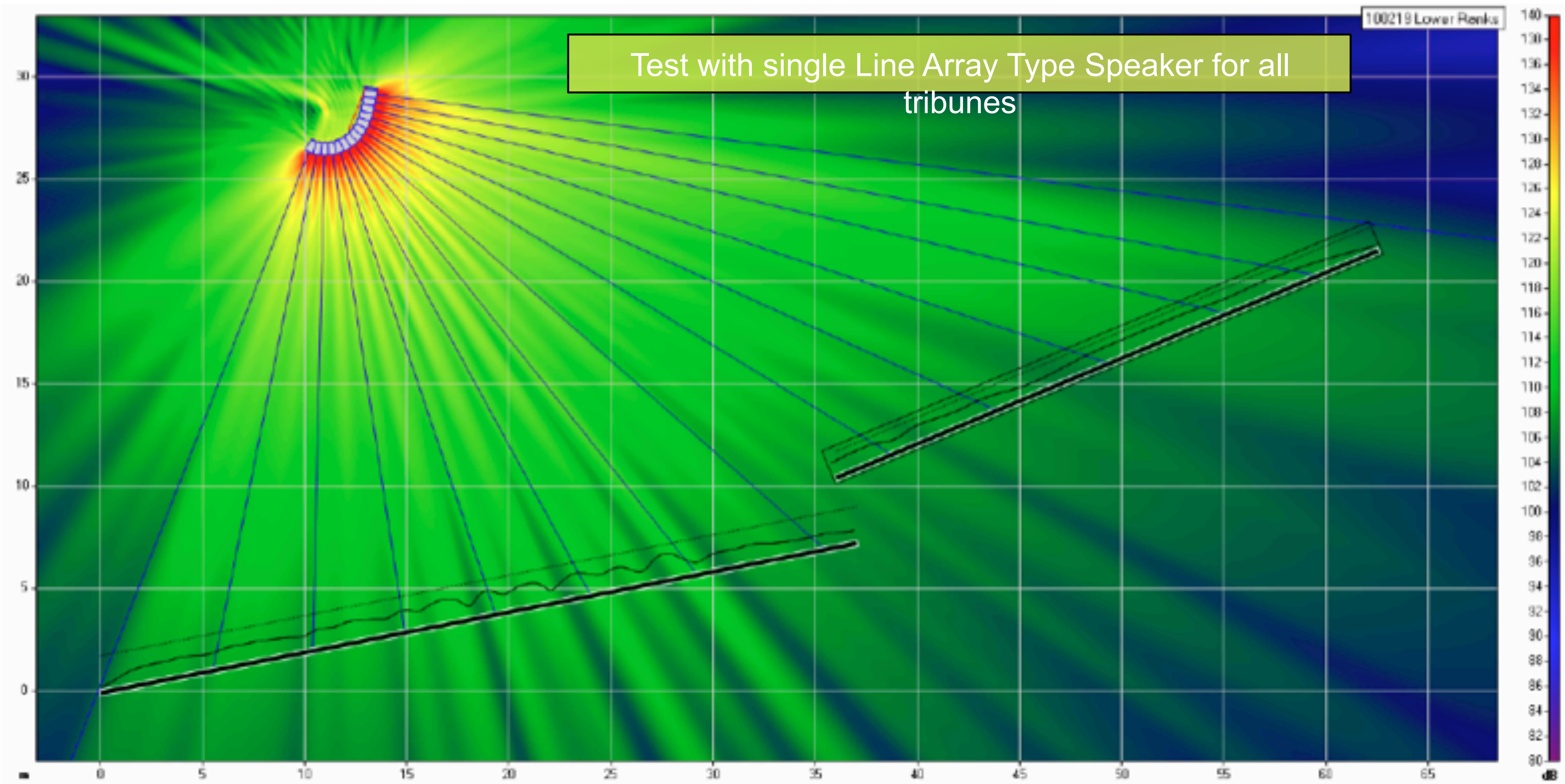
	Type A	wide, short throw
	Type B	narrow, long throw
	Type C	wide, very short throw



STI SIMULATIONS

MINEIRÃO STADIUM

SIMULATION STUDIES - POINT SOURCE x



Due to the very wide vertical opening angle (90°), the line-source attribute does not apply anymore.
The Array acts as a point source, the sound distribution on the audience plane is insufficient.
More speakers would be needed in the array in order to achieve better coverage.

There will be a mechanical issue due to the large size and weight of the speaker cluster.

We recommend using distributed systems, with opening angles suitable to the situation.

STI SIMULATIONS

MINEIRÃO STADIUM

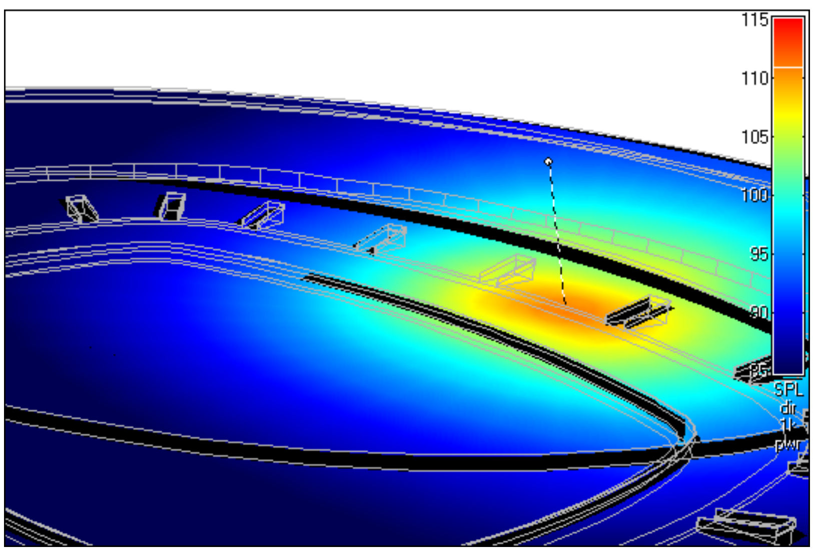
SIMULATION STUDIES - POINT SOURCE x LINE ARRAY

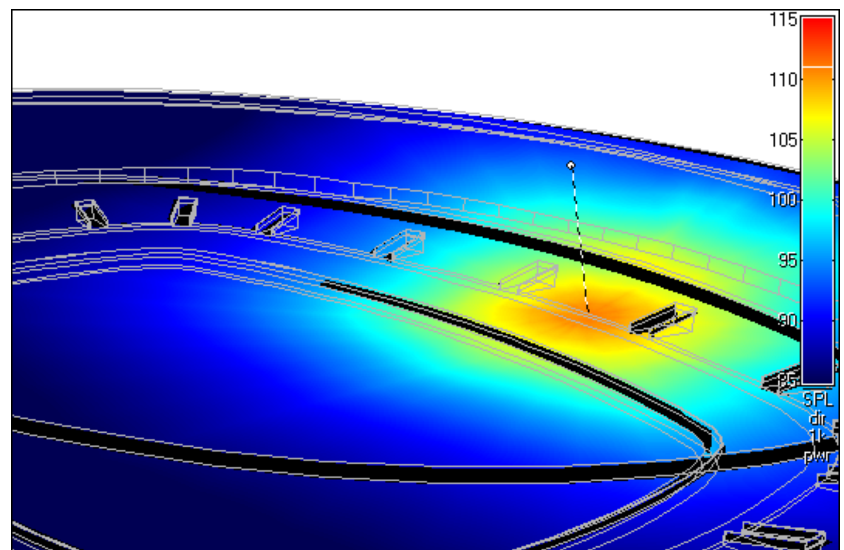
SUGGESTED SYSTEM OPTION A

Point Source - 90°x50°

SUGGESTED SYSTEM OPTION B

Point Source - 70°x70°





STI SIMULATIONS

MINEIRÃO STADIUM

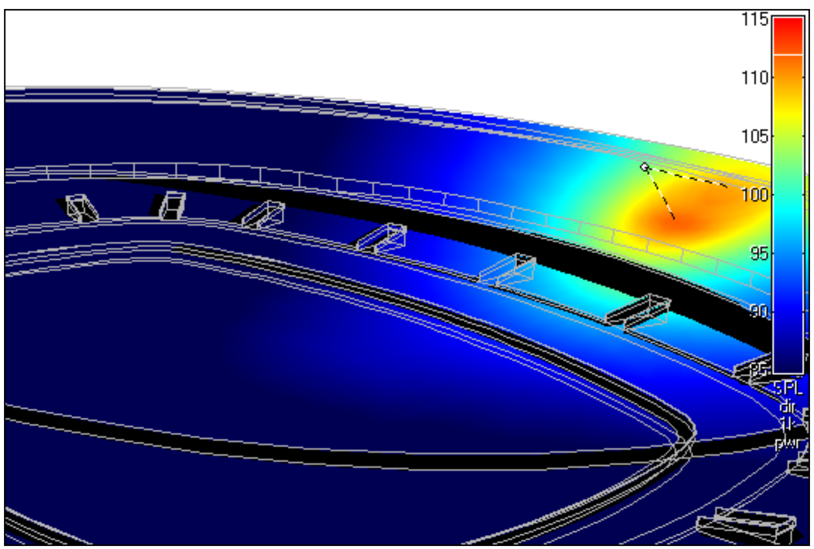
SIMULATION STUDIES - POINT SOURCE x LINE ARRAY

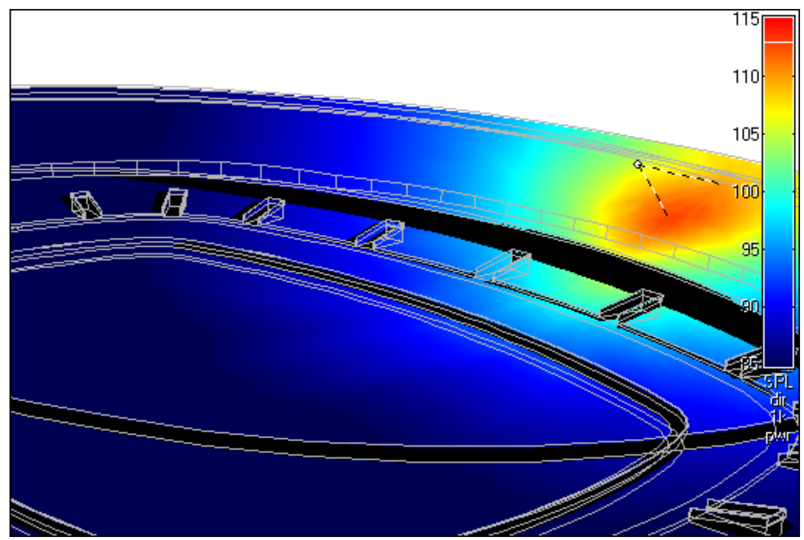
SUGGESTED SYSTEM OPTION A

2x Point Source – 90°x50°

SUGGESTED SYSTEM OPTION B

2x Point Source – 90°x40°





SYSTEMS

REQUIREMENTS - USE

STI SIMULATIONS

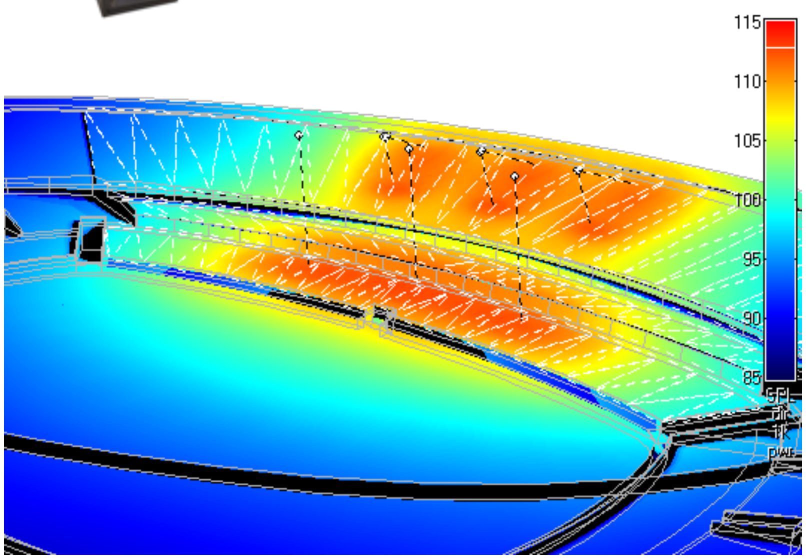
MINEIRÃO STADIUM

SIMULATION STUDIES - POINT SOURCE x LINE ARRAY

SUGGESTED SYSTEM OPTION A

Three Upper clusters
2x Point Source (smaller)

