ArupAcoustics

Kristin Jones

I Tevereterno

Audio and Visual
Systems Concept Design

Report ref
AAc/71590-50/181/R01

ARUP

ArupAcoustics

Kristin Jones

I Tevereterno

Audio and Visual Systems Concept Design

August 2003

Ove Arup & Partners Consulting Engineers PC
155 Avenue of the Americas, New York NY 10013
Tel +1 212 229 2669 Fax +1 212 229 1057
www.arup.com/acoustics

Job number 71590-50/181

Job title	I Tevereterno		Job number 71590-50/181
Document title	Audio and Visual Systems Concept Design		File reference
Document ref	AAc/71590-50/181/R01		

Revision	Date				
Draft 1	05/02/03	Filename	R01-nwport.doc		
		Description	First draft		
			Prepared by	Checked by	Approved by
		Name	Michael Keane, Alban Bassuet	Neill Woodger	Neill Woodger
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ☐

CONTENTS

1. INTRODUCTION

Kristin Jones (KJ) asked Arup to conduct a study and provide recommendations regarding the engineering aspects of the proposed aural and visual effects envisioned for the Tevereterno project in Rome. This report discusses the background to the study, the analysis work that has been conducted so far and proposes conceptual designs for the audio and video systems .

The proposals have been developed from an initial design charette and report that outlined possible approaches to the achieving the desired effects after feedback and further discussion with Kristin Jones, a survey of background noise and ambient light at the site, and discussions with the soundtrack composers.

The concept designs provide a basis for moving to the next stage of the project. They provide a basis for discussion with sound and video contractors and enable the extent of he system and their potential impact in terms of aesthetics and cost to be more clearly understood.

2. THE PROPOSED EFFECTS

There are three proposed effects for the river. The Sonic Waves, the She Shadows and the Phospor-Essence. Our understanding of the artists concepts for these effects are described below, with some initial discussions regarding the technical complexities of the effect.

2.1 Phosphor-Essence

The intention is to produces the effect of phosphorescence in the water than forms a glistening snake that moves up the river between the two bridges. The effect is intended to be visible day and night.

The key technical decision that needs to be made is whether the effect projected onto the water surface, or is it produced from within the water itself. KJ has clearly stated that the preferred approach is that the solution is driven by the water, as it is the phenomenon of the current that the Phosphor-Essence is intending to augment.

2.1.1 Water Driven Solution

Some of the options discussed for the water-driven solution are as follows:

- A net of small light reflectors on the surface the surface that catch the sun like a fishing lair. These could use the light rods shown in the Appendix.
- Steams of bubbles that act like reflectors when they hit the surface, generated from an array of tubes with electronically operated nozzles under the surface, possibly lit from below.
- Mini-water wheels on the river surface that are small turbines that generate light
- Chemical dyes that are “printed” from a moving print-head like that in an ink-jet painter, onto the moving water surface. The print-head moves laterally across the river printing dye on the river surface as river moves below.
- Carbon dioxide ice-bubbles are released from a line of electronically operated nozzles under the water surface as the water flows above. This uses the ink-jet printer concept above, using bubbles rather than dyes.

Of all these possibilities, the ice-bubble concept offers the simplest solution, although much work would be needed to determine the effectiveness. Further research is needed on mechanical effects, and most importantly, restrictions that would be imposed by the City on the location a nature of any mechanical systems located within the river would need to be understood, particularly with respect to river traffic. It is also noted that much flotsom floats down the river and could become entangled in anything mechanical under the water surface.

Any solution that included lighting the river surface from the below would suffer from the problem of the rivers turbidity - it only has 10cm of visibility, so light sources would need to be located close to the surface.

2.1.2 Projected Solution

Whilst not the preferred solution by KJ, projecting the effect has a number of benefits, as it avoids locating any equipment within the water.

The key problem with the projected solution is that it would be unlikely that the effect would be visible during the day, and the key illusion that the phenomenon is coming from within the river would be difficult to achieve.

A projected solution could consist of either projectors located along each side of the river, or projectors located on each bridge. In both instances, the projectors would need to be synchronized if a seamless image on the river surface was desired.

The projection devices for the Phosphor-Essence effect as currently proposed could be relatively simple, consisting of a high power lamp with a motorized gobo. The illusion of movement of the effect across the river surface would be achieved using the same concept as used in a barber's shop sign.

Lazer sources could also be considered as an alternative, with pinpoints of light being reflected off the river surface.

2.2 She-Shadows

KJ's intention for the she-shadows is described as follows:

"She appears only at night, projected live on the high travertine embankments that contain the river. She is a mutable shadow, a metamorphosis of wolf and woman, the question of wild and tame. In suspended fluid motion, at night she slowly paces the banks of the Tiber, guarding the territory. She sniffs the air, pauses, sits, paws the ground, waits; she listens, is patient, fearless, alone…her shadow figure stretches... transforms, abstracting, then appears again, circulating... graceful and yet deliberate, she is a creature of the night……. she moves more slowly than real time, she moves as if out of time."

2.2.1 Projecting Shadows

Directly projecting a shadow onto a bright surface is not possible, as it is only possible to project light, rather than dark. However, a shadow illusion can be created on a dark wall, by projecting the halo of light around a silhouetted object. The illusion of a shadow will occur whenever the halo of light surrounding the silhouette is brighter than the ambient light leve on the wall surface onto which the shadow is projected.

For the effect to work best, the ambient light level on the wall surface should be as low as possible. This means that the ambient light levels, and the lighting system used for illuminating

the pathway must be considered in conjunction with the projection method, to ensure that the she-shadows are not washed-out by ambient lighting.

The issues associated with the creation of the she-shadows are as follows:

- the projection system could be located either on the same side of the river, or on the opposite side of the river firing across the river
- the illumination of the walking surface will need to be controlled to minimize light spill onto the wall
- the illumination level on the wall will need to determined with knowledge of the ambient light so that a sufficient contrast ratio can be achieved to create a visible shadow.

Depending on the location of the she-shadow projection system, shadows would also be created on the wall as people walked through the beam of the projector. If the projectors are the opposite side of the river, these "people-shadows" would be of relatively constant size, if the projectors are on the edge of the pathway, the people-shadows will vary in size depending on the proximity of the person to the projector. KJ has confirmed that the shadow interplay is a desirable part of the effect.

2.2.2 Projection Options

The projection device required for the she-shadow needs to be capable of producing animated images, so a digital or film projector is required. There are inherent problems with the use of mechanical film projectors ss they would require constant maintenance. It is concluded that at this stage, a digitally projected solution would be the most practical approach to achieve the desired effect.

Assuming that a digitally projected solution is progressed, there are a number of possible options:

- A large number of smaller projectors located along the river that are centrally controlled, synchronized and interlaced to enable the she-shadow the travel the whole length, or along a defined length, of the river.
- A fewer number of large high power projectors that are located on the opposite bank that project over a wider area of the wall. The number of projectors would be determined by the size of the image from each projector.
- A small number of large high power projectors on the opposite side of the river that use an automated mirror systems to pan the projected image along the river.

2.3 Sonic Waves

The intention for the sonic waves is that sounds are propagated along the river to create the effect of sonic waves passing the walker, with the sound appearing to emanate from the water. The sounds will include water effects, speech and music, with different pieces being composed by different composers.

2.3.1 Creating moving sounds

The effect of moving waves is best achieved with a distributed array of loudspeakers long the walkways each side of the river. Each loudspeaker will be on an individual channel to enable sound to transmitted to each specific loudspeaker, or panned between loudspeakers. This will

allow sounds to appear to travel along the river and come closer, pass and move away from the listener.

If the loudspeaker are located only the edge of the river only, it will be possible to pan sounds along the length of the river, but the will be no ability to move the sound horizontally across the walkway – it would effectively be a 1 dimensional sound environment.

To achieve a 2-dimensional control, a line of speakers along both edges of the walkway is needed. For a full 3dimensional capability, where sound images could be moved along the river, across the walkway and up and down, than a second array of loudspeakers would be required above the walkway at a height of around 3m.

From discussions with Kristin and other sound designer, it was agreed that a 2-D system would be progressed on the basis that this gives the sound designers some special control for effects, but retains the desire for the sound to be coming from the river, rather than from the sky.

2.3.2 Loudspeaker selection

The loudspeaker devices would need to be selected based on the final layout, the required sound quality and sound power, and the environmental conditions along the river. The following factors are important to consider in the design:

- the characteristic and sound level of the ambient background noise along the river – excessive traffic noise could limit the success and naturalness of the sound effects
- the maximum spacing of the loudspeakers required to realistically create the sound designers effects – this will depend on the nature of the sounds
- the appropriate frequency response and power handling requirement of the loudspeaker – this again will depend on the intended nature of the sound effects
- the directivity of the loudspeakers required to maximize the realism of sound traveling towards the listener, whilst minimizing cross-river sound-spill (this could be heard as an echo) and limiting sound-spill to any residential/sound-sensitive areas adjacent to the river

As with the projection system, the loudspeaker arrays will need to be interlaced and synchronized from a central processor.

3. SURVEY AND ANALYSIS

3.1 Site Survey

A site survey was conducted by Neill Woodger of Arup during the early evening of December 18th 2002 and the mid morning of December 19th 2002. Measurements and recordings were made of the ambient noise and light levels on the bridges and on the walkways along the river.

The background noise levels were dominated by traffic noise on the two roads either side of the river. During the evening measurements, traffic was backed up, whilst in the morning measurements it was more freely flowing.

The noise levels in the middle of the bridge were typically 60-65dBL_{Aeq}, whilst the noise level at the edge of the river was typically 55-60 dBL_{Aeq}, as shown in Figure 1. This is a high level of noise both on the bridge and walkway and, assuming that the audio system produces sound levels of no greater than 95dBA, limits the available dynamic range for the compositions to around 30dB. This fact should be considered by the composers when developing their works.

The ambient light level in the middle of the bridge was 32000lux in the daytime, at 10.30m with a blue sky, and 24lux under the street lights at nighttime. At the river edge, the ambient light levels were 4250lux on the wall in shadow during the daytime, and 2lux under the sidewalk illumination at nighttime. The levels of light on the proposed projection walls are very low, even with the current street lights at high level on the large walls.

This low ambient light levels at means that a corresponding low level of projected light is needed to achieve the contrast ratios required to produce a good shadow effects. This could however increase if additional illumination of the walkways either side of the river is required by the City as part of the project.

