Design concepts and understanding a stereo surround audio system for the Science On the Sphere.
By David Eltzroth

Science on the sphere is a powerful teaching and presentation medium. The sphere is unique in its ability to show a detailed, 360 degree image of many different planets, as well as diverse information about those planets. The Science on the Sphere, or SOS can be viewed from any position, 365 degrees in the round. The 365 degree viewing area creates some challenges for the implementation of the sound system portion of the SOS. To present the viewer with the ultimate "Sphere" experience, a sound system that addresses the unique requirements of the SOS is essential. Furthermore, a working knowledge of the SOS sound systems design is very important information for the audio engineer who creates sound tracks for content of SOS programs. This white paper will explain the sound system design concepts and requirements for installation and post production for creating content for presentations.

Surround sound was first invented by Walt Disney for the film Fantasia in 1940. Walt Disney wanted to simulate the sound of a live orchestra as part of the film's soundtrack. After much research, it was concluded that a surround sound system would be the most effective way to achieve the realism that Walt was looking for. However, it wasn't until around 1954 when surround sound gained some popularity in movie theaters. Television was making its way into people's homes, and the film industry felt that television would seriously hurt box office receipts. In an effort to keep people coming into the theaters, the film industry introduced wider screens typically referred to as Cinemascope or Panavision and surround sound. The early surround systems where expensive to implement and required special equipment to operate. The audio quality of those systems was incredible even by today's standards, but their use was not very widespread. Eventually in 1974, Dolby Labs introduced a surround sound process that was compatible with mono, stereo, and the new surround system. The new Dolby system was affordable. It could be used in theaters and in the home with a stereo television set and a consumer grade surround system. Over the years since the inception of surround sound, the electronics used in the surround sound system have changed along with technology. However, the loudspeaker placement in relation to the position of the audience and viewing screen has not changed at all. There are left and right loudspeakers for stereo music, a center loudspeaker for dialog or speech, and surround speakers located at either side and /or behind the viewers. These surround speakers are used for ambient sound effects and/ or acoustical cues that render a sonic impression of space of a desired environment. Not all loudspeakers within a surround system operate at the same time. The loudspeakers are called upon by the surround processor when needed to create the desired effect. This is sometimes referred to as steering. An example of this is when there is only dialog from a single narrator. The center loudspeaker will reproduce the narrator's voice and all other loudspeakers will be silent. If there is narration and stereo music than the narrator will emanate from the center loudspeaker and the music from the right and left loudspeakers. The persons creating the program decide which sounds will be routed, or steered, to which loudspeakers. When playing a surround sound program on a surround sound system, the steering process is automatic. The surround processor electronically follows the program's encoding, which steers the sound to the intended loudspeakers.

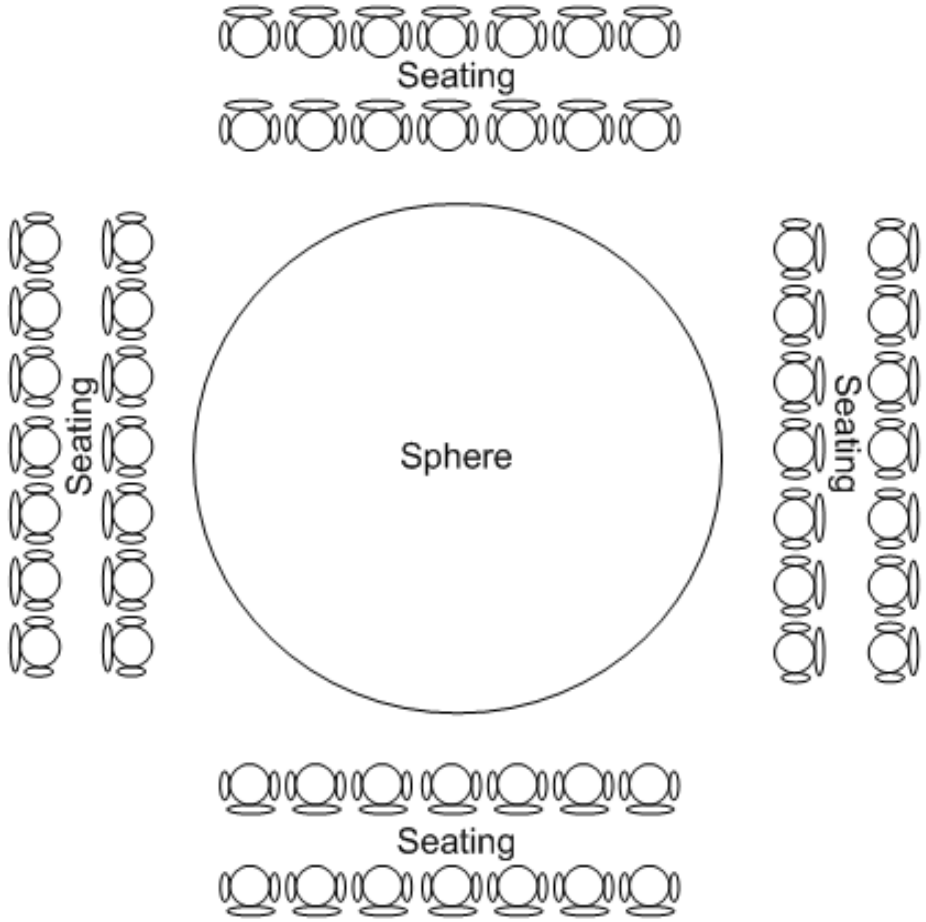
The basic concepts of the surround sound systems have been adapted to be compatible with the SOS venues and presentation system. With this adaptation, surround sound systems have been installed, tested, and as of this writing, are in use at two of the Science on the Sphere venues. The Visitors Center at Goddard Space Flight Center in Greenbelt, Maryland and The Science Museum in Danville, Virginia.