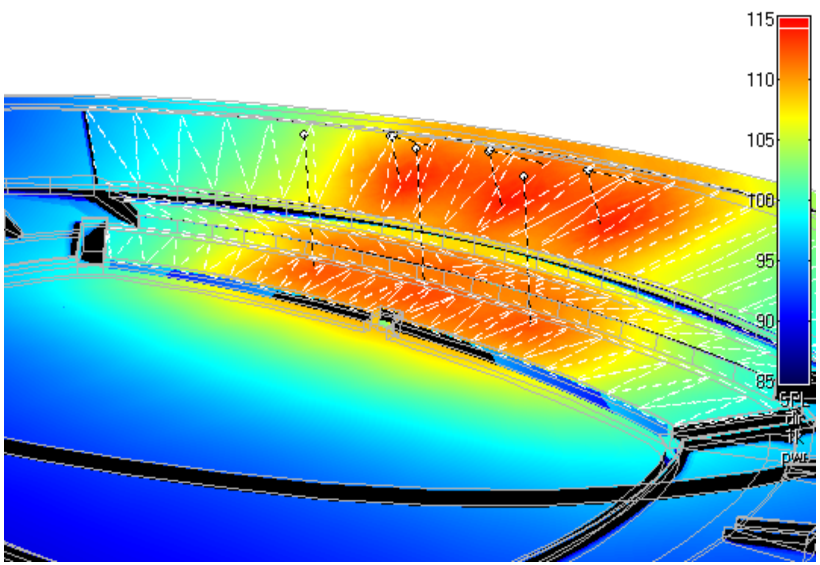
Three Lower clusters
1x Point Source – 60°x40°



SUGGESTED SYSTEM OPTION B

Three Upper clusters
2x Point Source (smaller)

Three Lower clusters
1x Point Source– 70°x70°



SYSTEMS

REQUIREMENTS - USE

STI SIMULATIONS

MINEIRÃO STADIUM

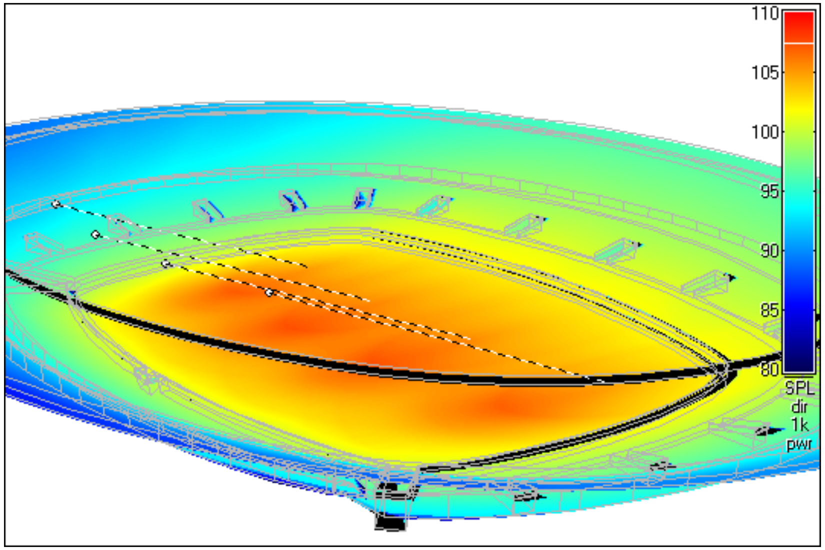
SIMULATION STUDIES - POINT SOURCE x LINE ARRAY

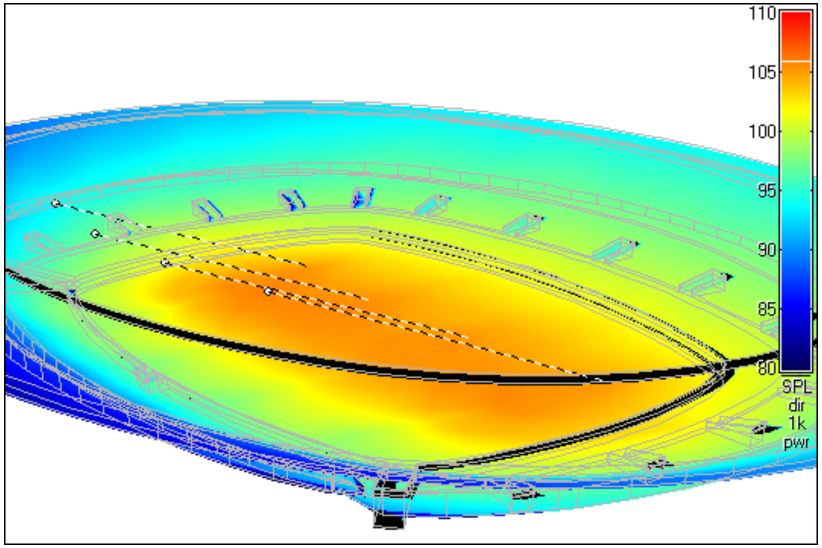
SUGGESTED SYSTEM OPTION A

4x Point Source

SUGGESTED SYSTEM OPTION B

4x Point Source (long throw)





SYSTEMS

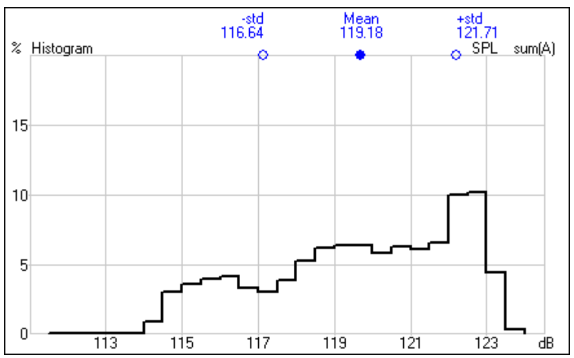
REQUIREMENTS - USE

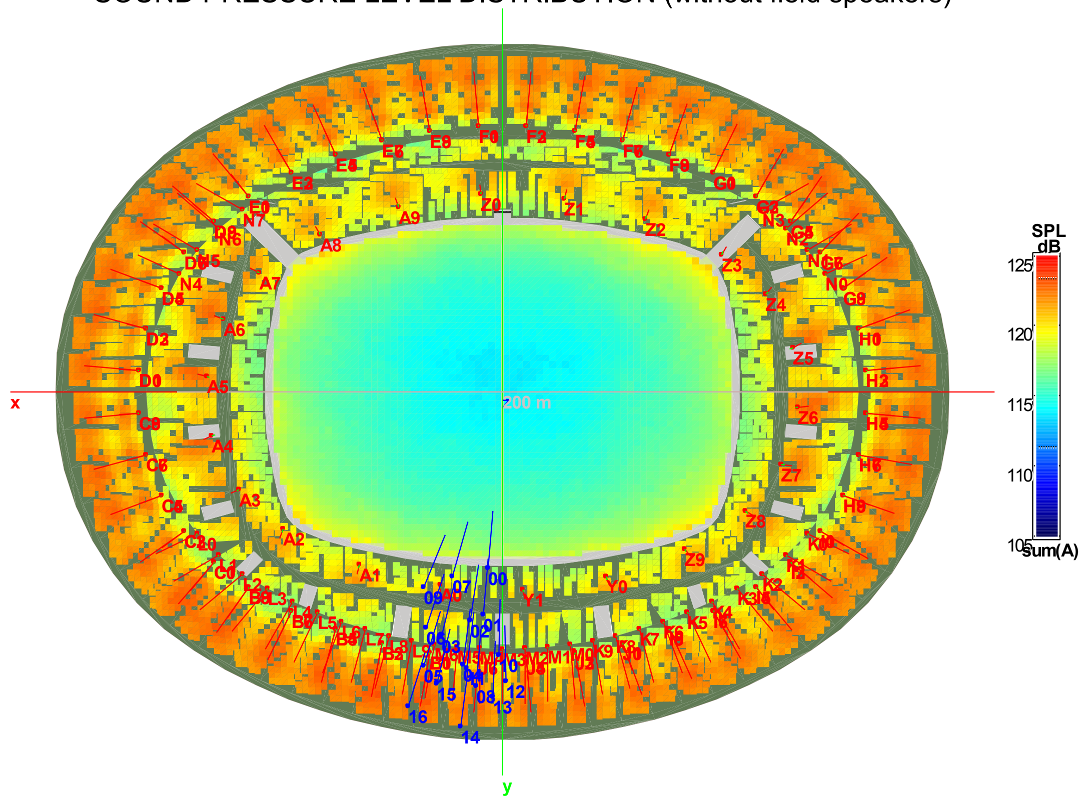
STI SIMULATIONS

MINEIRÃO STADIUM

SIMULATION STUDIES - POINT SOURCE x LINE ARRAY

SOUND PRESSURE LEVEL DISTRIBUTION (without field speakers)



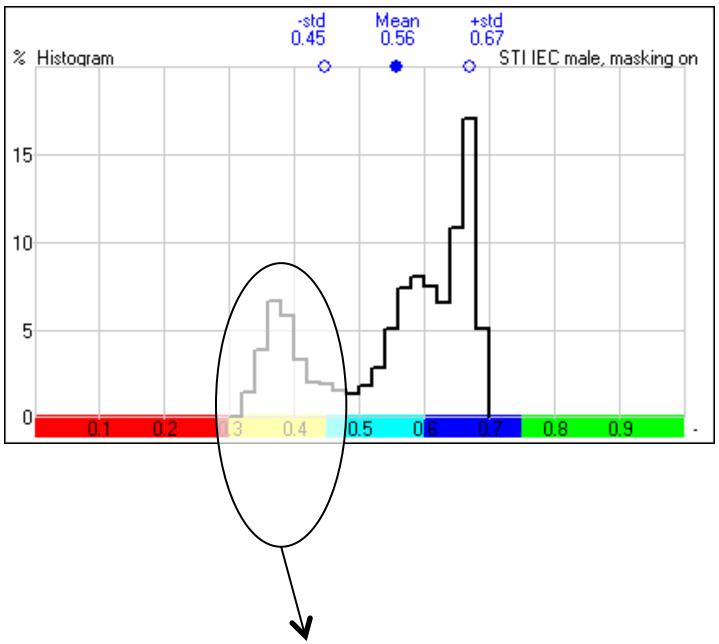


Mean SPL dB(A) 119dB
Standard Deviation +/- 2.5dB

STI SIMULATIONS

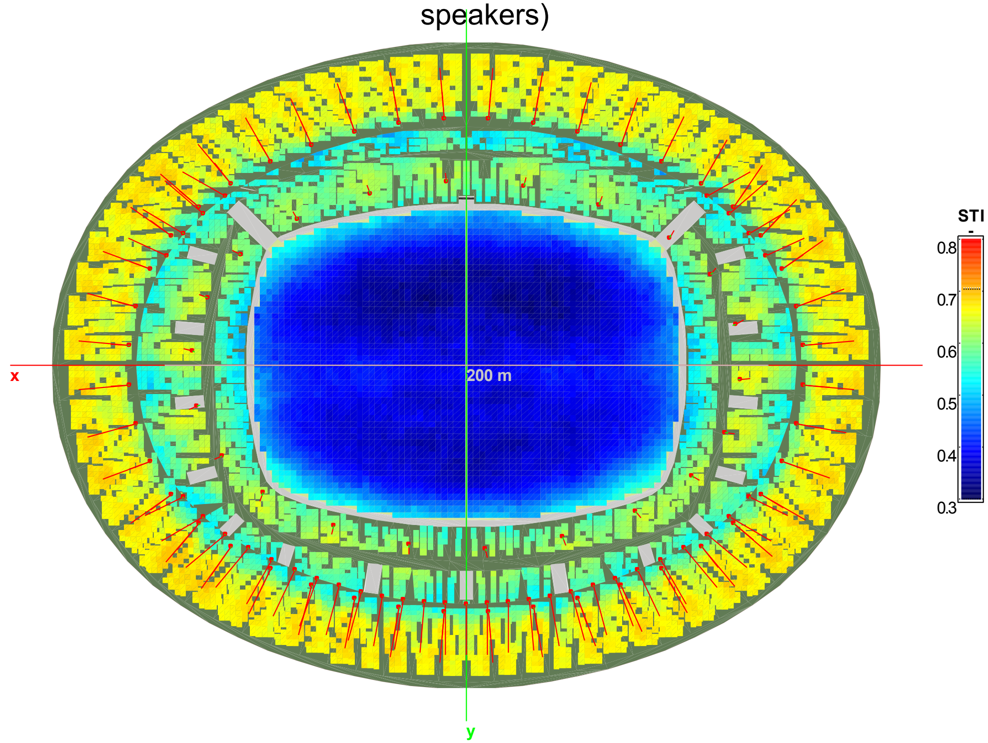
MINEIRÃO STADIUM

SIMULATION STUDIES - POINT SOURCE x LINE ARRAY



Field Area – not active

SPEECH INTELLIGIBILITY DISTIBUTION (without field speakers)