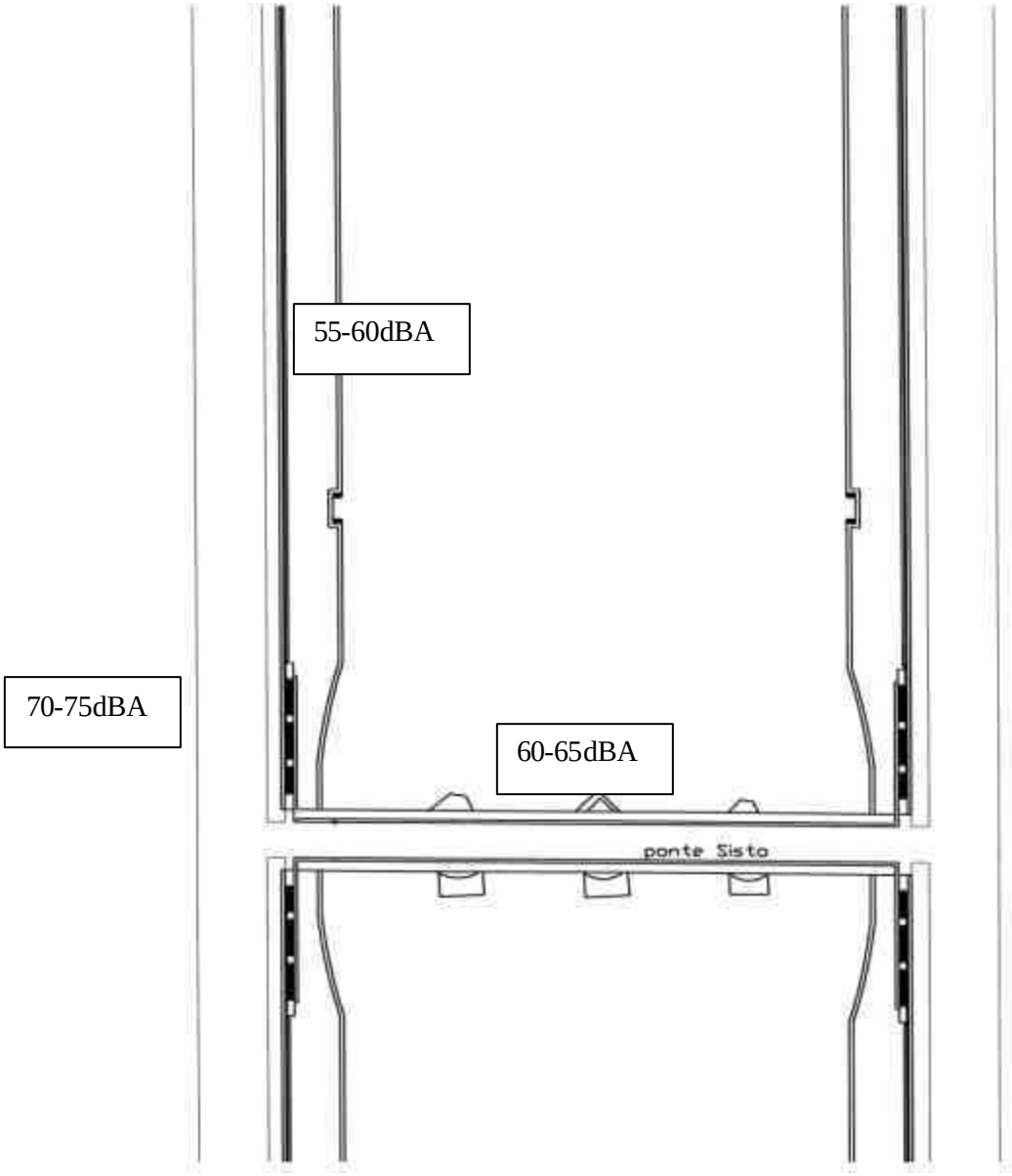


Figure 1: Measurement of sound levels at representative positions around the river.

3.2 Projection Analysis

The projection analysis considered two issues. Firstly, understanding the parameters associated with the production of a shadow effect, and secondly assessing the options for projecting the shadows.

3.2.1 Shadow Illusions

Using our light and sound laboratory, a static image of a glow effect around a black disk (the "eclipse" in Figure 2) was produced to enable the contrast ratios needed to generate the shadow effect to he studied.

Using a luminance meter to measure the contrast ratio, it was determined that only a very small difference, less than a factor or 2:1, was needed between the brightness of the projected glow and the background light on the surface for the shadow illusion to be present.

The illusion is strengthened due to the phenomenon that the darkness of the shadow appears to be darker than the area outside the glow effect, even though measurement actually shows the shadow to be brighter than the outside zone.

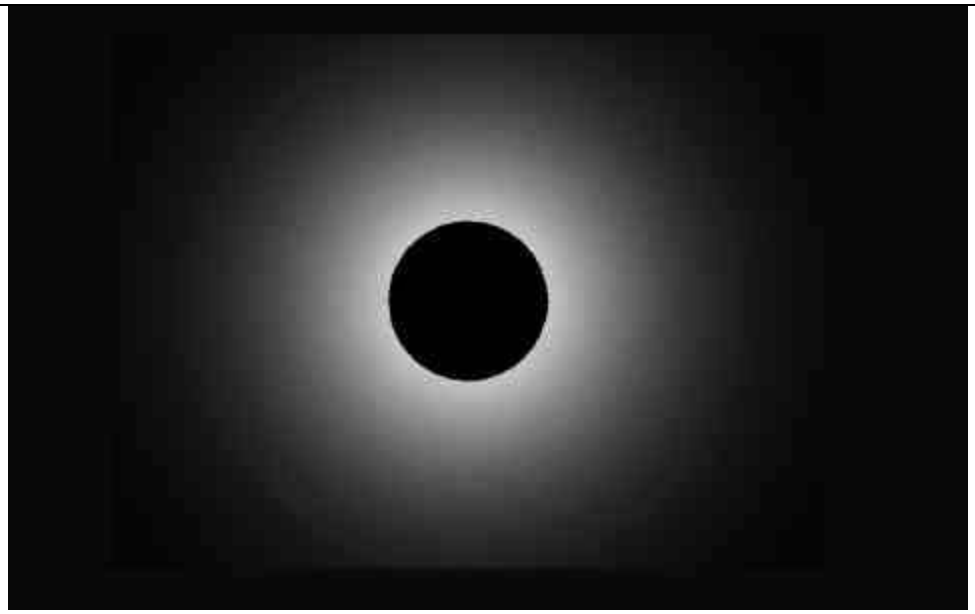


Figure 2: "Eclipse"

An investigation was undertaken to determine the most efficient was of digitally animating the glow effect around a moving image. This was done by taking a standard 3-D animation of a character walking, defining an "Alpha Channel" around the perimeter of the character, then using the "Glow" effect in 3-D Studio to apply a glow to the perimeter. These are standard techniques in 3-D Studio, and can be applied to any animated movie once it is in digital format (Figure 3).

Figure 3: "She-Shadow"

3.2.2 Projection Analysis

The projection distance across the river is 105m, the height of the projection wall is 12m and the length of the projection wall is 450m. This is a huge area to cover, as a comparison, a very large projection screen in a large movie theatre is 10m high by 20m wide.

As discussed previous there are two alternatives for achieving the projection, a distributed array of projectors that spans the whole length of the walkway, or a smaller number of moving projectors that produce a smaller image that is mechanically panned along the wall.

The distributed array can be achieved with either short throw or long throw projectors. Both options require similar power projectors as the image size is the same in each case. The short throw option would require small projectors with a lens focal length of around 1:1 located along the edge of the walkway to be on at least 10m centers, resulting in approximately a requirement for 90 projectors. Each projector would need to be bright enough to produce a image size in the order of 12m x 9m, which is a very large image itself and requires a high power projector.

The distributed long throw option would require projectors located across the river. Assuming a maximum available focal length of 12:1, this would result in an image size of 9m x 12m, and would also require 90 projectors to cover the whole length of the river.

Both of these scenarios would appear to require unfeasibility large numbers of expensive, with complex control software to allow moving images to seamlessly pass along the array of images.

For this reason, a moving projector is recommended. There are again two options, either a single short throw projector mounted on a rail or trolley system, that moves parallel to the walkway along the river, or a number of fixed long throw projector mounted across the river that pans the image along the wall using a moving mirror.

The easier option from an installation perspective is to use a small number of fixed long throw projectors located on the wall across the river and to use a panning mirror to move the image. From a geometric analysis of the angles, and some practical test panning projectors in the sound

and light lab, it was determined that the range or panning should not be more than 30 degrees from the perpendicular. Allow some overlap of the image, this means that 3-4 projectors are required each side of the river to cover the whole 450m stretch.

The key issues that need to be addressed to make this option work will be to solve the keystone distortion and intensity variation as the image is panned along the wall. This can potential either be done using software to pre-adjust the image digitally before projection.

3.2.3 Projection Brightness

The brightness of the projected image is dependent on the size of the image. In both short throw and long throw scenarios, the image size is expected to be in the order of 9m x 12m, which is an image size of 108m2. Based on the previous study, a contrast ratio of 2:1 is required to achieve a shadow effect, and the ambient light level on the wall is 2 lux., so a light level of 4lux is required from the projector, over an area of 108m2. This gives a brightness requirement for the projector of 10,000 ANSI Lumens, assuming that the wall surface has a reflectivity of 40%.

The contrast ratio can be improved by decreasing the image size, which can be achieved by using a longer throw lens. The longest throw lens available for a 10,000 ANSI lumen projector is approximately 15:1, resulting in an image size of 7m x 9.3m, with area of 65m2. Assuming the same parameters the resulting brightness on the screen would be 6.6lux, or a contrast ratio of 3.3:1.

Further improvements could be achieved with specially designed lenses with even larger focal lengths, although these would need to be built specially for the project.

3.3 Audio Analysis

The audio analysis consisted of determining the requirements for the sound system to create Sonic Wave effects on each side of the river. The issues for the sound system are the choice of the loudspeaker design to create realistic moving sounds along the platform, the residual background noise created by the traffic, and the possible echoes created by loudspeakers located on each side of the platform.

To determine the performances of the sound system, we used computer modeling to simulate the acoustic on each side of the river. The acoustic properties of each element of the architecture such as absorption and diffusion coefficient including air, water, and the loudspeaker properties have been imported into the computer model.

3.3.1 Moving sounds: loudspeaker layout concept

To create the illusion of moving sounds on the horizontal plane of the platform, two positions of loudspeakers are needed. One needs to be close to the river, and one close to the wall. Those two loudspeakers create a stereo pair, which can create the illusion of sound moving at any distances between across the platform. Then, to make the sound traveling along the side of the river, this stereo pair of loudspeaker needs to be extrapolated all along the platform. This results in two lines of devices, where each loudspeaker close to the river and each loudspeaker close to the wall create a pair. It becomes then possible to create the illusion of sound moving anywhere on the listening plane parallel to the platform. Sound can be pushed forward on the platform, by changing the level between pair of loudspeaker. Sound can be moved across the platform, by changing the level between each loudspeaker constituting a pair. Figure 4 represents the loudspeaker layout concept.