The audio portion of any presentation is the emotional engine that creates impact which has a profound influence upon the viewing audience. A poor audio system losses or greatly diminishes the impact intended by the program' s creator.

The SOS Sound System

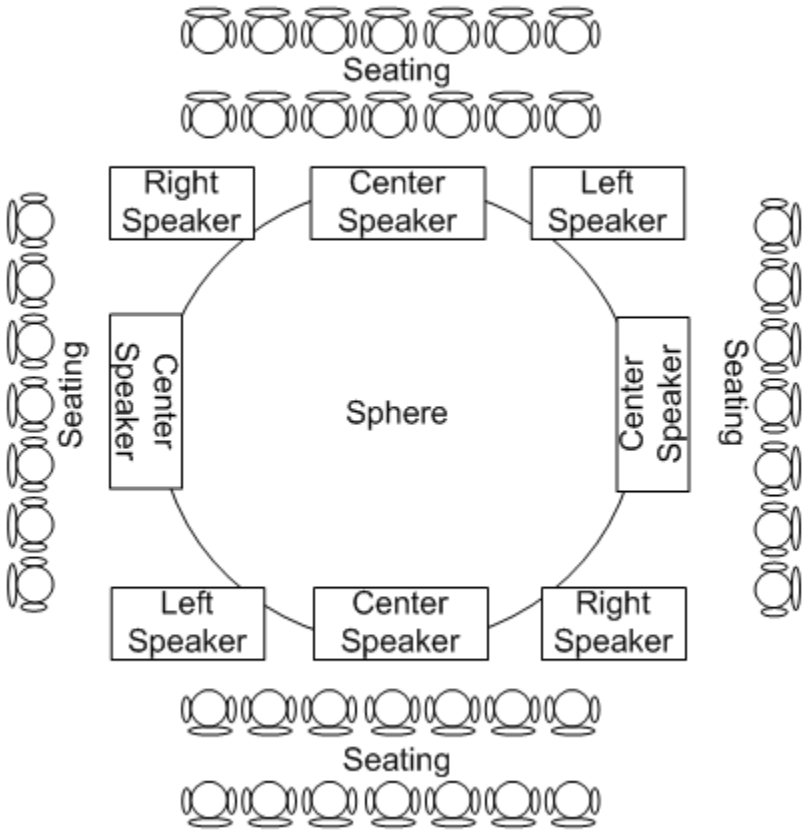
The first area of the SOS sound system that needs to be addressed is the 360 degree viewing area. In most of the venues seating for the SOS is on four sides. The drawing below illustrates a typical SOS configuration.

Illustration #1



As you can see in illustration #1 there are four distinct seating areas. Depending on a venue's room shape, the amount of seating on the four sides of the sphere will vary. i.e. a rectangle shaped room vs. a square shape room. The sides of the sphere with the largest number of seats will be considered the primary seating area. and the sides with the smaller number of seat the secondary. Other considerations like entrance and egress doors. or other architectural factors. may dictate which side of the sphere is primary and which is secondary. The reason we want to define primary and secondary seating is that the sound system speaker layout has a primary and secondary location.