SYSTEMS

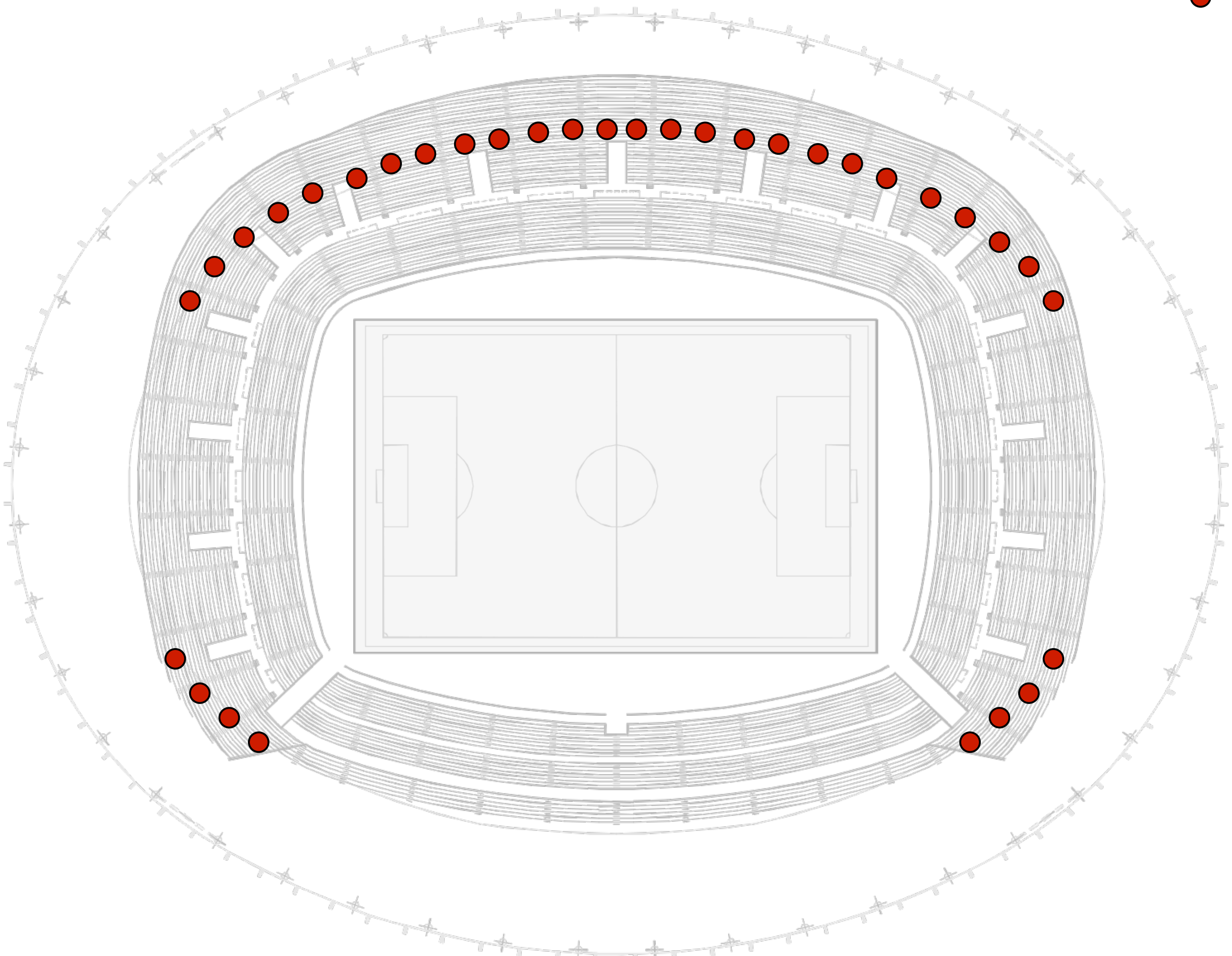
REQUIREMENTS - USE

STI SIMULATIONS

MINEIRÃO STADIUM

SIMULATION STUDIES - POINT SOURCE x LINE ARRAY

Under Balcony Speakers "E"
26 North
8 South
Point Source – 90°x40°



MINEIRÃO STADIUM – FIFA 2014

REFLEXÃO

MINEIRÃO – FIFA 2014

SYSTEMS

REQUIREMENTS - USE

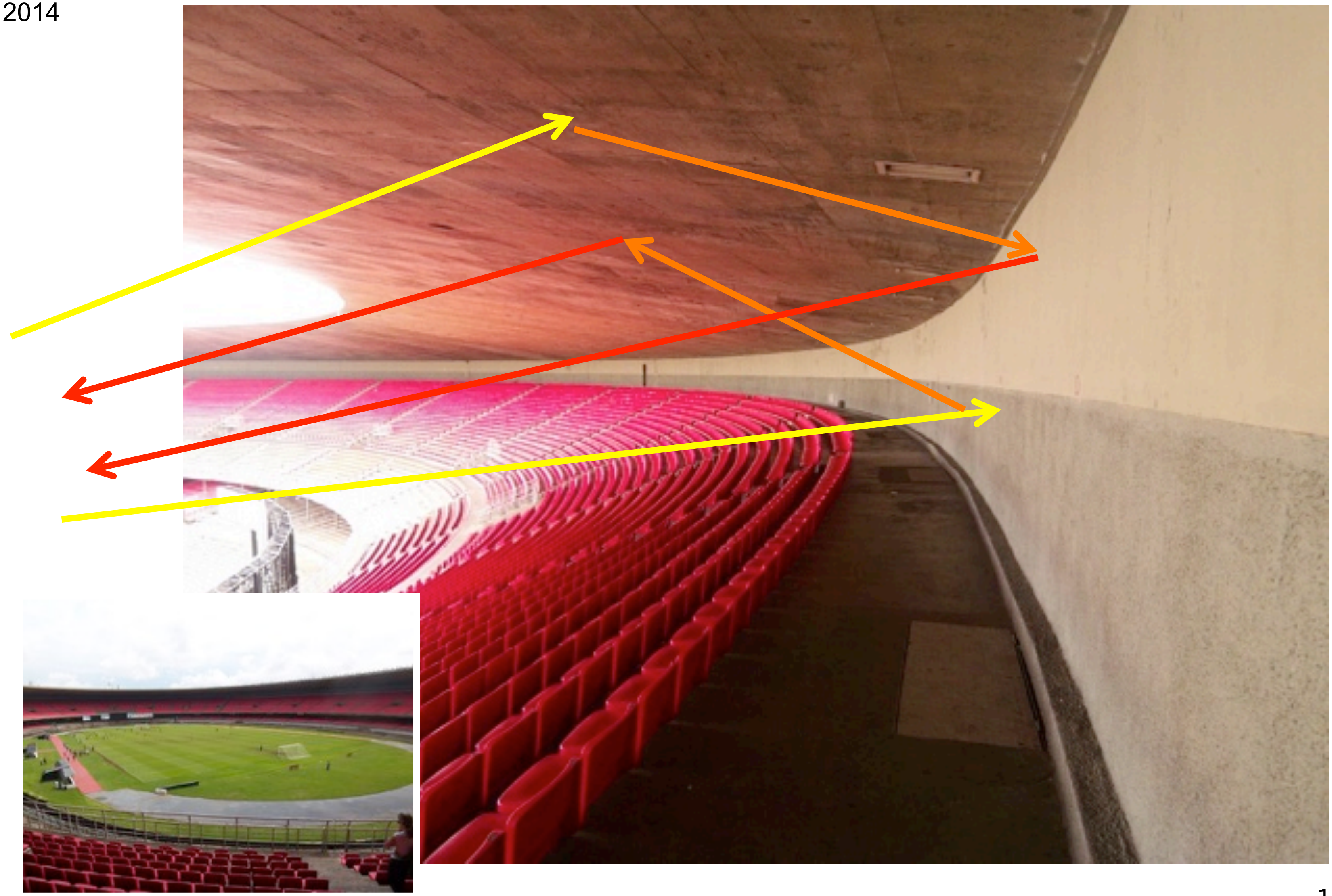
MINEIRÃO STADIUM – FIFA
2014
EXISTING CONDITIONS PRIOR TO RENOVATION

SYSTEMS

REQUIREMENTS - USE

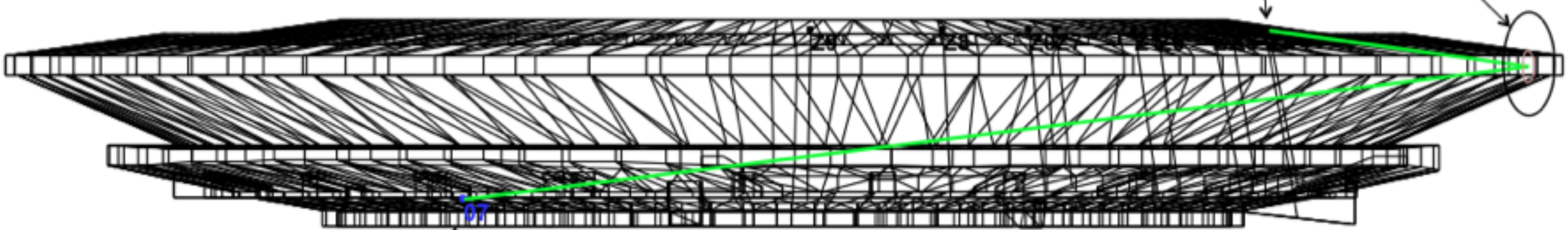
MINEIRÃO STADIUM – FIFA
2014
EXISTING CONDITIONS PRIOR TO RENOVATION

MINEIRÃO STADIUM – FIFA 2014

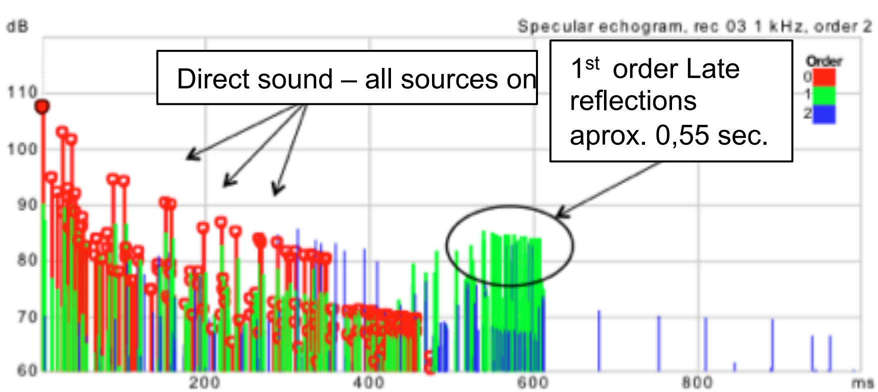


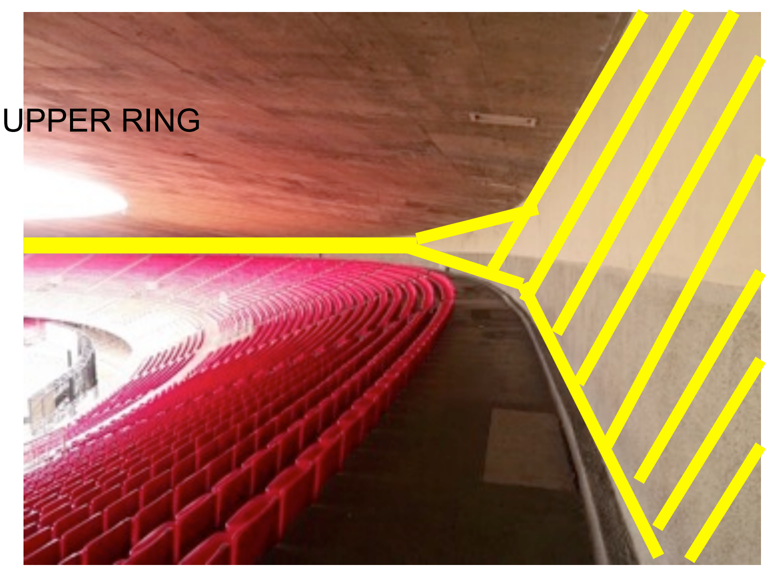
MINEIRÃO STADIUM – FIFA 2014

Reflection path



SPECULAR ECHOGRAM W/O ACOUSTICAL TREATMENTS AT THE UPPER RING





SYSTEMS

REQUIREMENTS - USE

MINEIRÃO – FIFA 2014

STI PREDICTIONS

WITHOUT ACOUSTICAL TREATMENT		
Mean	0.57	(FAIR)
Min.	0.46	(POOR)
Max.	0.66	(GOOD)