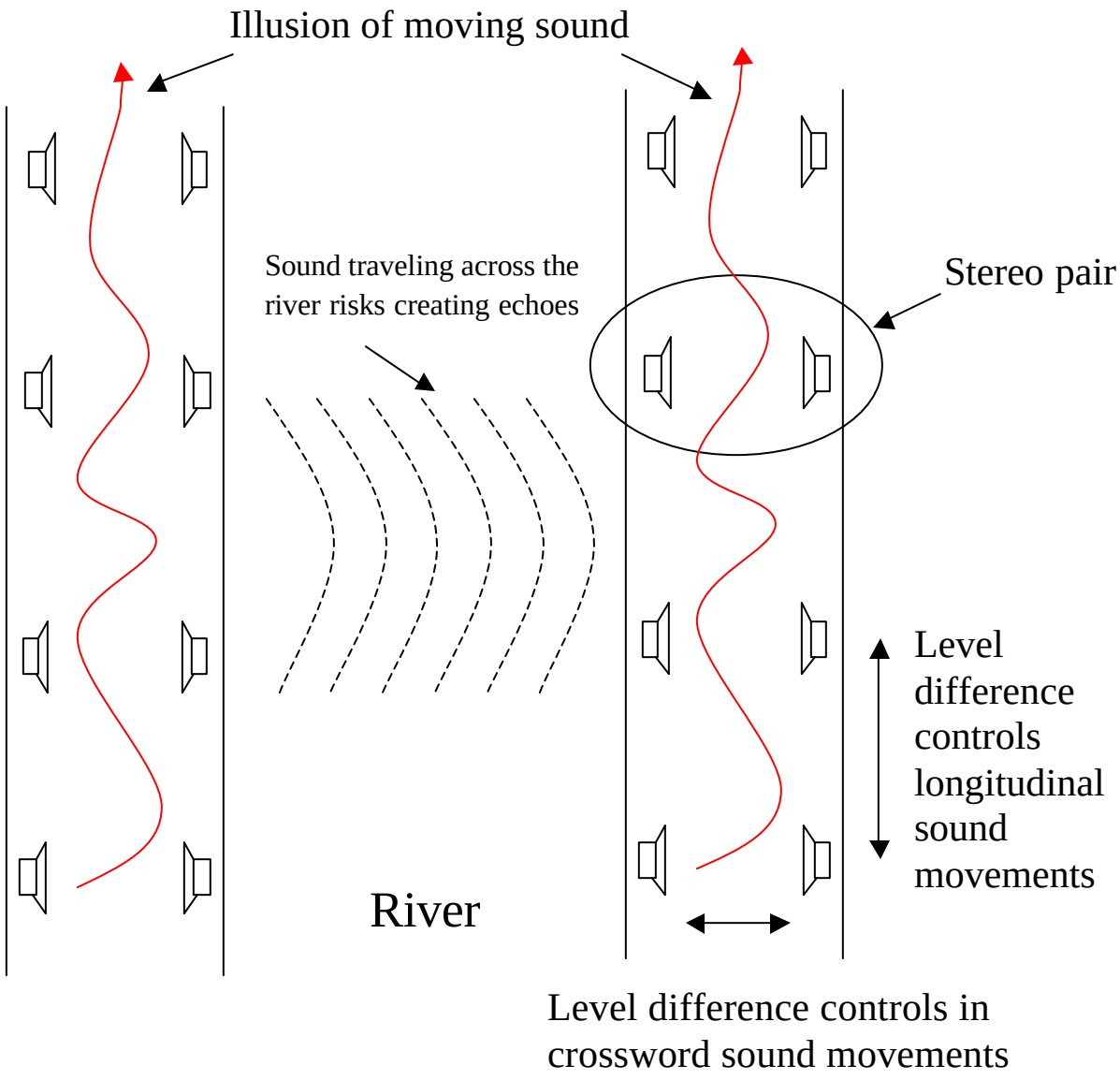


Figure 4: Loudspeaker layout concept for creating Sonic Waves.

3.3.1.1 Prediction of loudspeaker system performances

We built a computer model of the river with the loudspeaker system. Modeling all the loudspeakers on the platform is not necessary as only a few loudspeakers around the listening positions are important for creating Sonic Waves. The other loudspeakers have a minimum contribution to the sound. Therefore, for the calculation, five pairs of loudspeaker around a listening position on each platform have been chosen as a representative situation. Figure 5, 6 and 7 show some renderings of the computer model. Figure 8 shows a visualization of the in-ground mounted loudspeaker on the platform, during daytime.

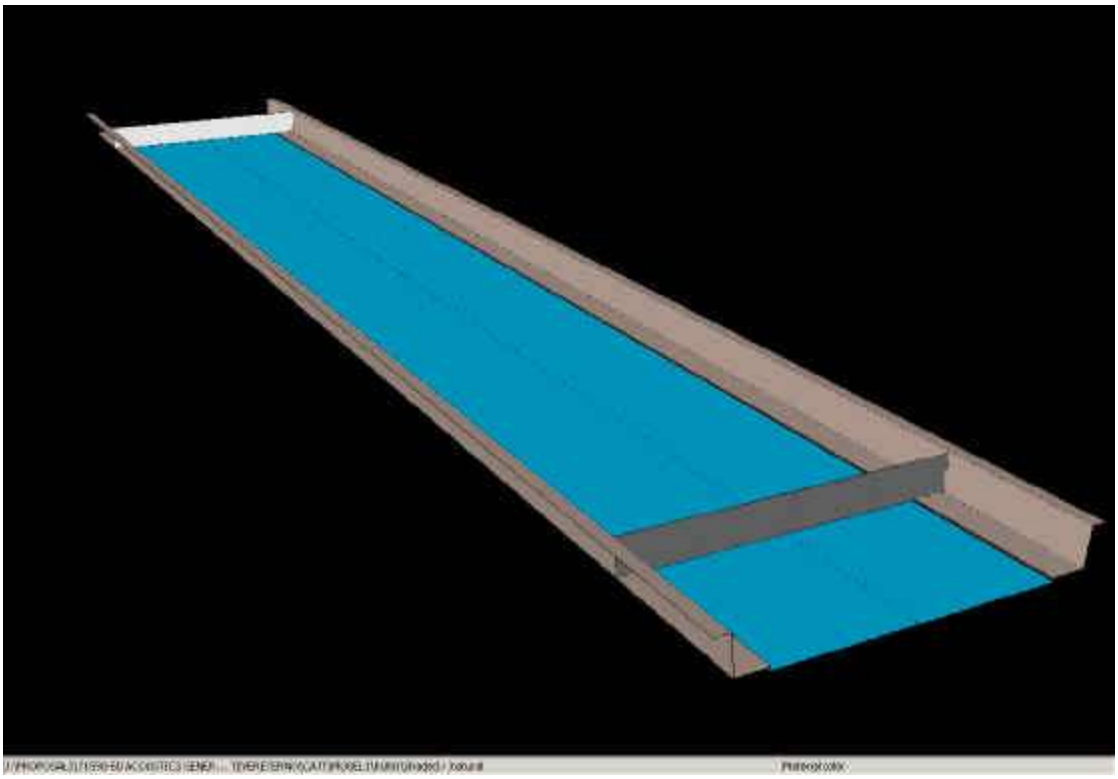


Figure 5: Computer model rendering

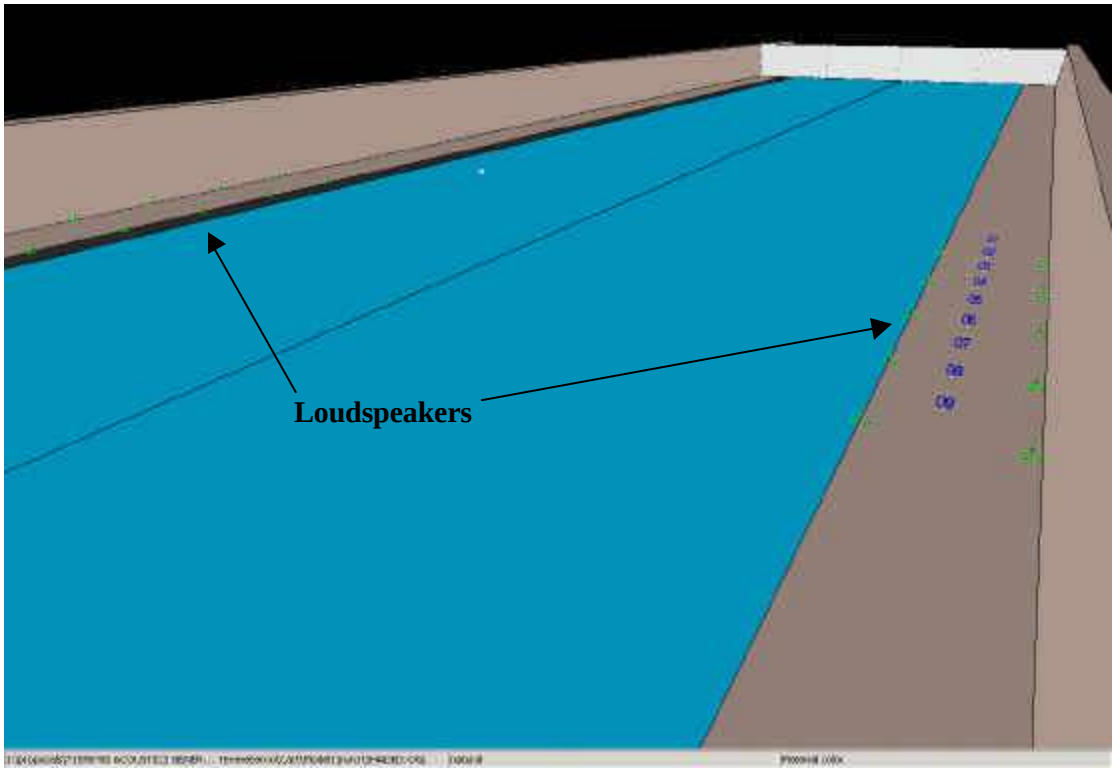


Figure 6: Computer model rendering, showing the loudspeakers positions in green, and the receiver positions in blue, where the acoustics is calculated.

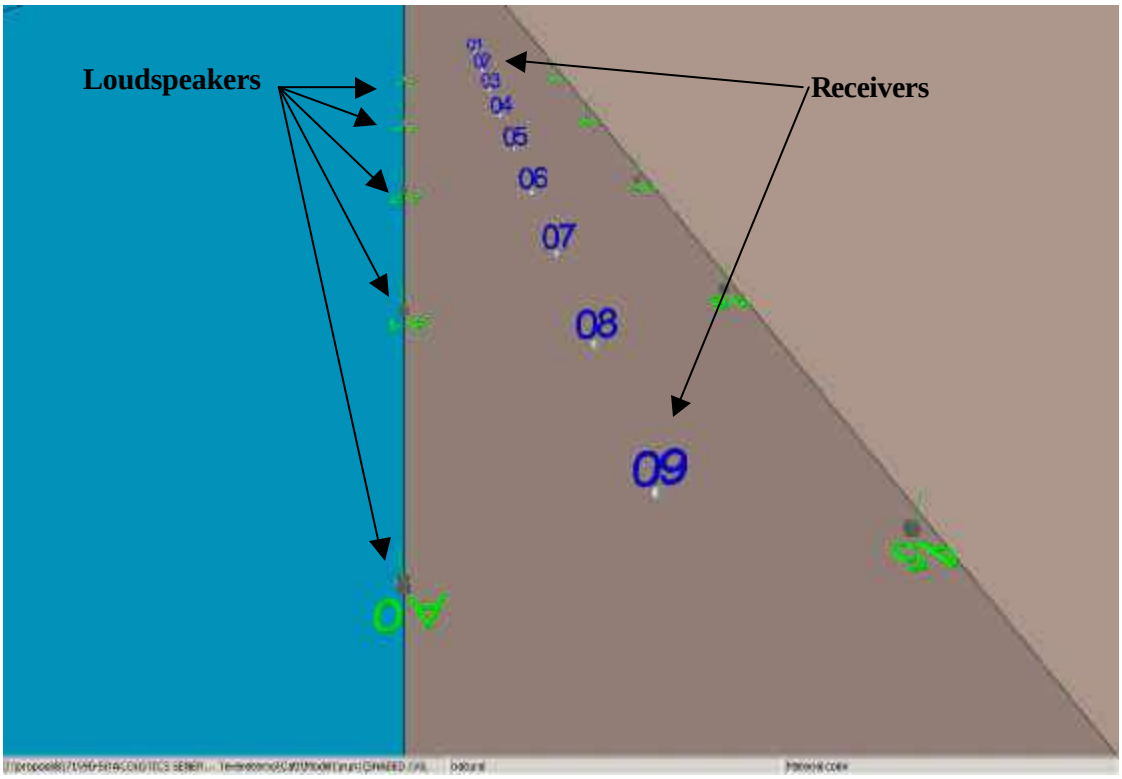


Figure 7: Computer model rendering, showing the loudspeakers positions in green, and the receiver positions in blue, where the acoustics is calculated.