Illustration #2

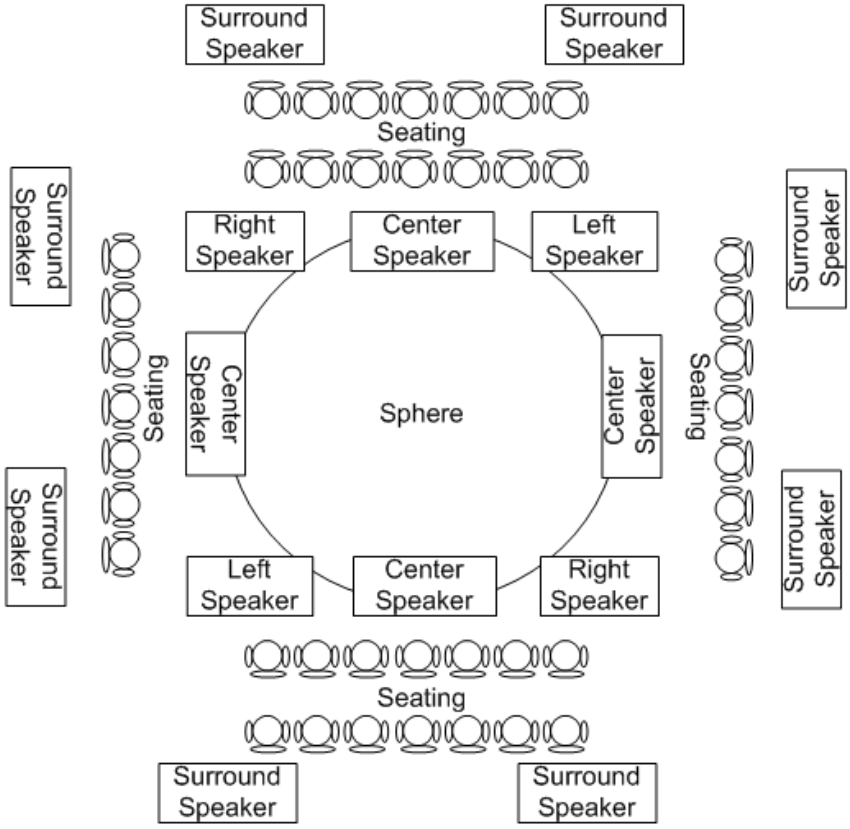


In illustration #2, the left and right side of the drawing have fewer seats than the top and bottom. The top and bottom of the drawing are the primary location and the left and right sides are the secondary. If you look at the loudspeaker layout, you will see that the top and bottom sections of the drawing have a left, center, and right loudspeaker, but the left and right sides only have a center loudspeaker. This would appear to diminish the sound on the left and right sides of the sphere. However, because of the size of the sphere, and close spacing of the left, center, and right loudspeakers, this layout works quite well. After conducting several listening test at The Visitors Center SOS facility at Godard, we found that adding left and right speakers to the secondary sides of the sphere actually degraded the audio. The additional speakers resulted in acoustical mixing, producing monaural (or mono) sound. Audio production engineers should be aware of, and consider this loudspeaker layout when mixing audio for an SOS presentation.

Three sides of the room have the correct left to right loudspeaker orientation, and one side does not. This could become problematic if the sound track is attempting to move an audio image from left to right or vice versa. On the left side of the room, in illustration #2, facing the sphere the left and right loudspeakers are reversed. In this seating section the sound would move from right to left and the image on the sphere would move from left to right, which could become disorienting to the viewer. Producing audio tracks that move audio from left to right or right to left is not recommended with the SOS surround system. However, moving audio from in front of the viewer to behind the viewer is quite effective with this system design, and should be used when appropriate. This brings us to the surround, or rear loudspeakers. The surround loudspeakers serve two purposes. One is the surround, or rear channel, of the surround sound processor. The other and more important use is for the PA