WITH ACOUSTICAL TREATMENT		
Mean	0.61	(GOOD)
Min	0.52	(FAIR)
Max	0.67	(GOOD)

STI INSUFICIENT

STI SUFICIENT

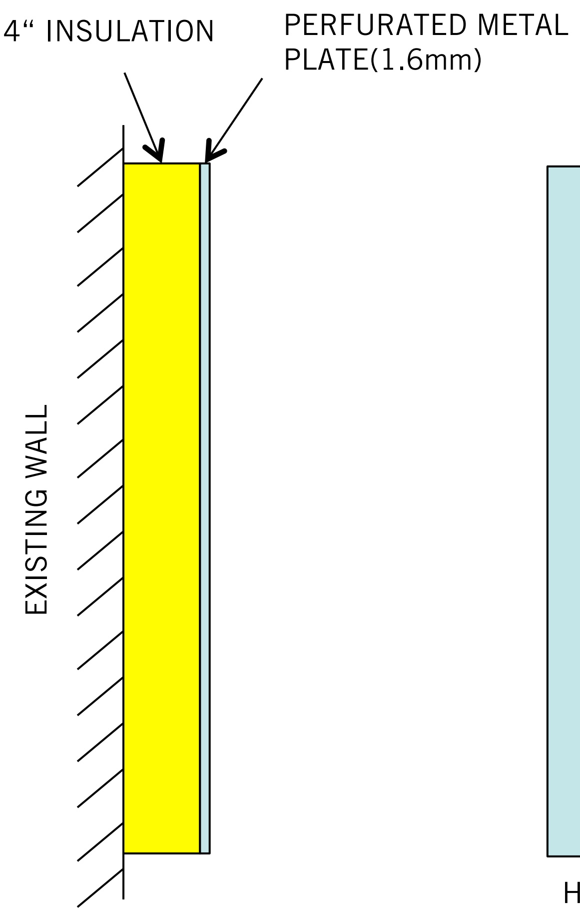
Stadia with occupied audience	***Simulated Reverberation Time RT60 in octave bands [s]***							
Stadium	*125*	*250*	*500*	*1k*	*2k*	*4k*	*8k*	*16k*
TEN01, Center Court	2,0	2,0	2,0	1,9	1,8	1,4	0,8	0,3
TEN02, Court 1 (5000)	1,1	1,2	1,2	1,2	1,2	1,1	0,7	0,3
TEN03, Court 2 (3000)	1,0	1,1	1,1	1,1	1,1	1,0	0,6	0,4
Maracanã Stadium	4,8	4,6	4,3	3,8	3,0	1,9	0,9	0,3
Mineirão - no treatment	6,8	5,7	4,4	3,6	3,1	1,3	1,0	0,4
Mineirão - absorptive	6,5	5,1	3,6	3,1	2,5	1,2	1,0	0,4