The outputs of the model were used to reproduce the Sonic Waves in the Arup listening SoundLab, using some of the materials from the sound engineers hired for the project.

Different types of loudspeaker and distances between devices have been tested. The optimum design consists of omni-directional loudspeakers separated with 10.5 meters. This design provides a uniform sound coverage and creates the illusion of smoothly moving sounds along the platform.

Figure 8 shows the response of the sound system to an impulse of sound. It can be seen that the loudspeakers located on the opposite side of the river create echoes 25 to 30 dB lower than the level produced by the nearest loudspeakers on the platform. Assuming that the listening level on the platform will be around 85 dB SPL, the level of the echoes will be between 50 to 60 dB SPL. Considering that the average background noise level created by the traffic is around 60 dB SPL, the echoes will disappear within the background noise, without creating any disturbances. We checked by listening to the computer model mixed with the sound of the background noise recorded during the site survey, that the echoes disappear within the level of the traffic noise. No echoes are perceived.

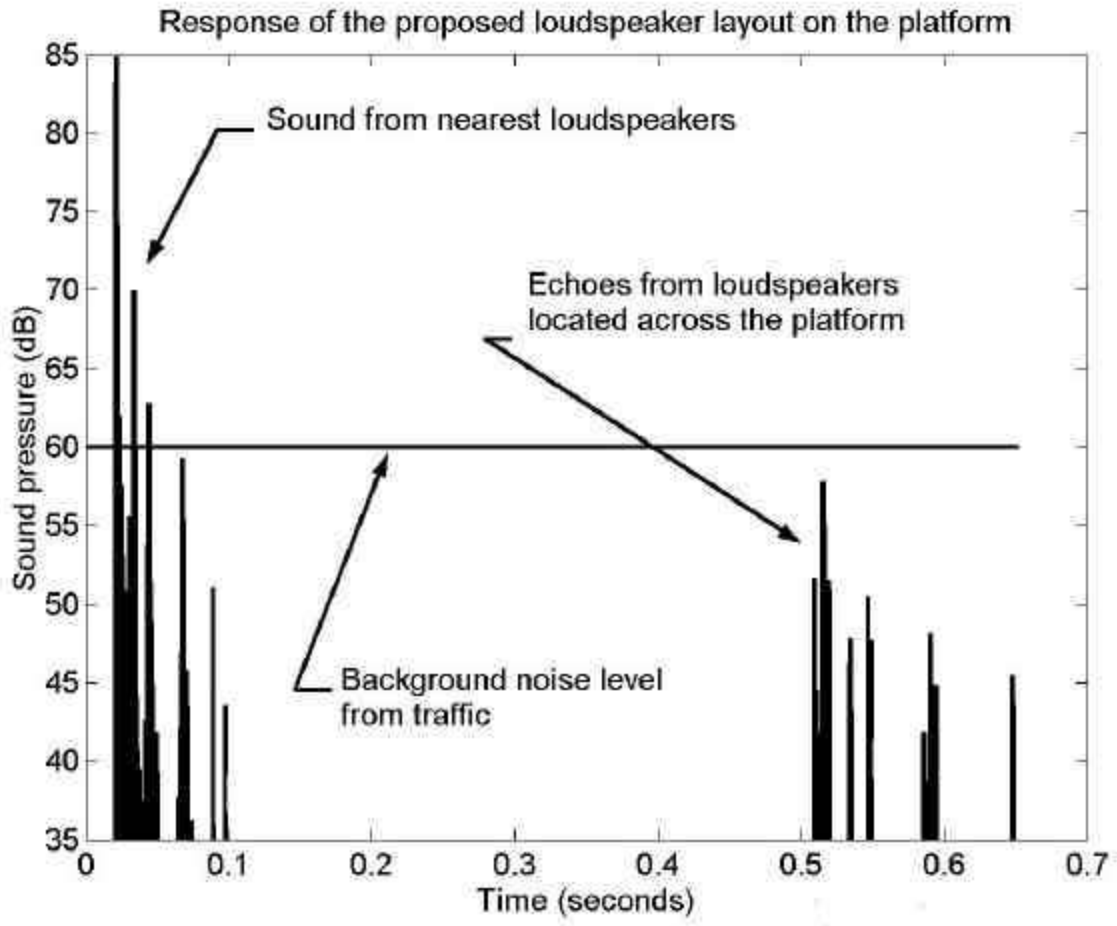


Figure 8: Response of the sound system to an impulse at one position, showing the direct sound from the nearest loudspeakers and the echoes from the loudspeakers located across the platform, with a delay of half a second. It can be seen that the level of the echoes are under the level of the background noise created by the traffic.

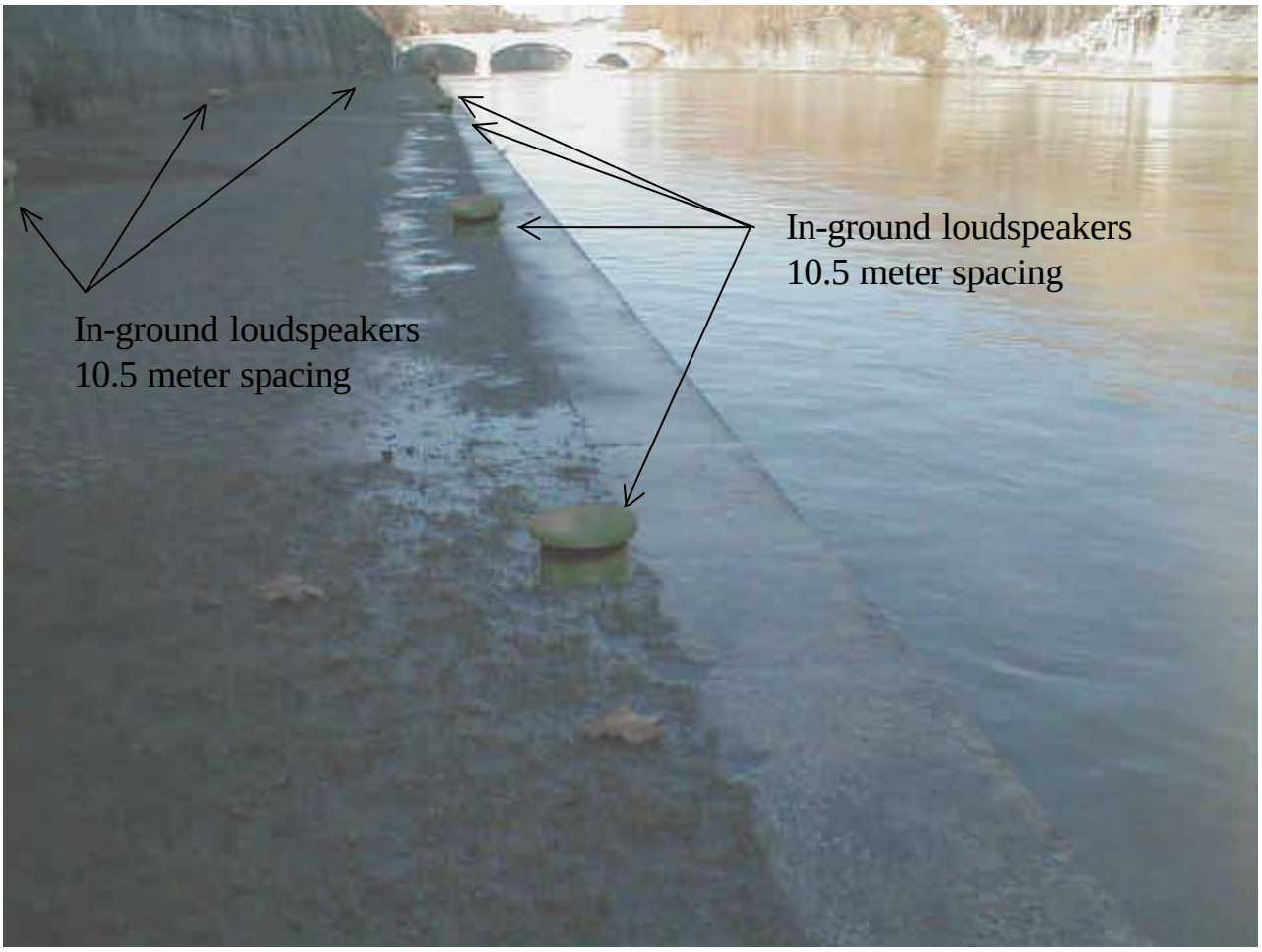


Figure 9: Visualization of the in-ground mounted loudspeaker on the platform, during daytime.

3.4 Proposed Audio System

This section proposes the audio equipment set up for creating the Sonic Wave effects.

3.5 Audio Equipment

3.5.1 Loudspeaker type

The option chosen for the loudspeaker is an omni-directional radiating device with minimum visual intrusion, and high efficiency:

- Outdoor ground mounted loudspeaker, with the possibility to plant the loudspeaker into a decoration
- Loudspeaker minimum frequency range: 60 Hz – 16 kHz ± 6 dB
- Omni-directional directivity in the range 60 Hz – 10 kHz
- Loudspeaker efficiency: > 90 dB SPL @ 1m, 1Watt

Ground mounted loudspeakers with a minimum of visual intrusion will create the illusion of sounds coming from the river.

90 dB SPL is the minimum recommended efficiency to achieve the required sound level on the platform. Efficiency level above 90 dB SPL allows reducing the power of the amplifiers and therefore their cost.

The choice of additional sub-woofers is not justified because the background noise from the traffic will mask the sound effects at low frequency. Additional sub-woofers would also be visually intrusive, and would require additional expensive amplification.

Omni-directional loudspeakers will help creating smoothly moving sounds across the platform. The choice of omni-directional loudspeakers will avoid the effect from traditional loudspeakers that reinforce the sound towards their main axis of radiation. For this reason, the choice of horn-loaded loudspeakers is to be avoided.

The company TIC Industries (Canada – USA) is specialized in the manufacture of outdoor omni-directional loudspeakers. The products GS 3T, GS 5T and GS 10 have the features described above. We would suggest using these loudspeakers, or any equivalent devices manufactured in Italy or Europe that meet these requirements.