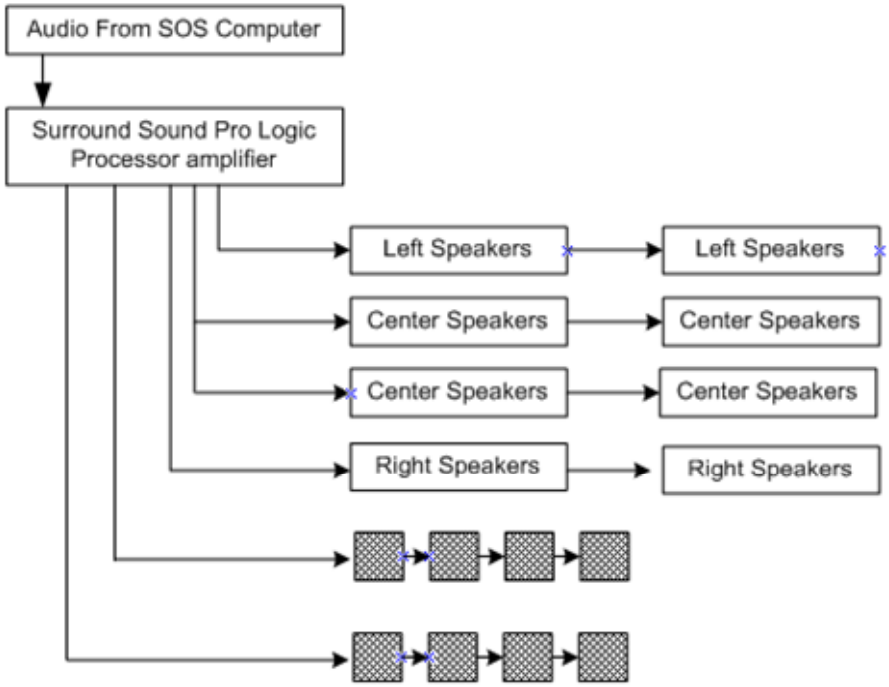
system, which is used to amplify a presenter's voice through the use of a microphone. If your SOS room is small and /or the need for voice amplification is not necessary, than fewer surround loudspeakers can be used.

Illustration #3



In Illustration #3 a small SOS loudspeaker system is shown. This system does not have voice amplification capability. There is no connection for, or the adequate number of loudspeakers to support a microphone.
A voice amplification microphone system is different in many ways from any other sound system type.
A normal surround sound system is shown in Illustration #3. The surround speakers channel carries the sound track ambiance and /or sound effects that are used to support the three main front channels: the left, center, and right loudspeakers.

Illustration #4: Block diagram of a small SOS surround system used in the Illustration #3 layout



A voice amplification system is a primary audio system by itself, which requires a larger capacity sound system, and is more demanding of audio components and loudspeakers. Furthermore, feedback, ringing, and squealing are not acceptable, but can be a side effect of an insufficient under powered voice amplification system. Through experience we have discovered that using a larger numbers of loudspeakers to achieve higher microphone volume diminishes the chance of microphone feedback (better known as ring, squealing and sometimes haling). In fact, when we densely populated a ceiling with loudspeakers, feedback is diminished to the point that the presenter can freely move about within the sound field and not have to worry about feedback or other sound problems. When an SOS venue requires a voice reinforcement microphone system, that portion of the audio system should be designed as a high performance microphone system first. The surround channel can then be connected to the voice reinforcement microphone system as an auxiliary input. We have found that ceiling mounted loudspeakers placed 6 feet apart throughout the room renders very good microphone performance. Typically 6 foot mounting centers are not practical because of other ceiling mounted obstacles such as air ducts, light fixtures, and sprinkler heads, and so on. 8 foot centers are a good compromise, but spacing wider than 8 feet should be avoided because of diminished microphone performance. An example of 6 to 8 foot mounting centers is shown in illustration #5.

Illustration #5: This is an example of ceiling mounted loudspeakers mounted on 6 to 8 ft centers