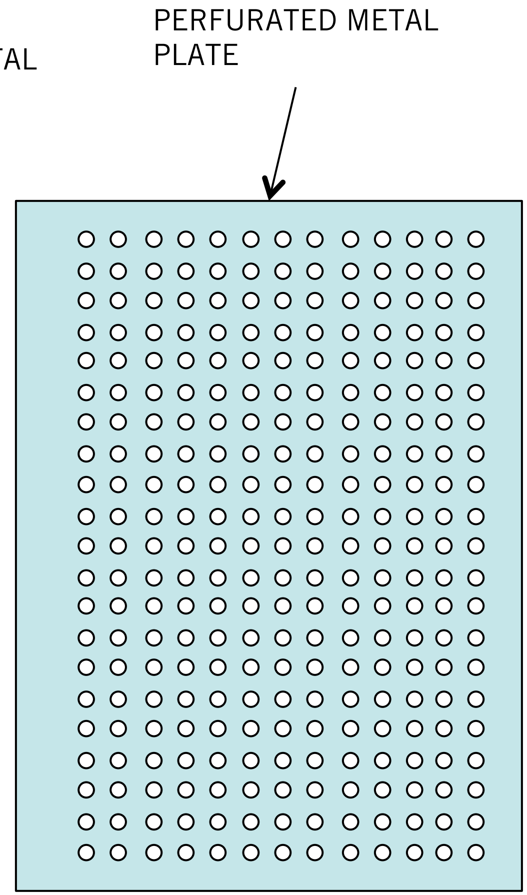
COMPORTAMENTO DO SOM

REFLEXÃO

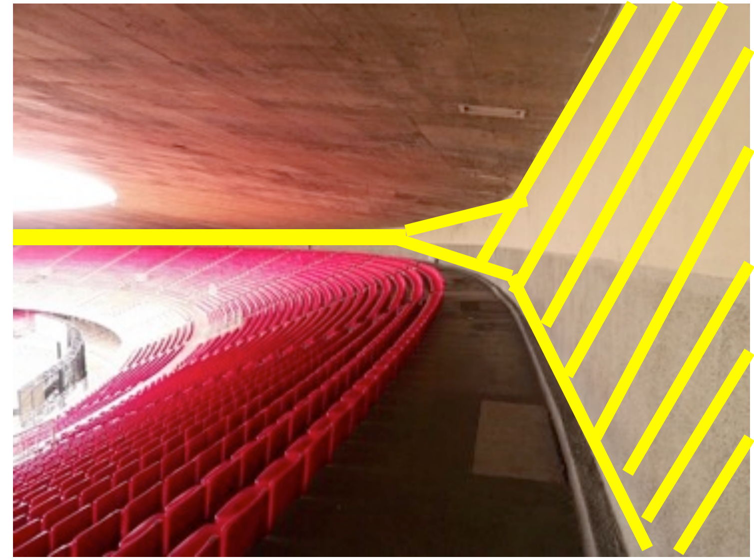
MINEIRÃO – FIFA 2014

SUGGESTED ACOUSTICAL TREATMENT

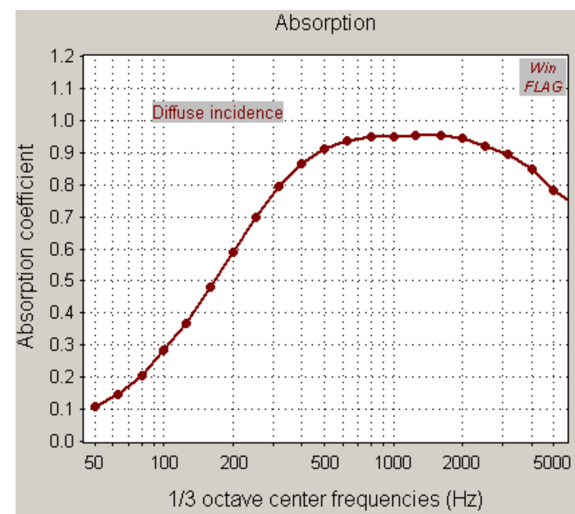




HOLE DIAMETER: 5mm
PERFUARTION GRID (c-c): 10mm
PERFURATION: 20%



ABSORPTION CURVE



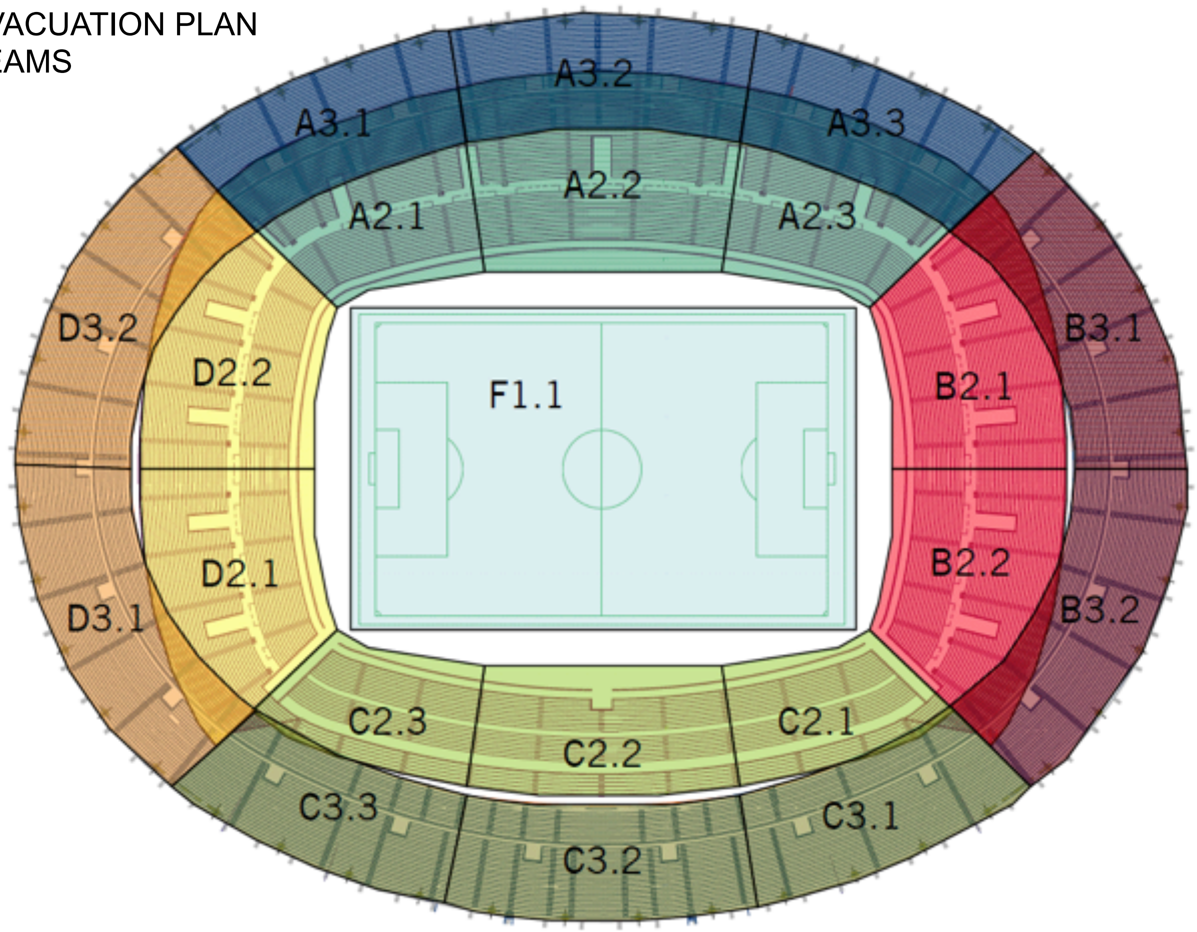
SYSTEMS

REQUIREMENTS - USE

ZONING

MINEIRÃO
STADIUM

- EVACUATION PLAN
- TEAMS



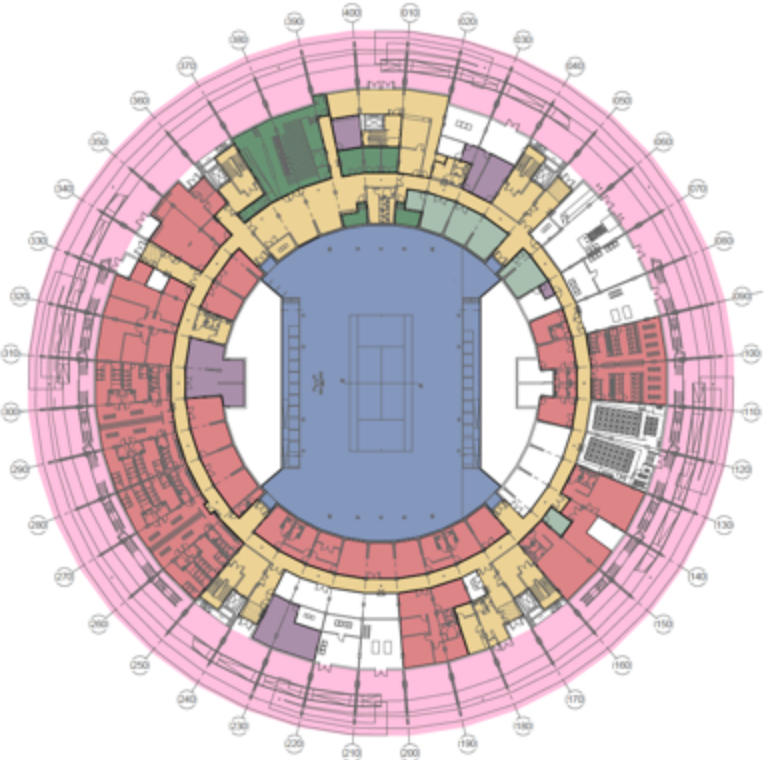
SYSTEMS

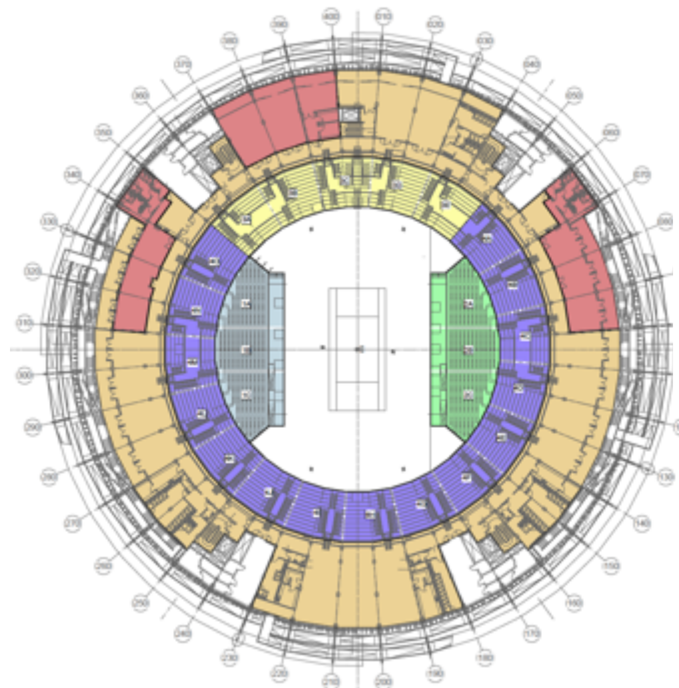
REQUIREMENTS - USE

ZONING

RIO 2016 – TENNIS
01

- PAGING
- EVACUATION PLAN





ÁREAS INTERNAS E FOH:

- MÍDIA - PRESS / TV / BROADCASTING
- CIRCULAÇÕES / CONCESSÕES / ESCADAS / FAMÍLIA OLÍMPICA
- ATLETAS / VESTIÁRIOS ATLETAS / JUÍZES / OFICIAIS
- RESULTADOS / PLACAR / CONTROLES / C.C.R.
- GERAIS
- FRONT OF HOUSE / BACK OF HOUSE

ARQUIBANCADAS E FOP:

- F.O.P.
- ARQUIBANCADA 1
- ARQUIBANCADA 2
- ARQUIBANCADA 3
- ARQUIBANCADA 4
- ARQUIBANCADA 5
- ARQUIBANCADA 6

TABELA DE ALT

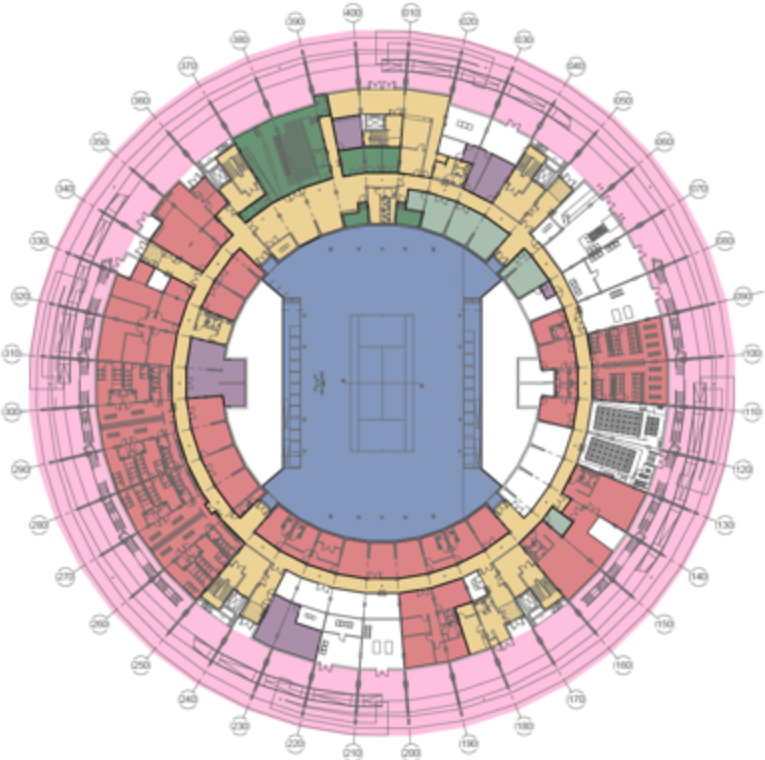
ZONA
FOP
ARQUIBANCAD
ARQUIBANCAD
ARQUIBANCAD
ARQUIBANCAD
ARQUIBANCAD
ARQUIBANCAD
FOP