As described previously, the loudspeaker layout consists of two parallel lines of loudspeakers on each side of the river. Considering the optimum loudspeaker spacing of 10.5 meters, as described in the system performances prediction section, the total number of loudspeaker is 192. It is a multiple of the number 2 as this is more compatible with the available audio electronic devices. they typically operate on number of outputs such as 24 - 48 - 96. The array of loudspeaker on the inside of each platform should be as close as possible to the river. The array of loudspeaker on the outside of each platform should be as close as possible to the wall.

3.5.2 Amplification

The amplification consists of 12 units of 8 channels amplifiers (96 channels per platform), as each loudspeaker is a separate channel. The choice of multi-channel amplifier allows reducing the price of each channel of amplification and the rack space needed. Each channel should be at least 100 Watts RMS @ 8 ohm to provide sufficient continuous sound level above the background noise and headroom for transient sounds to be reproduced without distortion. The

amplifiers do not need to use high voltage lines and transformers, such as 70 Volt lines, as each channel of amplification is dedicated to a single loudspeaker. Moreover, high voltage amplification is less cost effective, as it requires additional transformers inside the amplifiers. There is no justification for high voltage line of amplification.

QSC, Crown, Rane and other companies manufacture multi-channel amplifier. The 8 channels amplifier QSC CX-168 is currently the least expensive device for natural sound multi-channel amplification.

3.5.3 Cabling

As the amplification is using low voltage line connection, the cable needs to be standard loudspeaker cable. The concept for the cabling consists of decomposing the cable size according to the distance between the loudspeaker and the amplifier to reduce the cost and to maintain a minimum of line loss.

All the cable should be tightened together inside a cable raceway to be installed on one side of each platform. The cable should not create more than 1 – 2 dB of line loss. As the line loss in the cable is proportional to the cable length, the gagging can be reduced for the loudspeakers closer to the amplifiers. The choice of the cable section can be sub-divided, depending on the distance separating the amplifier to the loudspeaker:

- from 1 to 170 meters: 16 gage pair of cable
- from 170 to 340 meters: 14 gage pair of cable
- from 340 to 500 meters: 12 gage pair of cable

3.5.4 Computer Software

Sonic Wave effects will be created using computer software by adjusting the signal send to each loudspeaker. As the sound installation is unique a specific custom-design control program needs to be created. The software Max-MSP is particularly suited for creating custom design application for signal processing operation. Figure 8 shows an example of interface controlled that we created in Max-MSP. This program is manufactured by cycling74 and works on Macintosh computers. The use of the sub-program Spatialisator developed by IRCAM is also recommended to create acoustic effects.

We propose to write the program for creating the Sonic Waves. The panning should also provide options for the sound designer, like the speed of sound movement, the possibility to create groups of loudspeakers, the possibility to alternate the movements of the sound on each platform, to change the reverberation effect, etc.

Max-MSP can easily control the 192 individual channels, as the maximum number of channels in the program is 999.

3.5.5 Computer Hardware

A hardware unit is needed for each platform. Each one should contain the audio files stored digitally on separate hard drive and have one Macintosh computer. Each unit also needs audio interfaces to convert from digital signal to analogue signal to feed the amplifiers. As the signal sent to each loudspeaker needs to be controlled individually, there are 96 audio channels. Therefore, the digital to analogue interface needs to convert 96 audio channels per platform.

The company Marck of the Unicorn manufactures audio converters at cost effective prices and good quality. For each platform, four converters 24 i/o could compose the digital to analogue

conversion. These four devices would also need to be connected to their dedicated interface with the Macintosh (one interface controls four 24 i/o). This interface provides Fire Wire connection with the computer.

3.5.6 MIDI Controller

Sequencing and synchronization of the sound effects of the platforms is controlled by MIDI code (Musical Instrument Digital Interface), as shown in Figure 10. This will allow starting and stopping the program automatically at certain hours and to create scenes of effects. These could consist of predefined sequences of moving sounds that have been created in Max-MSP (Max-MSP accepts MIDI code).

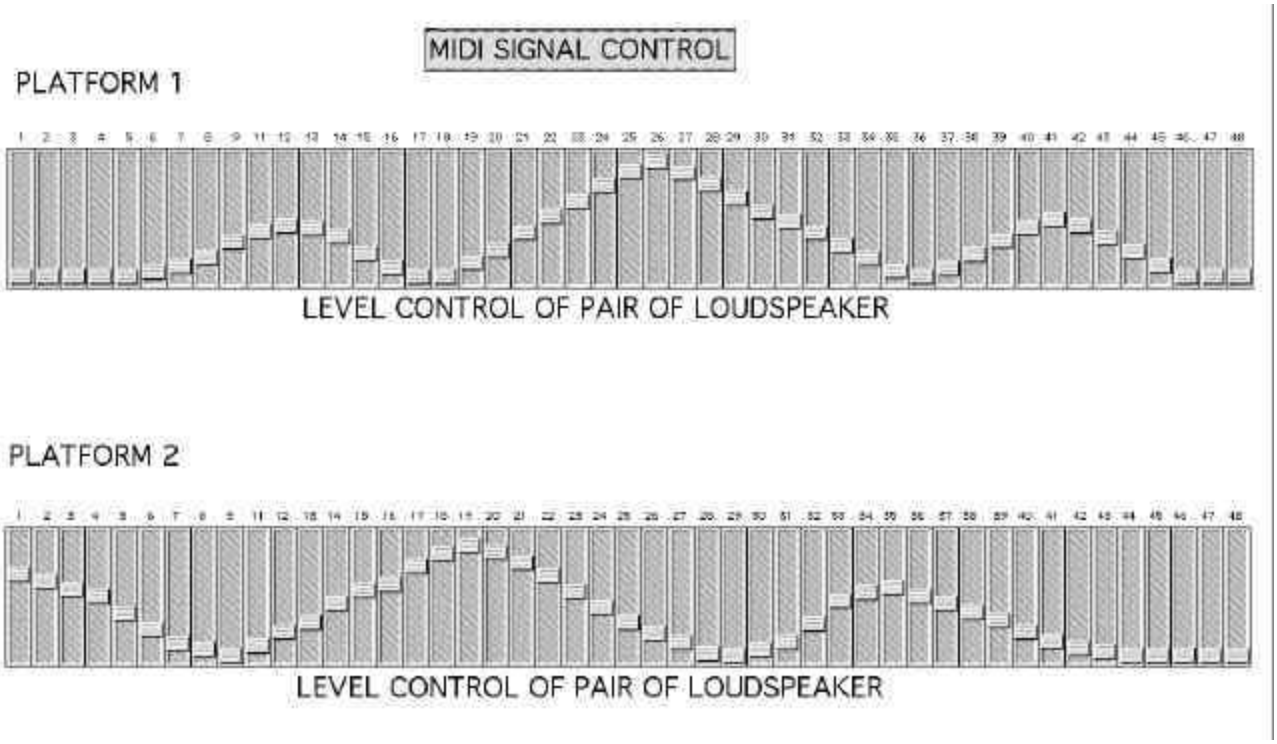


Figure 10: Example of interface control created in Max-MSP for creating Sonic wave along the platforms. The program controls the level of each pair of loudspeaker to make the sound moving from end of the platform the other.

3.6 Proposed Video System

This section describes the video equipment set up for creating the She-shadow effect. For the option involving projection over the river, the projector layout consists of 4 devices on each side of the river, spaced approximately at 100m intervals, as shown in Figure 11. The projectors should be mounted high on the walls to enable clearance over the walkway below as shown in Figures 12-13. The projectors will project an image approximately 9m x 12m onto the wall on the opposite side of the river. A motorized gobo consisting of a computer controlled orbital head will be used to make the projected She-Shadow move along the walls of the walkway (Figure 14). The computer also provides powerful image processing ability, including the pre-distorting of the image to account for the effects of panning a projection on a wall. The 4 projection systems on each side of the river can be programmed/controlled via a single interface.

The video system is the most expensive sub system and is likely to be rented. This system can be rented from Scharff Weissberg in New York (212.582.3860).

3.7 Video Equipment

3.7.1 Projectors

The recommended projector is a 10,000 lumen DLP projector. Many manufacturers supply projectors for this application, including NEC, Barco, Christie, Digital Projection, and Panasonic. The Barco ELM G10 is shown as an example.

3.7.2 Custom Lenses

The long throw of the projectors when combined with the desired image size requires a lens with a focal length larger than the standard lenses provided by manufacturers. This item requires further investigation with the video supplier and the lens manufacturer. Buhl is a recommended manufacturer of custom projector lenses.

3.7.3 Orbital Head

A motorized gobo consisting of a computer controlled orbital head will be used to make the projected She-Shadow move along the walls of the walkway. High End Systems manufacture such a device as part of their Catalyst system. The Catalyst Orbital Head is a dual mirror system which bolts onto the front of a projector, allowing static or video images to be projected anywhere within a 360 by 250 degree hemisphere. The Orbital Head is controlled via DMX 512.

3.7.4 Catalyst Media Server

The media server consists of a Macintosh computer and an interface box used to connect to the projector. The Media Server offers a wide array of image processing tools, including the pre-distorting of the image to account for the effects of panning a projection on a wall. The Media Servers can be interlinked and controlled/programming using a DMX 512 interface.

3.7.5 Catalyst Control Interface

The Media Servers can be linked via a lighting console with a DMX 512 interface. High End systems recommend using a “WholeHog 3” lighting console for the interface.

3.7.6 Video Cabling

Power, video and control cabling will be required for each projector. The video cabling will be dependant on the final choice of projector, the location of the equipment and associated distances. Due to limitations on the distance that video signals can be transmitted, amplification of the signal may be required. This should be studied in detail with the supplier of the video equipment.

3.8 Equipment Costs

To provide indications of the cost of the systems, retail costs for the equipment listed above is shown in the table below. It is anticipated that much of the equipment will be rented as opposed to purchased. Further studies will be required to determine the cost benefits of renting versus purchasing different items of equipment. Engineering and installation costs are not included in the table.

Audio System	**qty**	**price each**	**total price**
Loudspeakers	192	$100	$19,200
Amplifiers	24	$2,450	$58,800
AD/DA converters	8	$1,500	$12,000
AD/DA interface	2	$2,000	$4,000
Mac G4	2	$3,000	$6,000
midi controller	1	$1,000	$1,000
speaker wire (ft)	200,000	$1	$100,000
subtotal			$201,000
Video System			
Projector	8	$85,000	$680,000
Custom Lens	8	$5,000	$40,000
Catalyst & Mac G4	8	$31,400	$251,200
Control Interface	2	$22,000	$44,000
Cabling	1	$50,000	$50,000
subtotal			$1,065,200
Grand Total			$1,266,200

4. CONCLUSIONS

This report has presented the research, analysis and systems design work conducted by Arup relating to the solutions for the audio and video presentation systems for the Tevereterno project. A recommended approach to both the audio and video systems has been presented that will enable the artists proposed Sonic Waves and She-Shadows to be realized.

The audio system for the Sonic Waves has been prototyped in the Arup SoundLab, and has been demonstrated to work in the manner intended. The SoundLab has also shown its use in helping the composers with the composition of their soundtracks, particularly the optimisation of the soundtrack relatively to the background noise environment.