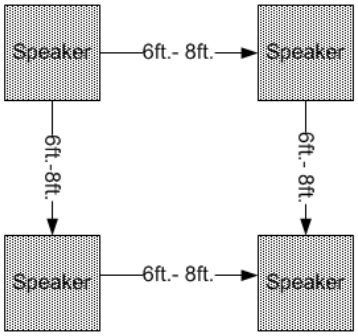
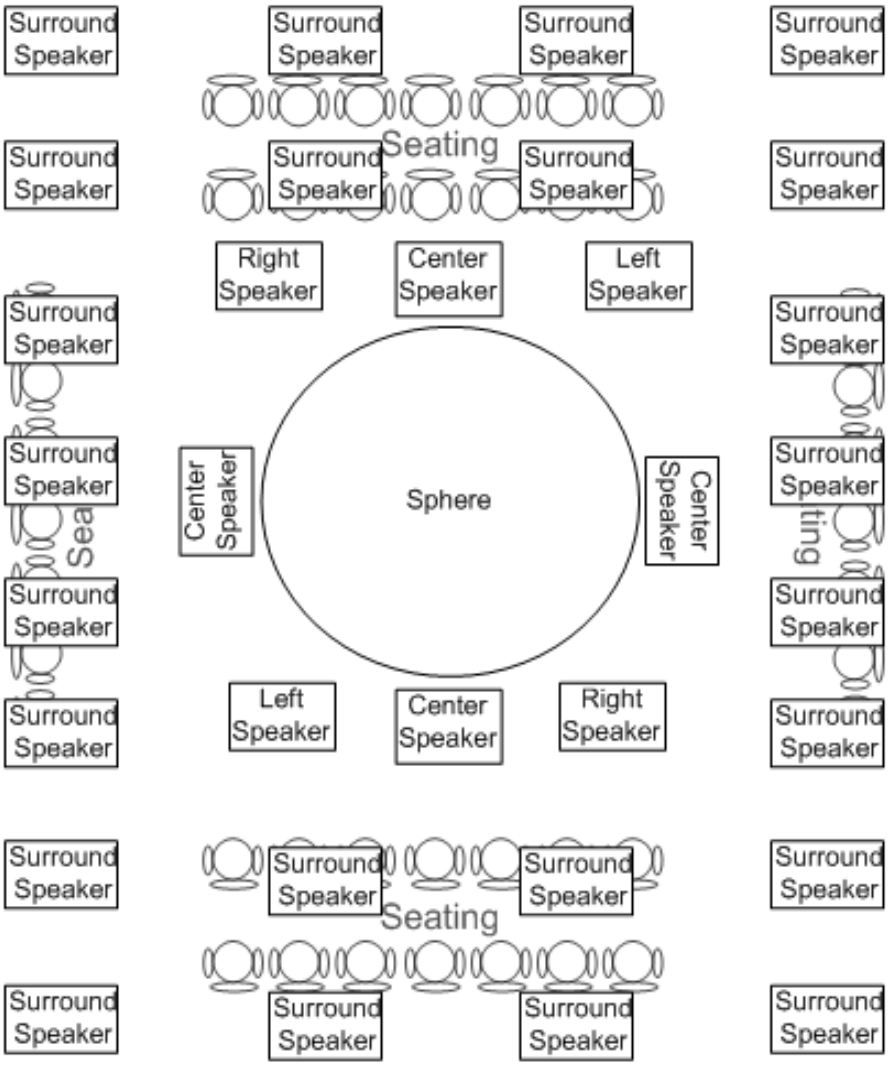


Illustration #6: Example of an SOS surround sound system with voice reinforcement.