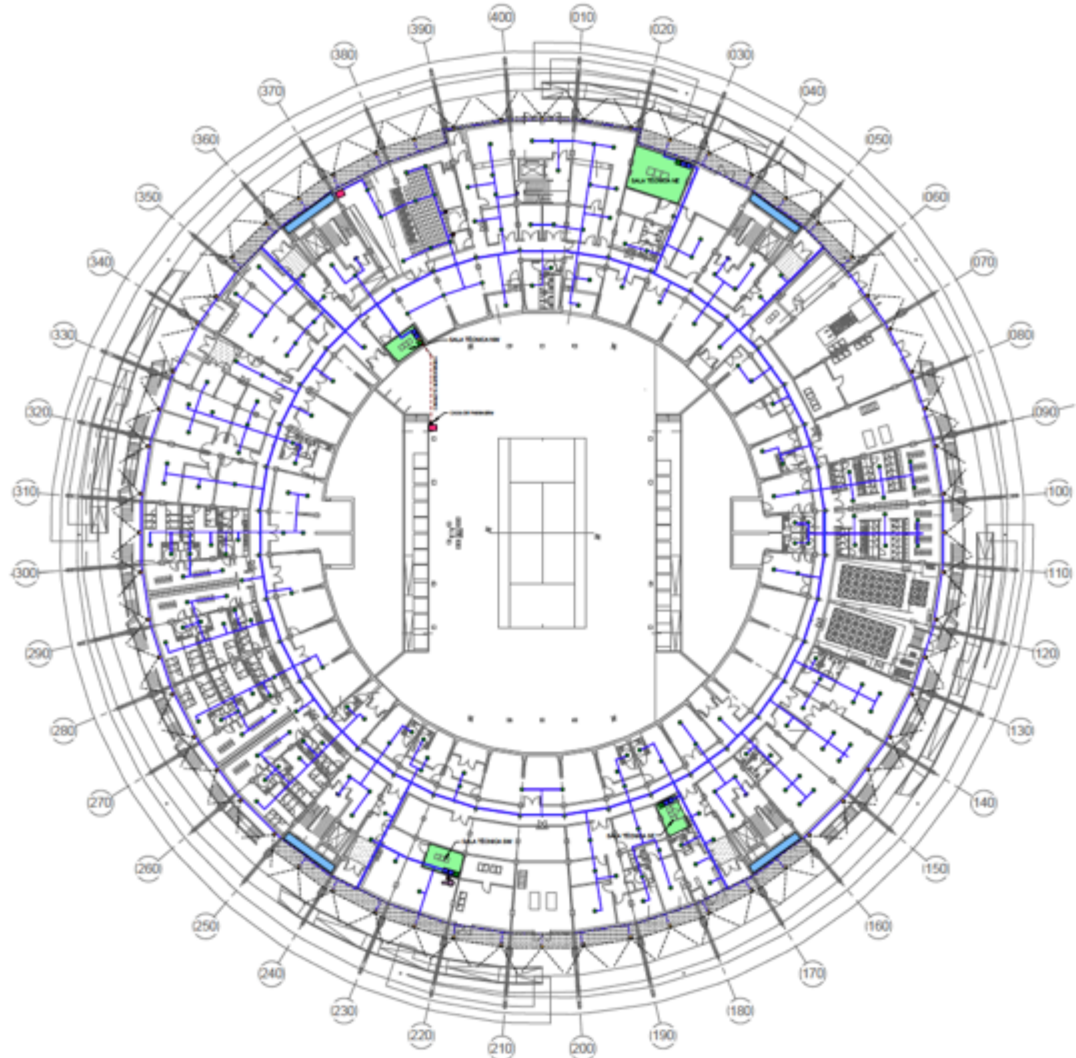
REQUIREMENTS - USE

ZONING

RIO 2016 – TENNIS
01

- PAGING
- EVACUATION PLAN





SYSTEMS

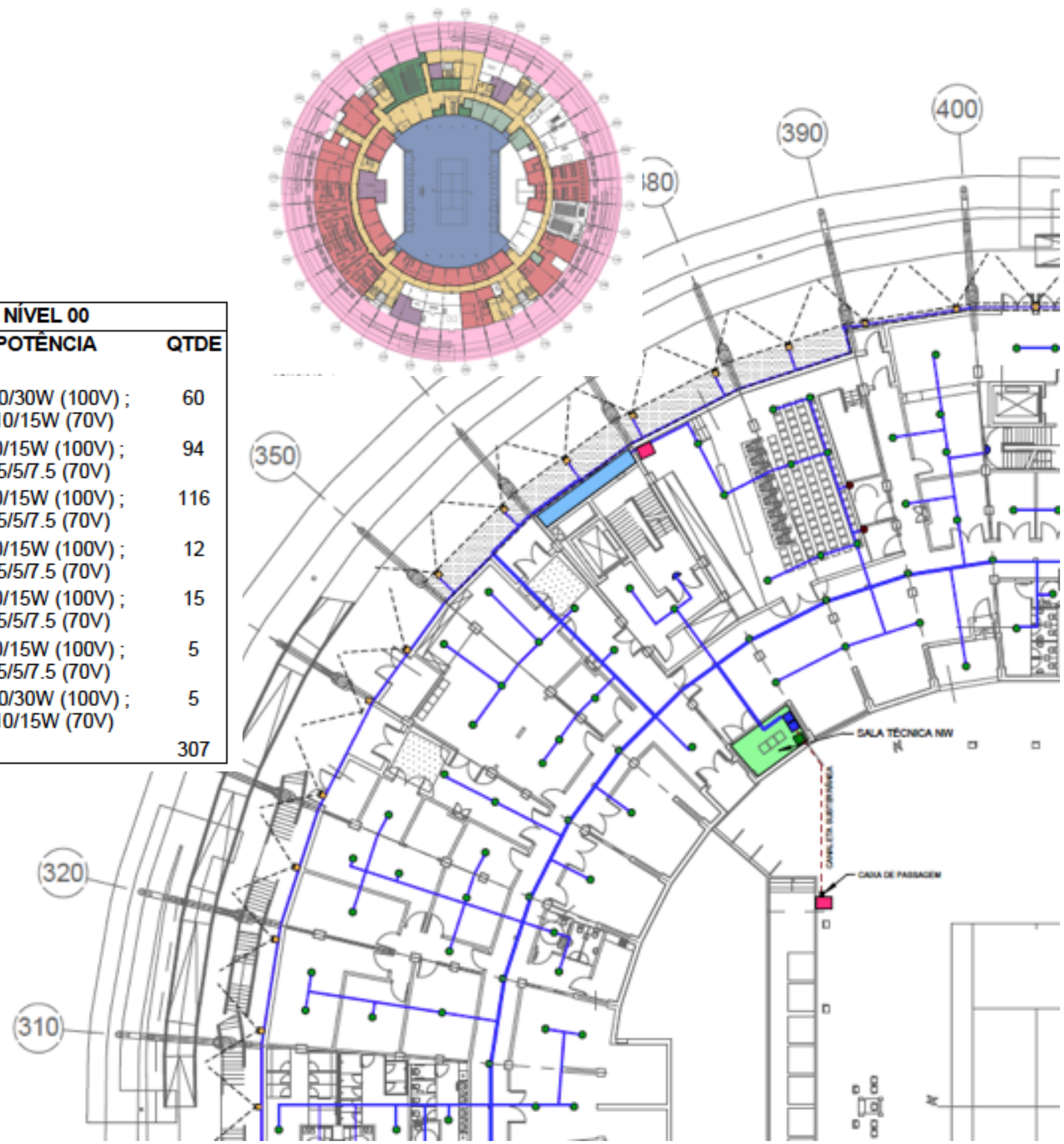
REQUIREMENTS - USE

ZONING

RIO 2016 – TENNIS 01

- PAGING
- EVACUATION PLAN

TABELA DE ALTO FALANTES DAS ÁREAS INTERNAS E FOH - NÍVEL 00				
NÍVEL	**ZONEAMENTO**	**TIPO**	**POTÊNCIA**	**QTDE**
Nivel 00	FRONT OF HOUSE	Externa	10/20/30W (100V) ; 5/10/15W (70V)	60
Nivel 00	ATLETAS / VESTIÁRIOS ATLETAS / JUÍZES OFICIAIS	Forro	5/10/15W (100V) ; 2.5/5/7.5 (70V)	94
Nivel 00	CIRCULAÇÃO / CONCESSÕES / ESCADAS / FAMÍLIA OLÍMPICA	Forro	5/10/15W (100V) ; 2.5/5/7.5 (70V)	116
Nivel 00	GERAIS	Forro	5/10/15W (100V) ; 2.5/5/7.5 (70V)	12
Nivel 00	MÍDIA - PRESS / TV / BROADCASTING	Forro	5/10/15W (100V) ; 2.5/5/7.5 (70V)	15
Nivel 00	RESULTADOS / PLACAR / CONTROLES / C.C.R.	Forro	5/10/15W (100V) ; 2.5/5/7.5 (70V)	5
Nivel 00	CIRCULAÇÃO / CONCESSÕES / ESCADAS / FAMÍLIA OLÍMPICA	Parede	10/20/30W (100V) ; 5/10/15W (70V)	5
				307