A solution for the video system has been proposed, but due to the scale of the project, there are technical issues that need to be investigated further in more detail. It is recommended that a mock-up test is conducted at the site to test the projection of the she-shadows, and to determine if a specially designed long-throw lens is required to provide the image quality standards expected by the Artist. This is a relatively simple test and can be conducted with rented equipment.

Further studies are also required on how the equipment will be procured, in particular, what will be rented and what will be acquired. It is generally assumed that the video equipment will be rented as this is the major cost item of the system. The engineering infrastructure requires further investigation, in particular the availability of power, and conduit runs, and the available locations for central equipment and control.

It will also be important for the audio and video systems designs to evolve as the artists ideas evolve. The proposed systems are flexible, but clearly have limits of capability. As the scope of the project increases, additional technical features may be necessary. It is also important for the artists to understand the nature of the technical "canvas" that they have at their disposal, and the opportunities that exist with the use of the systems.

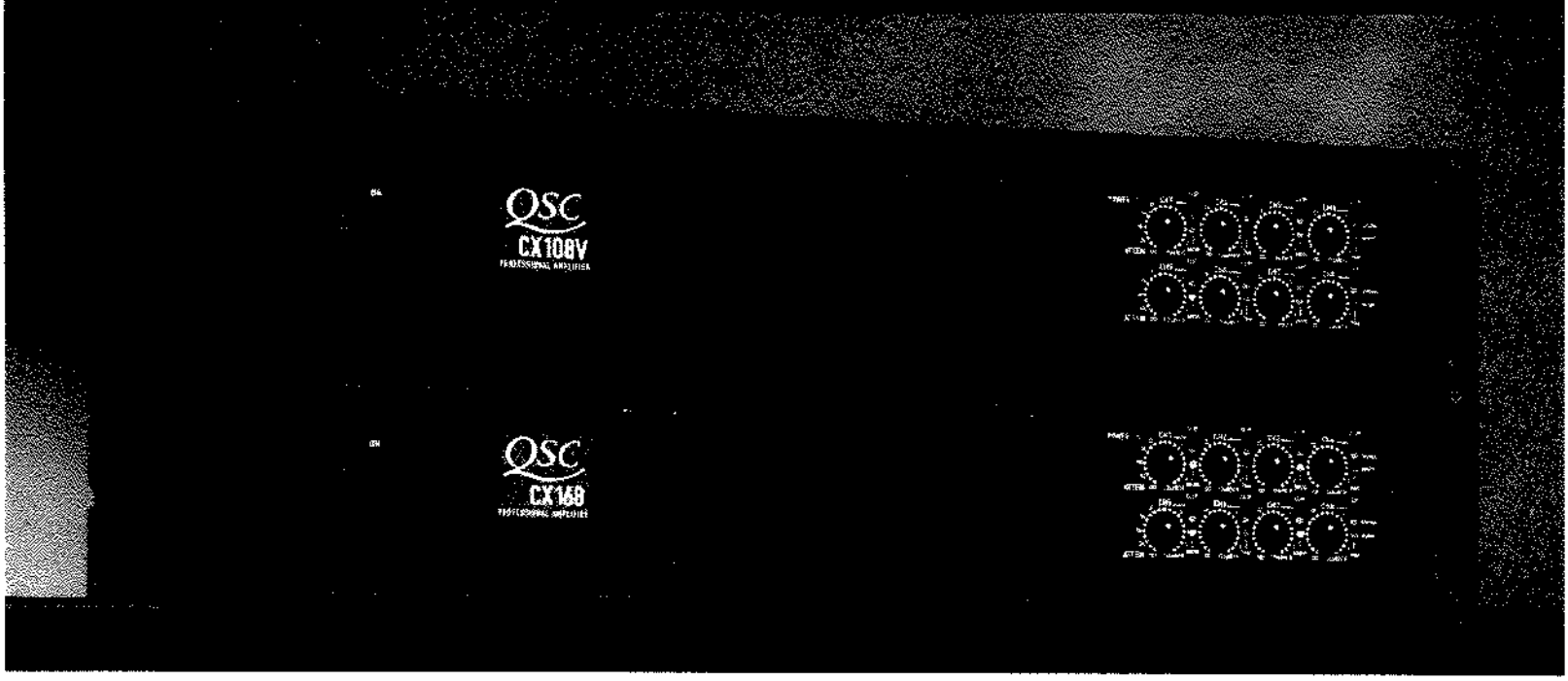
The recommended next step of the project will be to conduct the necessary site tests with rented video equipment to test the proposed video solution, to conduct the engineering integration and equipment procurement studies and to meet with the artists to develop further the sound and video compositions for the installation.

APPENDIX A

CX
8-channel

PROFESSIONAL POWER AMPLIFIER

Preliminary Specifications



Designed for permanently installed sound systems where rackspace is at a premium, QSC's CX108V and CX168 provide unprecedented levels of channel density for multi-channel amplifiers. The CX108V and CX168 provide 100 watts/ch. @ 70 volts and 90 watts/ch. @ 8 ohms respectively. With both models, each pair of channels may be bridged to configure these amplifiers as 4-, 5-, 6-, or 7-channel units. Like the entire CX Series, the 8-channel models feature DataPorts for remote amplifier management or signal processing, incorporate QSC's legendary PowerWave™ technology, and deliver our unmatched reputation for quality and reliability.

POWERWAVE™ QSC's PowerWave™ technology takes your audio to an entirely new level. Delivering tighter bass and clean, transparent highs, PowerWave also cuts waste heat, boosts reliability, and eliminates unwanted noise and hum. PowerWave is a revolutionary switching power supply technology that provides ample current to the audio power circuitry by charging the supply rails over 200,000 times per second through an ultra-low noise impedance circuit. Unlike amplifiers that use conventional supplies, the audio signal is never starved prematurely and remains crisp and clean.

CX 8-CHANNEL AMPLIFIERS

Model	70V	8Ω	4Ω
CX108V	8x100W	–	–
CX168	–	8x90W	8x130W

20 Hz–20 kHz, .05% THD, all channels driven
*20 Hz–20 kHz, 0.1% THD, all channels driven

CX 8-Channel Features

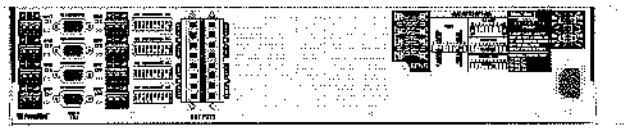
- 100 watts per channel at 70 volts (CX108V)
- 90 watts per channel at 8 ohms and 130 watts per channel at 4 ohms (CX168)
- Compact size — only two rack spaces and 14" deep for reduced rack space
- Channel pairs bridgeable for maximum flexibility
- Exclusive PowerWave™ switch-mode power supply technology for high performance and compact size
- Active Inrush Limiting eliminates AC inrush current, removing the need for expensive power sequencers
- Four HD15 DataPorts (one per channel pair) for QSControl computer control or QSC's signal processing accessories
- Custom integrated gain control security cover for tamper-proof installations
- 1-dB recessed detented gain controls for fast and accurate settings
- Detachable Euro-style input and output connectors
- DIP switch control for clip limiters, high-pass filters, bridge-mono and parallel operation
- Selectable high-pass filters protect speakers and prevent speaker transformer saturation with minimal effect on program material (50 Hz or 75 Hz; CX108V) (33 Hz or 70 Hz; CX168)
- Comprehensive front panel indicators including signal, clip, bridge-mono and parallel-input LEDs
- Fully protected — including DC, infrasonic and ultrasonic, thermal overload and short circuit protection
- High-performance Class AB+B complementary bipolar output circuitry
- Light weight — only 21 pounds (9.5 kg) for easier racking and shipping
- 3-year warranty plus optional 3-year extended service contract

QSC

1675 MacArthur Boulevard • Costa Mesa, CA 92626 • Ph: 800/854-4079 or 714/957-7100 • Fax: 714/754-6174
www.qscaudio.com • email: info@qscaudio.com

SPECIFICATIONS	CX168		CX108V
Stereo Mode (all channels driven)	**Continuous Average Output Power Per Channel**		
8 ohms 0.05% THD 20 Hz–20 kHz	90 Watts		—
4 ohms 0.1% THD 20 Hz–20 kHz	130 Watts		—
Midband Ratings	**All Channels Driven**	**Single Channel**	
8 ohms 0.1% THD 1 kHz	100 Watts	120 Watts	—
4 ohms 0.1% THD 1 kHz	140 Watts	180 Watts	—
70V 0.2% THD 20 Hz–20 kHz	—		100 Watts
Bridge Mono Mode	**Bridge-Mono Mode Operation**		
16 ohms 0.1%THD 20 Hz–20 kHz	180 Watts		—
8 ohms 0.1% THD 20 Hz–20 kHz	260 Watts		—
140V 0.2% THD 20 Hz–20 kHz	—		200 Watts
Noise (20 Hz–20 kHz)	-107 dB		-107 dB
Input Sensitivity (for full-rated output power)	1.35 Vrms @ 8 ohms		1.41 Vrms @ 70V
Voltage Gain	20x (26 dB)		50x (35 dB)
Input Clipping	6 Vrms (+18 dBu)		6 Vrms (+18 dBu)
Output Circuitry	Class AB+B		Class AB+B
Frequency Response	20 Hz–20 kHz, ± 0.2 dB 8 Hz–50 kHz, +0/-3 dB		20 Hz–20 kHz, ± 0.1 dB 8 Hz–60 kHz, +0/-3 dB
Damping Factor	Greater than 200 (5 kHz and below)		Greater than 500 (5 kHz and below)
Input Impedance	6 kΩ unbalanced, 22 kΩ balanced		6 kΩ unbalanced, 22 kΩ balanced
All models	**All models**		
Distortion (SMPTE-IM)	Less than 0.02%		
Distortion (typical) 20 Hz–20 kHz: 10 dB below rated power 1.0 kHz and below: full rated power	 Less than 0.05% THD Less than 0.02% THD		
Connectors	Input: 3-pin Euro-style detachable terminal blocks, (one per channel) DataPort: HD-15 Connector, (Ch 1+2, 3+4, 5+6, 7+8) Output: Two 8-pin Euro-style detachable terminal blocks		
Cooling	Variable speed fan, rear-to-front airflow through tunnel heat sink		
Controls	Front: AC switch, Ch 1, 2, 3, 4, 5, 6, 7 & 8 gain knobs Rear: DIP switches for Ch.1–Ch.8, clip limiter on/off, LF filter on/off, LF filter freq select 33 or 70 Hz for CX168, LF filter freq select 50 or 75 Hz for CX108V, inputs parallel or stereo; bridge mode		
Indicators	PWR-ON: Green LED SIGNAL-35dB: Green LED (1 per channel) CLIP: Red LED (1 per channel)		PARALLEL INPUTS: Orange LED (1 per ch. pair) BRIDGED: Yellow LED (1 per ch. pair)
Amplifier Protection	Full short circuit, open circuit, thermal, ultrasonic, and RF protection; Stable into reactive or mismatched loads		
Load Protection	On/off muting; Individual channel DC fault blocking		
Dimensions	19" (48.3 cm) rack mounting, 3.5"(8.9 cm) tall (2 rack spaces), 14" (35.6 cm) deep (from front mounting rails)		
Weight	21 lb (9.5 kg) net, 27 lb (12.3 kg) shipping		
Power Requirements	100, 120, 230 VAC, 50-60 Hz (configured at factory)		

120V CURRENT CONSUMPTION		CX168	CX108V
Multiply currents by 0.5 for 230V units.	Idle	0.6 A	0.6 A
1/8 Average Power* (typical of program material at maximum unclipped power) *Pink noise	8 ohms	6.2 A	-
	4 ohms	9.2 A	-
	70V	-	6 A
1/3 Average Power* (typical of program material with severe clipping) *Pink noise	8 ohms	9.2 A	-
	4 ohms	14.2 A	-
	70V	-	9 A



Specifications subject to change without notice.