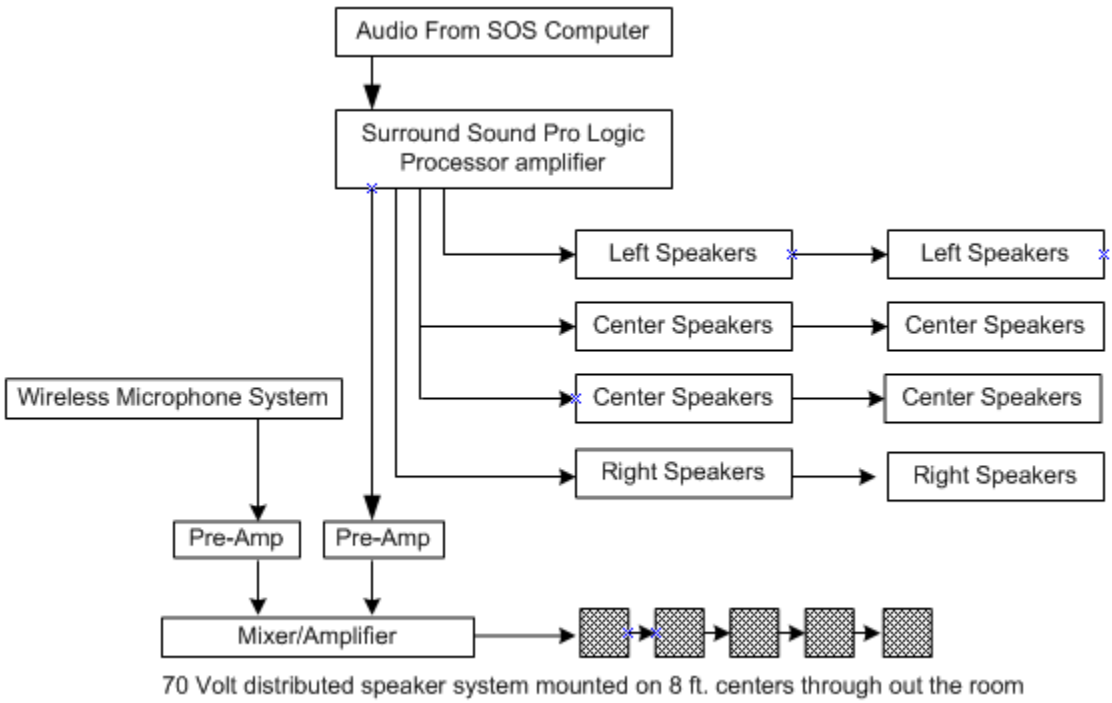


In illustration #6, loudspeakers that are marked “surround speaker” are used for the surround channel and microphone amplification.

The orientation and amount of left, center, right, and surround loudspeakers and their setup are only one aspect of the SOS audio system. The electronics that drive the loudspeakers are equally important. The sound for the SOS programs originates from the main SOS computer (or computers, depending upon the type SOS computer configuration that you have). The audio is fed from the computer as an analog left/ right stereo signal, typically outputted through a 3.5mm mini stereo jack. Depending on the choice of the SOS programs presented, a mono, left/ right stereo, or encoded full surround signal will be available through the analog left/ right stereo pair coming from the computer's sound card. In order to take full advantage of an encoded surround program, the analog audio must first pass through a surround sound decoder. Many decoders capable of decoding this type of signal exist under many different brand names. Surround sound decoding is built into many consumer and professional sound amplifiers, or it can be packaged as a standalone surround sound processor unit.

Many different manufactures offer integrated surround sound amplifiers. In the case of the two SOS surround systems that we installed, Denon surround receivers were used. The Denon receiver is a self contained, four amplifier, and surround sound decoder unit. It features individual amplifiers for each of the left, center, right and surround channels all in one unit. The same task can be accomplished using standalone separate components, i.e. four separate amplifiers and a surround sound decoder. Separate components can render a more robust sound system, but they do come at a higher cost. The integrated surround decoder with built in amplifiers will be sufficient for a small to medium sized SOS system not requiring microphone amplification. A system utilizing a microphone will require a second sound system that is both optimized for microphone use , and will work in harmony with the surround sound system. Illustration #7 shows an example of an SOS surround system that has an integrated microphone amplification system.

Illustration #7



There may be a desire to upgrade to a digital audio system or more advanced audio system schemes. This author has no objection to such an upgrade, and would always encourage sonic improvements in any sound system. However, keep in mind that currently SOS programming and computer systems provide only an analog left /right stereo output. The current SOS computer systems delivers excellent results with a standard surround

system, so upgrading to something more advanced like a digital system may not render any improvement at this time.
Certain equipment brands where chosen for our installations based on our experience and budget. This in no way mandates the use of the brands that we used. There are many excellent products available that will successfully perform the same functions. It is recommended that you consulted with your local audio specialist for your particular site application. It will help you, as an SOS administrator, to integrate a successful audio surround system if you share this document with your local audio system designer.

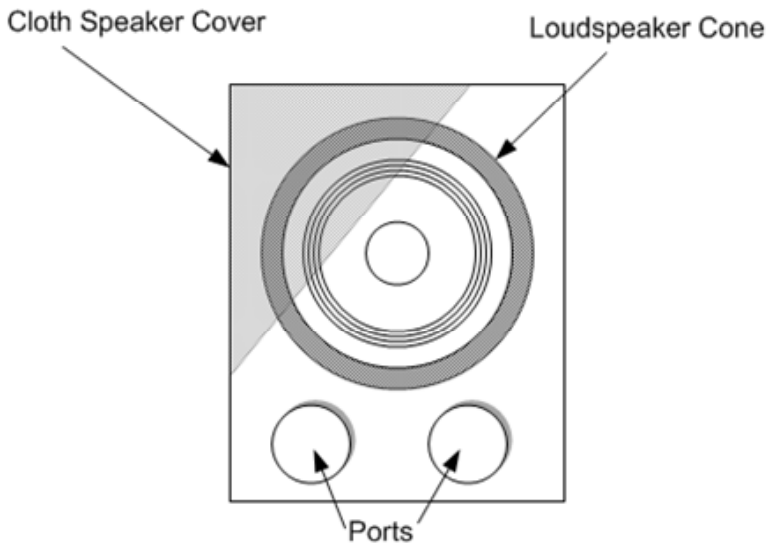
Below is a list of equipment that we have installed into SOS surround systems that have rendered excellent results.