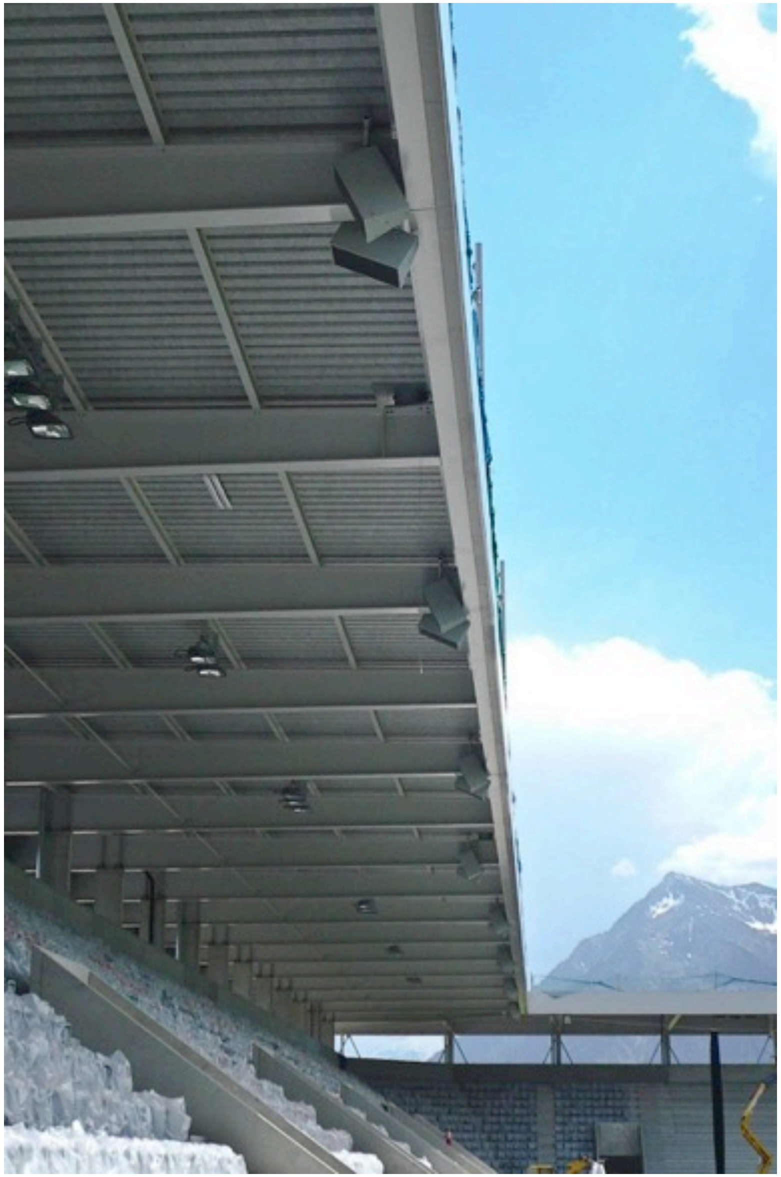


SIMULATIONS X FIELD TESTS

THUN ARENA - SWITZERLAND

REQUIREMENTS - USE

SIMULATIONS X FIELD TESTS

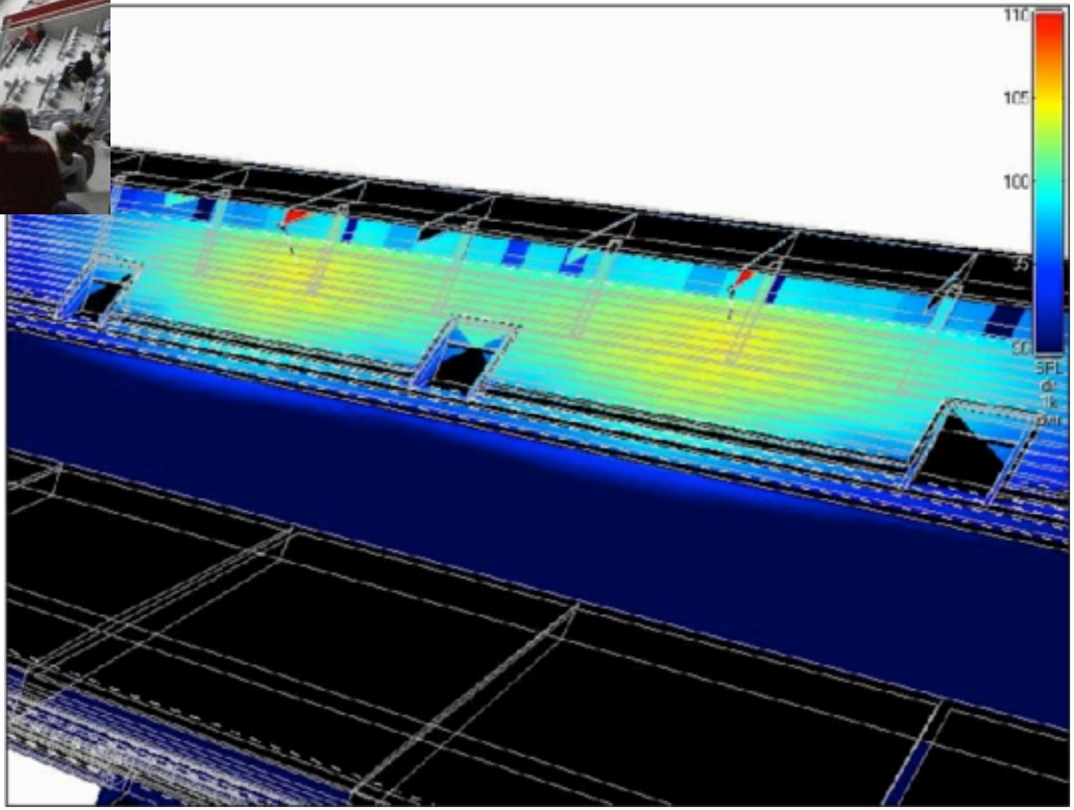


SYSTEMS

REQUIREMENTS - USE

WEATHER CONDITIONS

THUN ARENA - SWITZERLAND

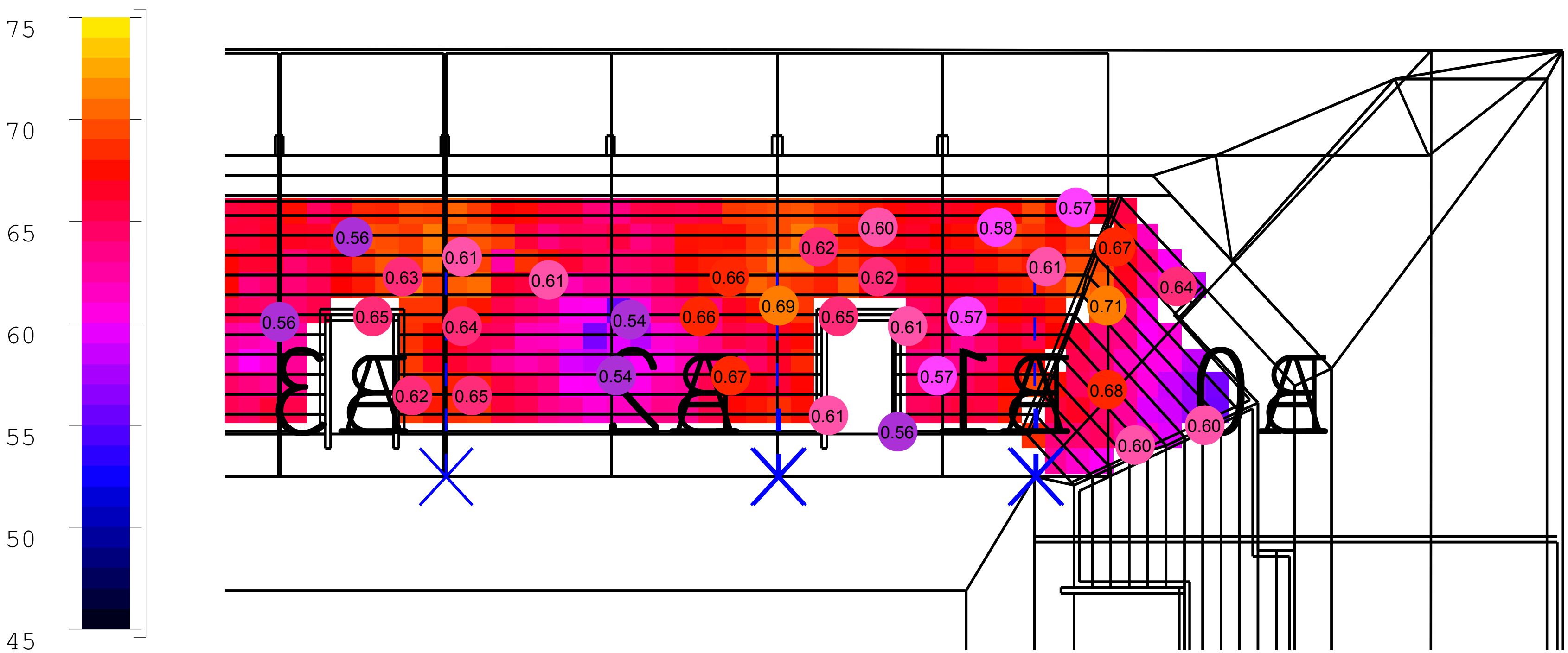


SYSTEMS

REQUIREMENTS - USE

THUN ARENA -
SWITZERLAND

PREDICTION x FIELD MEASUREMENTS

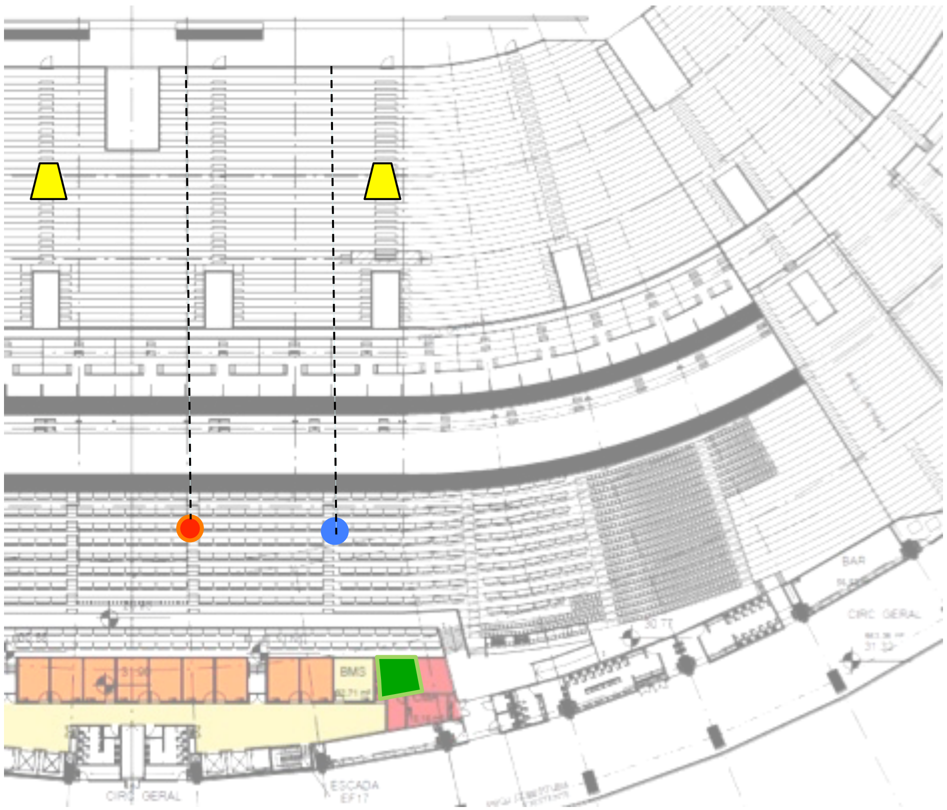


SYSTEMS

REQUIREMENTS - USE

MARACANÃ STADIUM

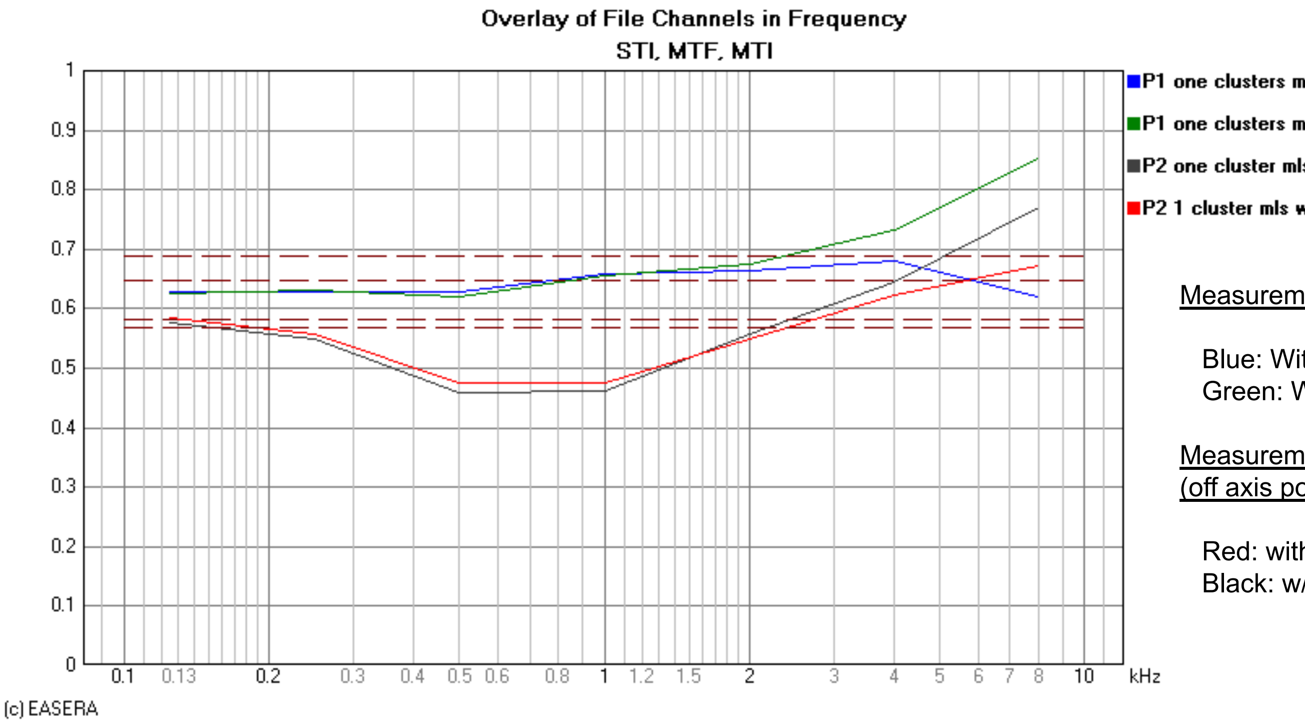
PREDICTION x FIELD MEASUREMENTS



- P1 – ON AXIS WITH THE CLUSTER
- P2 – EQUIDISTANT FROM CLUSTERS
- CONTROL ROOM
- CLUSTERS

MARACANÃ STADIUM

PREDICTION x FIELD MEASUREMENTS



Measurement at P1 – on axis with the cluster:

Blue: With processor on (limiter)
Green: Without processing

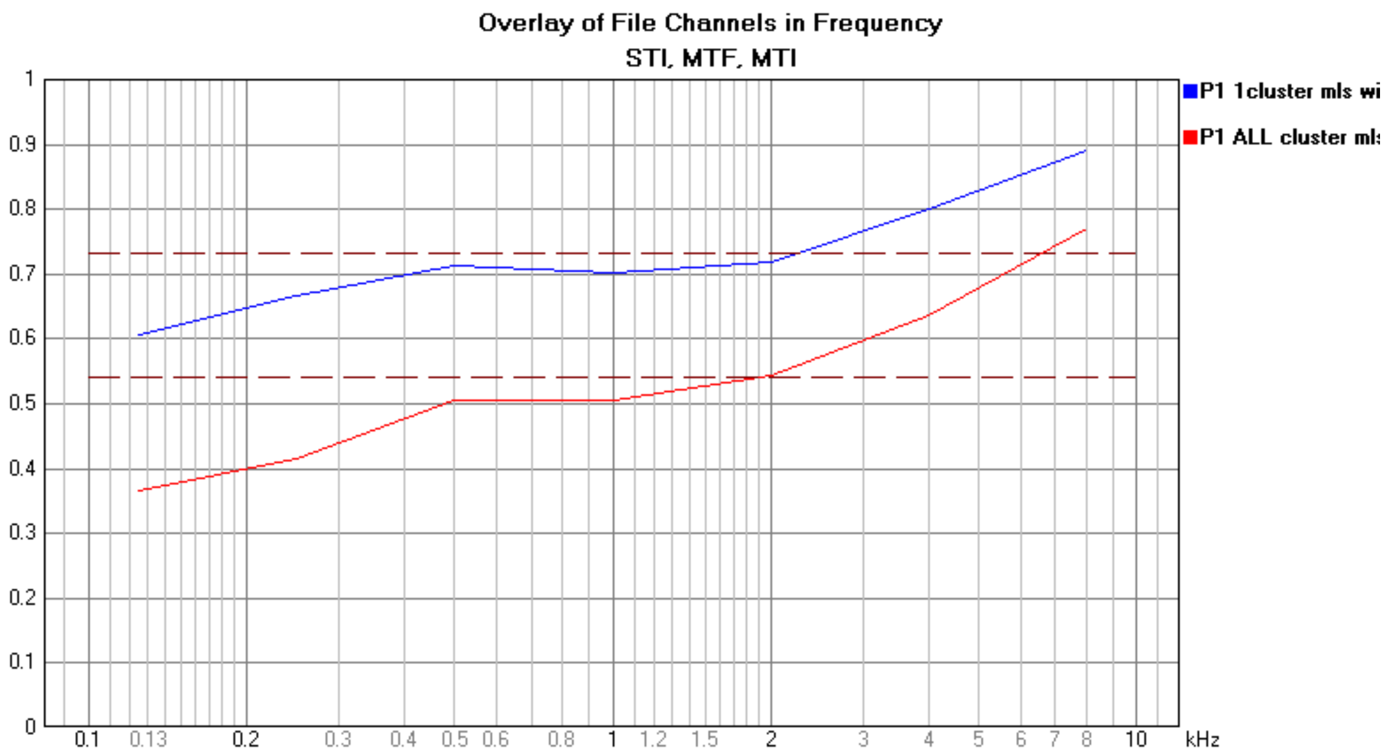
Measuremente at P2 – between cluster (off axis position):

Red: with processing,
Black: w/o processing

With processing activated (EV/Bosch settings) there is a degradation of the STI (P1: -0.04, P2: -0.015).

MARACANÃ STADIUM

PREDICTION x FIELD MEASUREMENTS



Position 1 (on axis, processing on), only one cluster active (Blue, STI = 0.73)* x. All Clusters Active (Red, STI = 0.54).

***Our CATT-Acoustic simulations result in STI de 0.75 in similar conditions (one active cluster, no audience, on axis).**

SYSTEMS

CASE STUDY – TRAIN STATION

Comparison of various sound reinforcement systems

Completely performed as virtual prototyping (no physical installation required!)