1675 MacArthur Boulevard • Costa Mesa, CA 92626 • Ph: 800/854-4079 or 714/957-7100 • Fax: 714/754-6174 • www.qscaudio.com

MOTU Audio 24I/O

Features
24I/O home
front panel
rear panel
expansion
cuemix dsp
legacy compatibility
setup wizard
feature summary
specifications
faq
compatibility

Related Links
24I/O home
24I/O tech notes
MOTU Audio interfaces
MOTU Audio downloads
MAS developers

Metering
The 24I/O's front panel is essentially a dedicated meter bridge for your hard disk recording system. Audio activity for every input and output is represented by its own five-segment LED bar graph.

Front Panel Power Switch
Useful in the unlikely event you wish to turn off your 24I/O. An interesting fact about MOTU Audio interfaces is that they are hot swappable. This means you can power off, plug-in, add and remove interfaces without turning your computer off or restarting. In fact, if you already have a 2408mk3 or other PCI-424 system, adding a 24I/O is as easy as plugging in an AudioWire cable.

[next]

MOTU Audio 24I/O

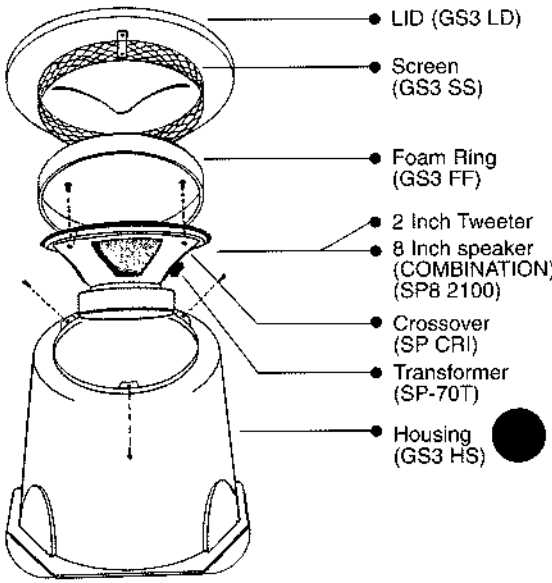
Features
24I/O home
front panel
rear panel
expansion
cuemix dsp
legacy compatibility
setup wizard
feature summary
specifications
faq
compatibility

Related Links
24I/O home
24I/O tech notes
MOTU Audio interfaces
MOTU Audio downloads
MAS developers

The MOTU Audio 24I/O interface fulfills the promise of host-based hard disk recording: to record, edit, mix process, and master multitrack recording projects entirely inside the computer. It provides 24 high quality, 24-bit/96kHz analog inputs and outputs in a cost effective, single rack space package, allowing you to connect and record from 24 simultaneous analog sources.

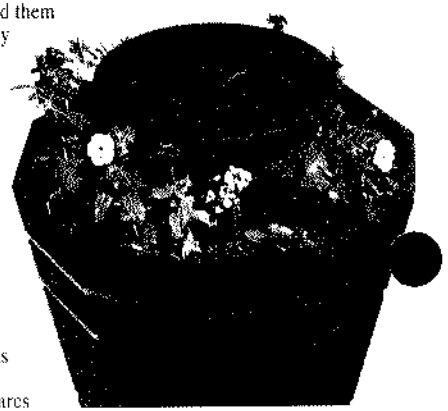
The 24I/O can be purchased as an expander for an existing PCI-424-based MOTU Audio System, or as a core system which includes the PCI-424 card and Audiodesk workstation software.

[next]



SPECIFICATIONS:	**GS 3T**
Horizontal Dispersion:	360 degrees
Vertical Dispersion:	30 degrees
Frequency Range:	40Hz - 20kHz
Crossover:	4.5kHz
Transformer:	25/70v In-Line 4Tap
Pressure:	91dB SPL at 1M
Sensitivity:	W/1 watt pink noise
Impedance:	8 Ohms
Weight:	4.2 lbs. (100W)
Size:	8" (204mm)
Free air Resonance:	40 Hz + -20%
Construction:	ABS/Polypropylene
Color:	Shrub Green

- Landscape around them
- Plant permanently
- In planters
- Patio's
- Pools
- Den's
- Spa's
- Parks
- Offices
- Hotel's
- RV parks
- Playgrounds
- Golf courses
- Fun centers
- Security systems
- Amusement parks
- Civil authorities
- Public thoroughfares
- Almost anywhere you can imagine ...

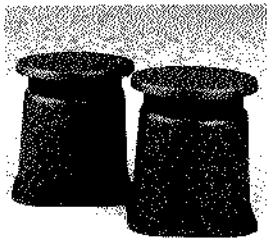


Omni-Directional Speakers

The GS series of Award winning Omni-directional speakers are known as the standard in commercial, exterior audio, ground applications. Now the GS 5P (consumer based) and GS 7L (professional commercial) models build on and compliment this market leader. Renowned, Reliable yet Economical are just some of the reasons you will see these units in almost every Theme Park, Civic and Commercial Installation worldwide.

Omni-directional speakers are planted directly in the ground to blend aesthetically with any surroundings, Pools, spa's, roof-top, gardens, estates to theme parks are perfect settings for this high quality, unique product range.

GS-5P MINI-OMNI *PAIR*

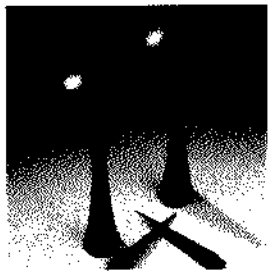


- Weatherproof Design
- Two-Way 80 Watt In Ground Speaker
- True 360° Sound
- 4.5kHz Speaker Crossover
- 30' Dbl. Insulated Speaker Cable
- Impact Resistant Enclosure
- Shrub Green to Blend with Landscape
- Easy Installation

GS 7L PRO OMNI-LIGHT

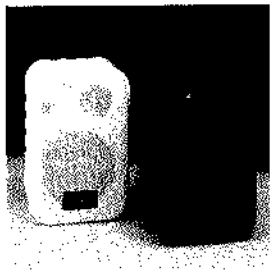
- 150 watt Speaker & Light
- True 360° Sound
- Gentle 360° Illumination
- 4.5kHz Speaker Crossover
- 12 volt 20w Halogen Bulb
- 50' Dbl. Insulated Cable
- 50w LV Transformer *Included!*
- Impact & Weatherproof Design

GS 10 T-SOUND



- Full Range 50w Speaker Pair
- 360° Sound
- 4.5kHz Speaker Crossover
- Weatherproof ABS/Polyprop/Mylar
- 50' Burial Cbl.
- Plant Post or Screw Fastners
- Easy Installation

PB/W 60 PATIO SPEAKERS

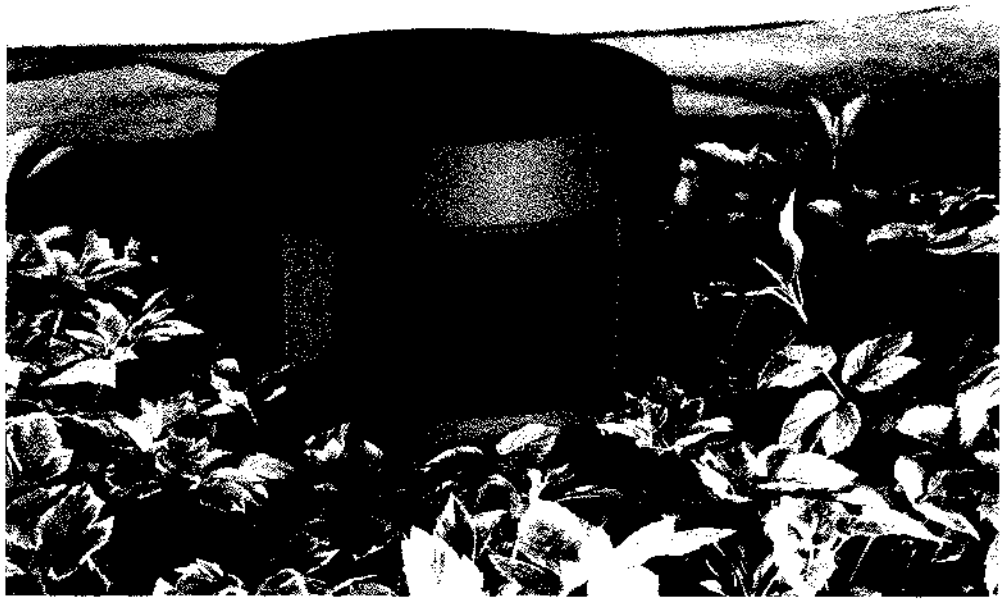


- Quality Indoor/Outdoor Weather Resistant Speakers
- Packaged in Pairs with Mounting Hardware and Speaker Wire Included
- Available in Black or White
- Powerful 60 Watt 3-Way Speakers
- Ideal for Patio, Deck, RV, or Boat as well as Upgrading Surround Sound.

SP-1200 4-WAY SWITCH BOX

- 4 Heavy Duty 2-Way Rocker Switches
- Quality Silver Plated Switch Connectors
- Supplied with Tool
- Load to Signal Source is Minimum 4 ohms (with 8 ohms Speakers) or 220 ohms with All Speakers Off

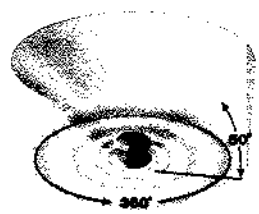
In-Ground Loudspeaker



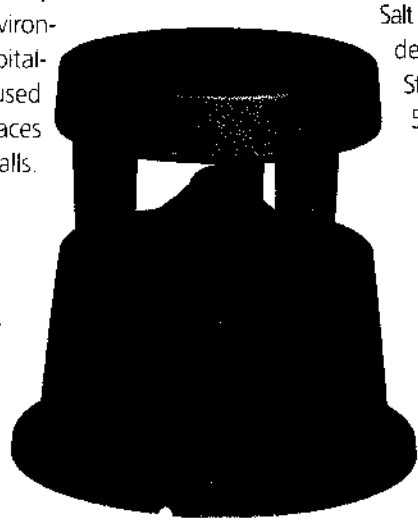
The FreeSpace Model 360P-II loudspeaker reproduces music with the presence and depth you would expect only indoors. And it delivers pages that can be easily understood – even in busy outdoor environments. All while disappearing into nearly any outdoor setting.