Denon DN365 Surround Receiver; Surround Sound Pro Logic Processor Amplifier
One Systems 3.5 Passive Loudspeaker; Left, Center and Right Loudspeakers
Shure ULXS Combination Handheld Lapel: Wireless Microphone System;
TOA M01F; Microphone Preamp Module
TOA U03R; Surround Preamp Module
TOA M912MK2; Mixer Amplifier;
Atlas Soundolier HT87; Loudspeaker Transformer Hi Fidelity
K-Mack C9 2.2 HO; 2 X 2 drop tile Loudspeaker
Allison AL10 ; 10inch 125watt powered subwoofer
Windy City 991360F; Loudspeaker Wire 16 AWG 2 conductor with overall jacket

The Subwoofer
The subwoofer is a wonderful invention, and a valuable asset to any audio system. Use of a subwoofer is strongly recommended in an SOS surround system. However, there is a lot of misinformation about subwoofers. This section will attempt to explain the proper integration of a subwoofer into an SOS sound system. One of the first things that should be considered is placement. There is a school of thought that a subwoofer can be located any place in a room and it will work fine. This concept is born from the theory that at low frequencies, sound in an acoustical environment becomes non-directional. It is true that at low frequencies sound becomes non-directional, but the frequencies at which this happens are very low and are closely related to the size of the room the subwoofer is located in. A majority of the low bass notes reproduced through a sound system are at about 50 to 60 Hz and rise to around 300Hz or higher depending on source material. At 50 to 60 Hz there is still some directionality, and the sound source can be identified and located by the human ear. Placing a subwoofer just anywhere in a room will cause a psycho acoustic disconnection between the high and low frequency loudspeakers.
When the subwoofers are placed in line with high frequency speakers, the highs and low become coherent and create a unified point source. The term point source is used herein and in the audio industry to describe the way sound propagates from a single place, usually, a loudspeaker or group of loudspeakers clustered together. The sonic results that are achieved by creating a point source are very much worth any effort that is required. Using the sphere as an example, the sound will be coming from the direction of the sphere itself. All of the sound will be perceived by the listener to come from the sphere. It is understood that in some installations it may not be possible to mount the subwoofer in line with the high frequency speakers to create a point source, in which case a compromise will have to be made. The low frequency portion of the sound will be perceived as coming from somewhere else in the room but not the sphere.
Subwoofers are available in either powered or unpowered versions, and both types work well. The unpowered subwoofer is only a loudspeaker in a tuned box. It will require a separate amplifier and crossover. The crossover divides sound into two or more parts. In the case of a subwoofer, the crossover sends the sub bass to the subwoofer, and the high frequency sound to the high frequency speakers. A powered subwoofer, however has the amplifier and crossover built into the subwoofer cabinet, and comes as a standalone solution. This type

subwoofer will require a standard AC power outlet at the sub's mounting location to power the internal amplifier and crossover. There are many different designs and types of subwoofers. For an SOS application, a direct radiating, ported subwoofer works best. In a direct radiating subwoofer, when you remove the cloth speaker cover you can see the loudspeakers cone. The term ported means that the subwoofer box is a bass reflex type enclosure. A bass reflex box has holes, called ports, which allow air to flow from the rear of the speaker (inside the enclosure) to the exterior of the box. Depending on the designer's preference, a box may have one or multiple ports. An example of a direct radiating, ported subwoofer is shown in illustration #8

Illustration #8



SOS Room Acoustics

The room's acoustics for an SOS venue are important, and should be a priority. In most cases, acoustics are not typically considered over other factors like furniture, architectural elements, or even paint colors. Poor acoustics can and will adversely impact the SOS viewing experience. The sound system and room acoustics work in concert with one another. A great sound system within a poor acoustic environment will not sound good at all. Having a good quality audio system can and will enhance the SOS viewing experience. A good acoustic environment will further enhance the SOS surround sound system with improved articulation and clarity. An acoustical consultant should be considered to evaluate a prospective or existing problematic SOS venue. Contracting an acoustical consultant may not always be possible and when it is not, a basic knowledge of acoustics can be very helpful.

There are several factors to consider when you are evaluating a space for a new or existing SOS venue.