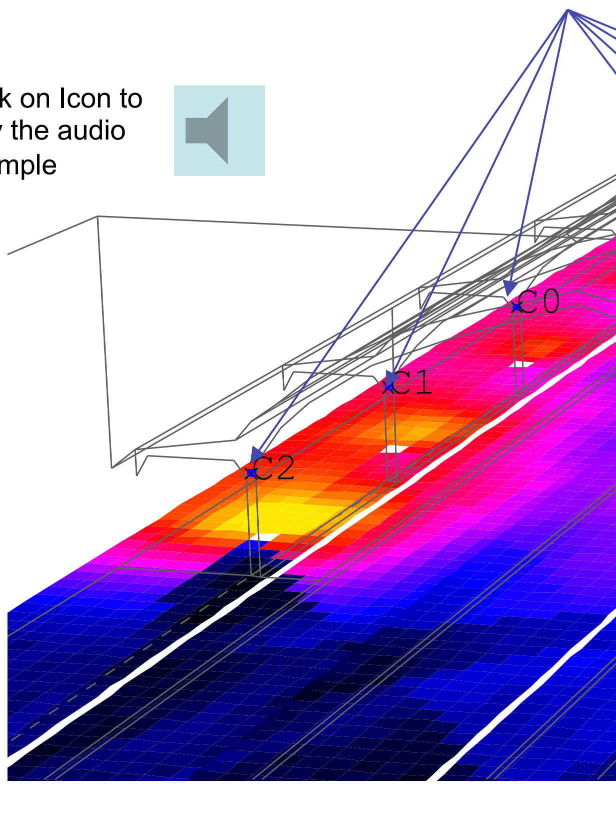
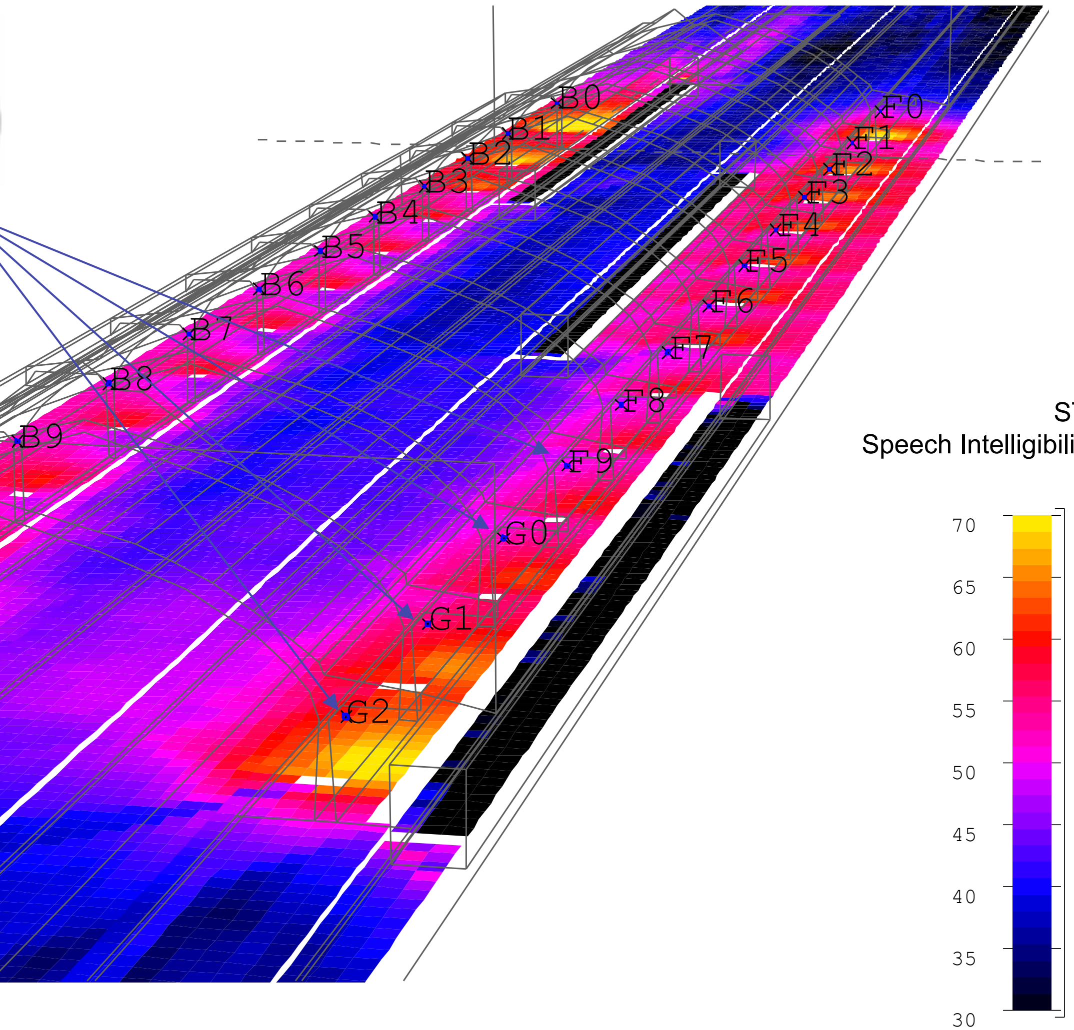
SYSTEMS

CASE STUDY – TRAIN STATION

SYSTEM 1

Broadband direct radiation loudspeaker installed on each roof truss / column

Click on Icon to play the audio example

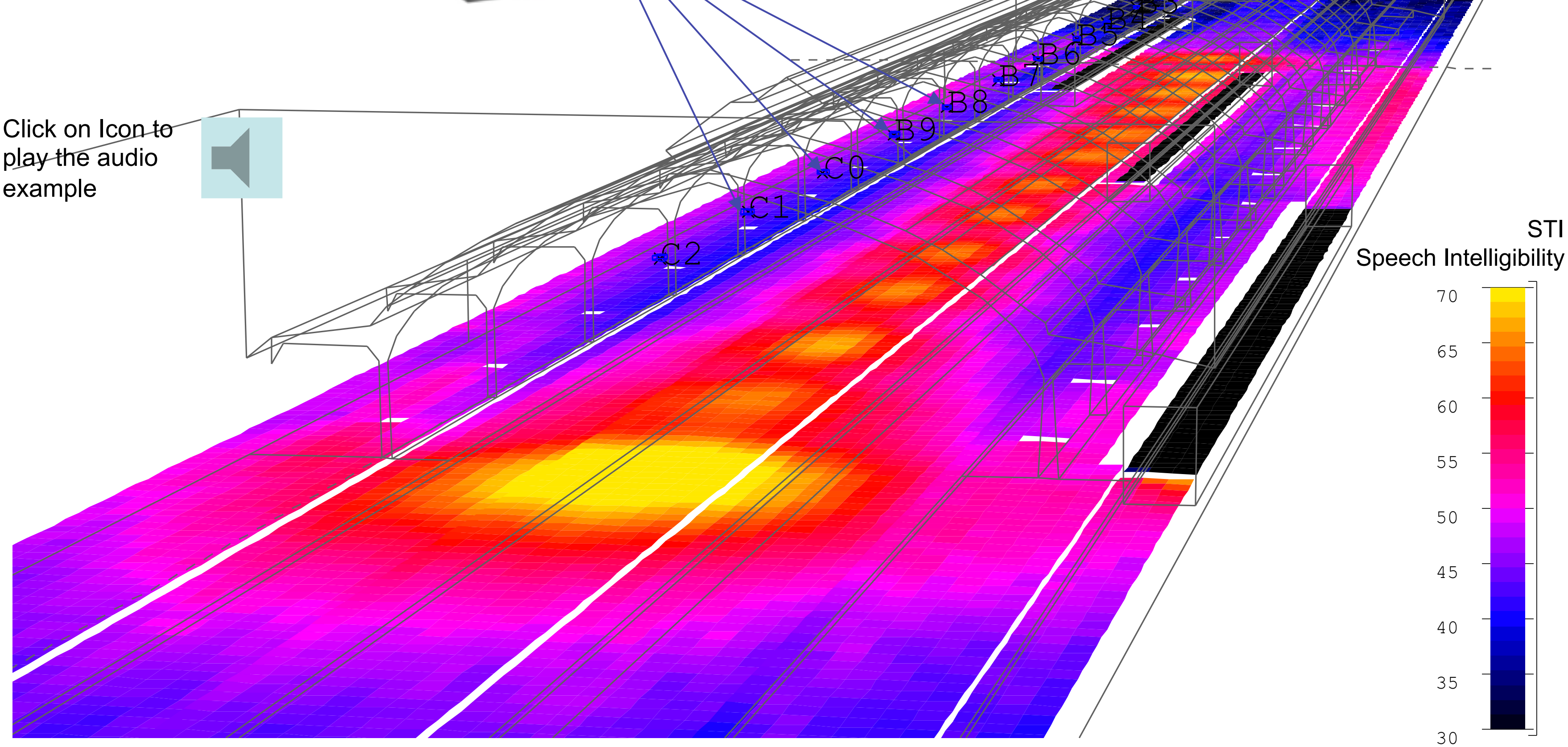
SYSTEMS

CASE STUDY – TRAIN STATION

SYSTEM 2

Two-way horn loaded loudspeaker installed on roof pediment

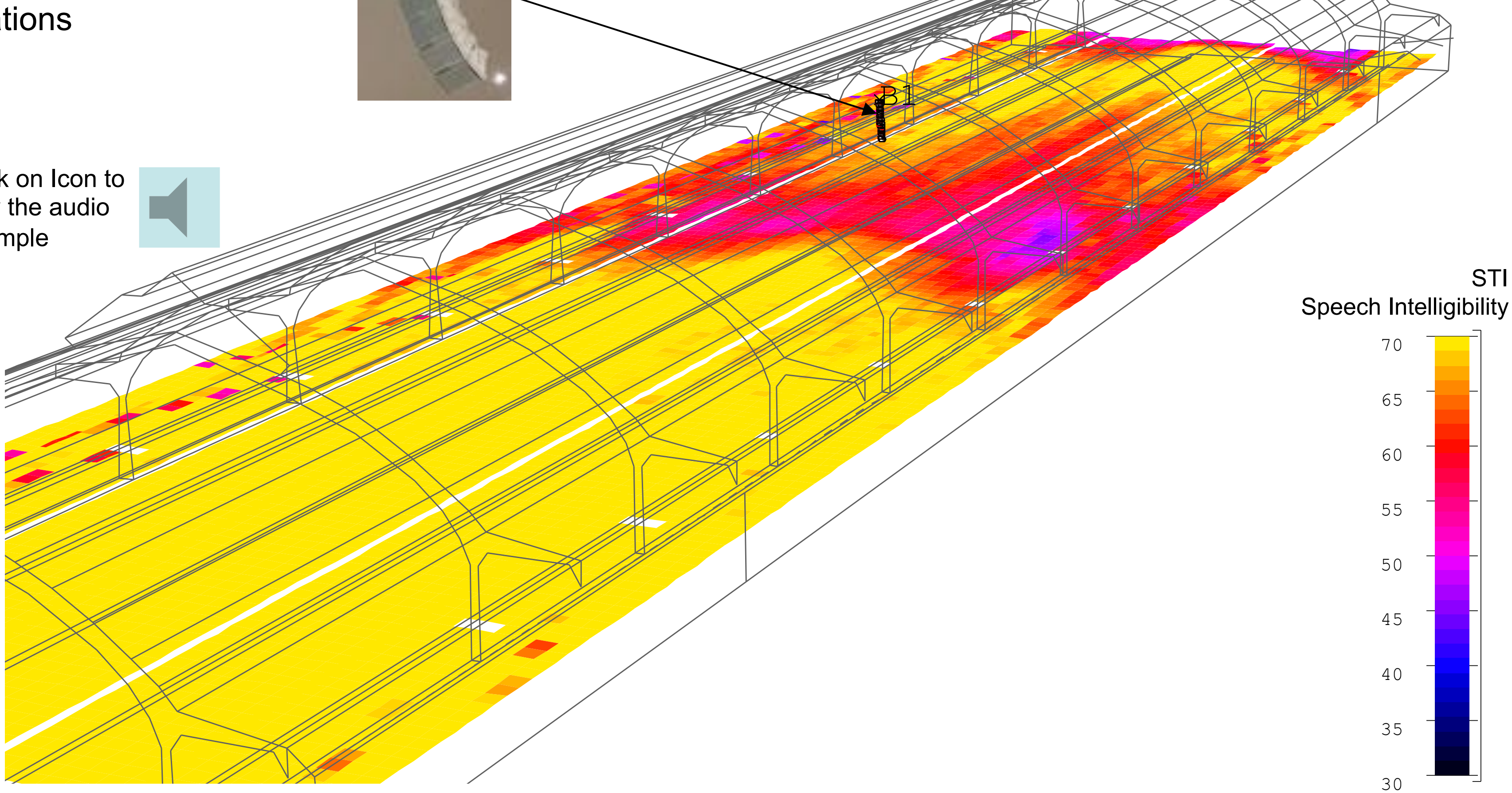
Click on Icon to play the audio example



SYSTEM 3

Multi unit line array loudspeaker (center cluster) hung at two locations

Click on Icon to play the audio example



CONCLUSIONS

- **THE GREAT MAJORITY OF LARGE SPACES, INCLUDING SPORTS ARENAS, STADIUMS, CHURCHES, PUBLIC SPACES, AIRPORTS, TRAIN STATIONS, DEMAND HIGH LEVELS OF INTELLIGIBILITY AMONGST OTHERS.**

- THE PROPER USE OF SIMULATION TOOLS HAS BECOME CRITICAL FOR SOUND SYSTEMS DESIGN.
- THE IMPLEMENTATION OF THESE SYSTEMS WILL SUCCEED WITH THE APROPRIATE COLABORATION, COORDINATION AND DETAILED PLANING THOUGHOUT THE PROCESS.

- A GOOD SYSTEM IS A TUNED SYSTEM!

- WE ARE NOT THE MOST IMPORTANT PLAYERS IN THE GAME AND THE SYSTEMS ARE USUALLY TAKEN FOR GRANTED. BUT IF THINGS GO WRONG WE WILL BE THE FIRST ONES PEOPLE SHOULD AND WOULD LISTEN TO…BUT ONLY IF THEY CAN HEAR US!

GRACIAS!
THANK YOU!

Sergio Molho

Marc Viadiu

www.wsdg.com