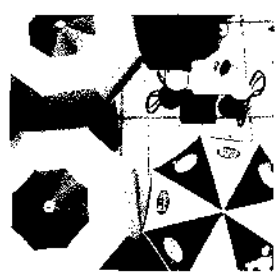
The durable 360P-II loudspeaker is designed to work in locations where many conventional speakers cannot – shrubbery, gardens, pool areas. It is a proven solution for outdoor locations such as restaurants, amusement parks, open-air retail environments, and resort and hospitality venues. It can also be used indoors in large open spaces like atriums, foyers, and malls.

Using an innovative design, the 360P-II loudspeaker provides 360° coverage, so fewer loudspeakers are needed than with many conventional ground-mounted loudspeakers. Sound is dispersed evenly both horizontally and vertically allowing listeners to hear consistent sound either sitting or standing.



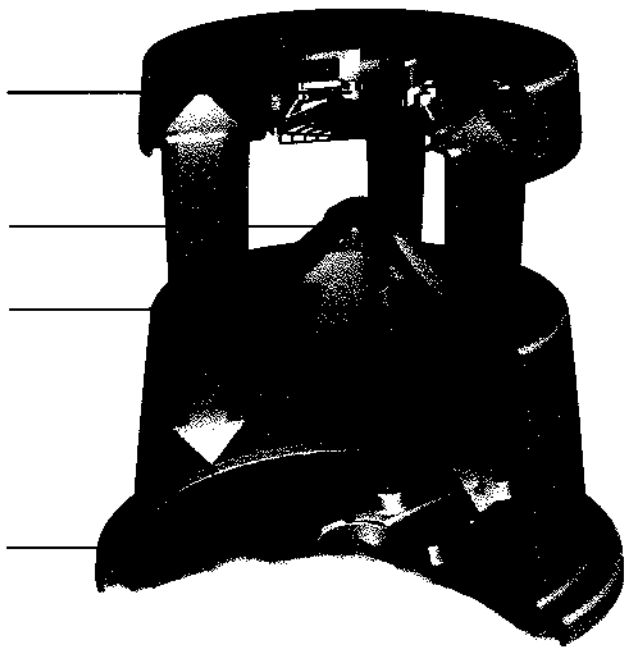
A heavy-duty enclosure and an advanced composite driver make the FreeSpace 360P-II loudspeaker exceptionally rugged and reliable. It is built to withstand sand, snow, rain, salt and temperature extremes of 158°F (70°C) to -40°F (-40°C). And it survives the Salt Fog test 66% longer than the demanding Marine Industry Standard. It is also backed by a 5-year transferable warranty.





In-Ground Loudspeaker

Versions: 70/100V transformer
Power handling capacity: 80W
Frequency response: 70Hz to 16kHz ±3dB
Maximum output: 100dB SPL ±3dB @ 1m
Dispersion: 360° horizontal, 50° vertical
Color: Green



Downward-firing Bose® environmental 4.5" full-range driver withstands weather extremes all year round.

Domed port grille reflects sound into the listening area for clear, consistent performance.

Centrally located port enhances low-frequency reproduction.

Base flange with 3 mounting holes provides stability and security when surface mounted or set in ground.

Product specifications subject to change without notice.

BOSE®
Better sound through research.

Barco ELM G10

The ELM G10 combines exceptional light output and high resolution with advanced signal processing to deliver a remarkable break-through in performance for large screen cinematic video display.
Equipped with high resolution Digital Micromirror Devices and a state-of- the-art optical system, the BARCO ELM G10 delivers a exceptional high light output of 10,000 ANSI lumens to meet and exceed the needs of the most demanding rental, staging and electronic cinema applications.

Product Pages
Main Page
Features
Specs
Options

Downloads
Barco ELM G10/R12
Barco Events Brochure

More Information
Contact us

Recommended application areas
Events
Presentations
Virtual & Augmented Reality

Related PressReleases
Barco LED Displays Light Up Geneva International Motor Show (6 March 2003)
BARCO Projectors Steal the Show with Water Screen Display for Dutch Open-Air Theater Production 'The Coat of Rotterdam' (25 June 2001)
BARCO Plays Leading Role in the 46th Annual Eurovision Song Contest (15 May 2001)

Ordernumber: R9001500

Ready for the Road
A wide range of special features and accessories make the ELM G10 especially suited for the most demanding Rental and Staging requirements. Special design features enable the projector to be handled, set-up and controlled in an exceptionally easy fashion. An extremely rugged steel frame con-struction allows the projector to be stacked quickly and safely, without the need for a stacking frame. An innovative modular construction establishes new standards of serviceability.

Exceptional Performance
The BARCO Elm G10 combines exceptional source compatibility with advanced TCRPLUS image processing to provide unique flexibility with superb video and film - like image quality.
Compatible with both current and future digital sources, the Elm G10 utilizes 13 bit digital signal processing for superb gray scale performance.
Together with the units remarkable 10,000 lumens of light output this results in image quality that is truly in a class of its own.

DLP
A TEXAS INSTRUMENTS TECHNOLOGY

QLD 5.6 - 12

Very long throw zoom lens designed for ELM with SXGA resolution.
Also usable on ELM with XGA resolution.

Product Pages
Main Page
Specs

More Information
Contact us

Option of
Barco ELM G10
Barco ELM R12
Barco ELM R12 Director
Barco ELM R18 Director

Ordernumber: R9840430

Catalyst™ Media Server

The Catalyst Media server is an image processing system that offers an unlimited range of DMX 512 controlled image processing effects.

Product Pages
Main Page

Special Link
- Catalyst Tutorial

Downloads
- Catalyst™
- Barco Events Brochure

More Information
- Contact us

Option of
- Barco ELM R12 Director
- Barco ELM R18 Director
- Barco SLM G5 Performer
- Barco SLM G8 Performer
- Barco SLM R10 Performer
- Barco SLM R6 Performer
- Barco SLM R8 Performer
- Catalyst™

Related PressReleases
- Barco and High End Systems Announce Strategic Alliance (7 February 2002)

Ordernumber: R9851530

Unlimited creativity
The Catalyst media server offers an incredible range of image processing tools. Controlled from DMX 512 it can process and manipulate high resolution graphics images, movies store on harddisk or live video images.

Use with Daylight Displays and Projectors
When used with Daylight Displays or Projectors, the Catalyst Media Server presents an unparallelled way to program, process and run content on the display to use it as a creative effects tool.

Complete
The Catalyst Media Server is delivered in a flight case that contains all processing equipment in a shock absorbing frame.

Catalyst™ Orbital Head

When attached to a projector, the Catalyst Orbital Head allows static or video images to be projected anywhere within a 360 by 250 degrees hemisphere.

Product Pages
Main Page

Special Link
- Catalyst Tutorial

Downloads
- Catalyst™
- Barco Events Brochure

More Information
- Contact us

Option of
- Barco ELM R12 Director
- Barco ELM R18 Director
- Barco SLM G5 Performer
- Barco SLM G8 Performer
- Barco SLM R10 Performer
- Barco SLM R6 Performer
- Barco SLM R8 Performer
- Catalyst™

Related PressReleases
- Barco and High End Systems Announce Strategic Alliance (7 February 2002)

Ordernumber: R9851540

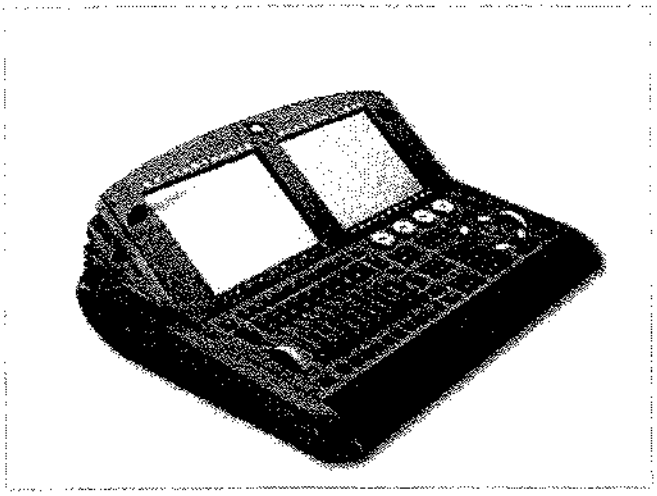
Use on projectors
The Catalyst Orbital Head is dual mirror system that bolts onto the front of an SLM or ELM. The position of the mirrors is programmable and controllable through DMX 512. In this way it allows the image produced by the projector to be moved around in space.

Use with Catalyst Media Server
When used in combination with the Catalyst Media Server, the complete system offers breakthrough in effects lighting. The capabilities range from simulating color and Gobo effects to the creative and innovative effects generated by the synergy of video and lighting.

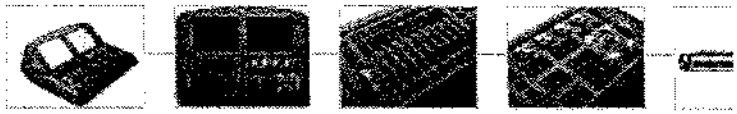
Complete
The Catalyst is delivered complete in a flightcase including power supply and all necessary hardware to mount the head on an SLM or ELM projector.

Compatibility
The Catalyst Orbital Head is compatible with **all** existing and new ELM and SLM projectors.

Wholehog III Console



Taking lighting control to new levels



Related Products
Processors:
DMX
MIDI / TC
Wings:
Programming
Playback
Widgets:
DMX Widget
LTC Widget
USB Hub
Widget Rack
Flightcases:
Console
Wing

Overview 3D View Tour Features Specifications Support Sales

Overview

The Wholehog series of consoles is the natural evolution of lighting control surfaces that started with the Wholehog console, progressed with the Wholehog II, and culminated in this, our most advanced console

The Wholehog III Console is very similar in layout and syntax to the Wholehog II, but with significant improvements to the operating system, and sophisticated new features. The huge user base that is famili Wholehog II will soon feel right at home with the new Wholehog III Console, leaving time to concentrate c exploring the console's advanced new features. For example, Wholehog III's automated fixture abstractio allows users to address different types and brands of automated fixtures in a common language, and the will respond in a common manner - all of the colors blend the same way, all of the patterns rotate at the s speed. Not only does this speed up programming, but it also allows for "fixture portability", or the ability tc program your show on Monday using a wash fixture from Manufacturer A, and then swap it out on Tuesd wash fixture from manufacturer B, without having to reprogram the show. It's just one of the huge time sa software features of the Wholehog III.

Not only have we made huge advances with the software - we've got the hardware to match. Gracing the surfaces of the Wholehog III are two bright, full color TFT touchscreens that tilt up for enhanced visibility, encoder knobs, two encoder wheels, 10 playback faders with familiar Wholehog II playback controls, a bu illuminated trackball, and hard toolbar buttons above both TFT screens.

To connect to the outside world, the console provides two monitor outputs, keyboard and mouse ports, M input and output ports, two USB ports, Fast Ethernet on a rugged Neutrik Ethercon connector, and sterec speakers with a stereo audio output. Show storage is handled by a built in shock mounted hard disk, with writeable CD-ROM drive and Zip disk drive neatly tucked away under the armrest.

Dimmable bi-colour (blue and white) custom made LED desklights ensure you can admire the sleek anoc dark blue aluminum finish, day or night. It's as beautiful to look at as it is - dare we say - fun to program a operate.

If you like Wholehog II already, you're going to love Wholehog III. If you're not yet a convert, you owe it to yourself to check out the new Wholehog III today!

For more information, download the preview brochure.