1. Room reflections, or elements within the room that cause a brief or long echo.

Problem; Hard walls, floors, ceilings

Solution; Wall treatments are very helpful in reducing reflections (echo) in an SOS room environment. It is a myth that carpet is a good sound absorber and should be used on the walls. This author would also strongly discourage the use of foam type sound absorbing products because of limited life cycle and fire code compliance issues. A rigid fiberglass board covered in a fire rated fabric is an excellent means of reducing room reflections. Floor to ceiling and corner to corner covering of walls with an absorption product is not necessary. Panels that are wall mounted with space between each panel will render very good results. Covering floors with carpet will help reduce sound reflections but floor coverings are not a total solution. Adding sound absorption to

the ceiling will have a strong impact. Treatments like acoustical tile ceilings or acoustical clouds work very well.
Acoustics and seating are very much related. An SOS venue should have comfortable seating because of the amount of time an individual spends viewing an SOS presentation. A person seated in a chair can have a very different acoustic value than an unoccupied chair. In a venue with a large number of chairs, the acoustic difference between a large and small audience can be quite extreme. Some chair manufactures make chairs that maintain an equal acoustic value occupied or not. This type chair is preferable for use in an SOS venue.

2. Leakage, or areas that will allow foreign sounds to enter the SOS room or allow SOS sound to leave the room.

Problem: Doors, open walk ways, windows, poorly constructed walls, ceilings, and floors

Noise leakage can work in two directions, Sound can come into a space, or sound can escape from the space. Either way, sound leakage can be (and usually is) problematic. An office next to an SOS venue can be an example of this. The audio from the sound system during loud parts of a presentation could make it difficult to concentrate or talk on the phone in the office. In the other direction, a phone in the office ringing could cause a distraction in the SOS venue. When focusing on leakages for an SOS venue, there are several questions that should be addressed.

What is in close proximity to the SOS venue?

Can the SOS venue be physically (acoustically) isolated from other areas in the building? Isolation could be as simple as closing a set of doors or as difficult as building new interior walls.

What is above and or below the proposed SOS venue? A bowling alley or machine room one floor above an SOS venue would be a source of objectionable noise.

Keep in mind that if air can flow in or out of a space, sound can propagate in or out of the space also.

Each venue will have different physical conditions and surveying your prospective venue for areas of offending noise leakage will be very beneficial.

3. Noise or anything that will create an unwanted noise within the SOS room.
   i.e. heating and air conditioning ducts, machines noise, water fountains, or equipment fans.

There are many things that can introduce or generate noise into an SOS environment. Heating and air conditioning ducts are usually the biggest offenders. Air flowing through duct work and diffuser vents can create a high level of noise if sound levels are not taken into consideration during the air system design. A poorly isolated rooftop heating and air conditioning unit can transmit mechanical noise into the venue. A drinking fountain with a water cooling system can produce a substantial amount of noise both inside and outside the SOS space. Most sources of noise can usually be quickly identified. Resolving some noise problems only require common sense. Others will require the knowledge of an experienced acoustician. It is wise to consider room acoustics when you are in the design phase of an SOS installation project. Assuming that a building contractor will take care of your acoustic problems without a written specification is naïve, and will likely leave you with a poor acoustic environment.

Conclusion

The purpose of this document is to illuminate the finer details vital to successfully producing an SOS presentation and implementing a compatible audio system in an SOS venue. Obviously, each production and

venue will be presented with its own set of challenges. The goal of this white paper is to offer an audio solution for the SOS theaters that is compatible from production through presentation. This document should at least inform program producers and bring to the attention of the audio technician the unique requirements and design philosophies of the SOS surround sound system. Furthermore the SOS administrator should take away an overall understanding of the unique aspects of an SOS venue and the complimentary audio system. Administrators, technicians and program producers should be able to use the information contained in this document, paired with their own expertise, to clearly navigate the creation of an exceptional, unique SOS audio experience.

Credits and Legal

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Fantasia is the title of the full length animated feature film produced by Walt Disney of Walt Disney Productions. Leonard Stokowski conducted the music used in the sound track.

Dolby Laboratories developed the surround sound process referred to as Dolby Pro Logic.
www.dolby.com

Denon is a manufacture of consumer and professional audio equipment and is distributed within the US through D & M Professional
www.d-mpro.com

One Systems, Loudspeaker manufacture.
www.onesystems.com
Shure Microphone manufacture.
www.shure.com
TOA Amplifier and other audio products manufacture.
www.toaelectronics.com
Atlas, Soundolier Loudspeaker and other audio products manufacture
www.atlassound.com
K-Mack Loudspeaker and AV furniture manufacture
www.kmackracks.com
Allison, manufacture of subwoofers. No known web site. We purchased ours through Parts Express but Allison subwoofers are available through many audio dealers.
www.parts-express.com
Windy City manufacture of all types of wire
www.smartwire.com