Understanding

CHURCH ACOUSTICS

A guide to better church acoustics

- What is acoustics?
- How to identify acoustic problems in a church?
- Planning and implementing an acoustic treatment

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A GUIDE TO CHURCH ACOUSTICS

Church acoustics. It usually begins with complaints like "We just can't hear what's going on", or sometimes with a dream, "If we could just build a better church, more people would come." No matter what the reason, a committee member is eventually selected and sent out into the world to collect information and bring it back for evaluation. We hope this guide helps provide some of the information needed to get the job done right.

For most church projects, the talent to get the job done lies right there in the congregation. But church acoustics is not like most projects. You'll do it once or twice in the life of the church. That's why it is important to have a guide. We work with churches every day and hope to provide you with a practical guide to help you get your church acoustic project started off on the right foot.

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Church Acoustics - What is it and what it isn't.

Let's begin this guide by defining church acoustics. It is generally that which manages the sound in the church (the room itself, and objects within the room). It is not about making sound. Church acoustics is what happens to the sound after it has been launched from the speaker, to insure that the people who are supposed to hear the sound, actually get to hear it. Church acoustics is a purpose built space, dedicated to getting the right sound to the right person, from the right direction and at the right time. It is not easy, but it can be done.

There are many things in a church which make sound : loudspeakers, musical instruments, air conditioners, people talking and moving ..... Once a sound source launches sound into the air, the acoustics of the church takes over and processes the sound, for better or worse, until the sound dies out.

Good church acoustics helps people to hear better what they do want to hear and to hear less of what they don't want to hear.

However, good acoustics can't make something sound good that basically sounds bad. The old saying is: GIGO-Garbage in, garbage out. If the piano's out of tune or the soloist can't carry one, having better church acoustics won't help. If the sound system is distorting, better church acoustics won't make it sound better.

Better acoustics only means that you'll hear whatever the sound is, better. In most situations, the sound system is

already just fine, the piano stays in tune and the choir sings in time. And that means the improvements you make in your church acoustics will be amply rewarded.

Church acoustics starts with the sanctuary but it doesn't end there. There is more to a church these days than a sanctuary, an entry and a cry room. The fellowship hall has a pretty significant acoustic requirement. And so does the daycare/after school program. There is usually at least one wing of smaller rooms and spaces, which provide for staff and activities, all connected together by a noisy hallway. Some offices really need quality privacy, like the pastor. Others, the receptionist and office manager, might be more open. There will be small teaching rooms, prayer rooms and even bathrooms. Each requires a certain quality of acoustic control and sound isolation. And so the other part of the job is noise control-keeping unwanted sounds away.

The types of adult and teen activities that a church hosts these days tends to require a lot more privacy in general than that of yester year. Often times, one room is hosting an AA meeting while next door is a Boy Scout troop meeting. Down the hall, a battered women's group is next to the teen club, and on and on... The diversity of today's church reflects its dedication to providing whatever is needed by the community to help them get better-both personally and in fellowship.

But all this side-by-side diversity in space utilization also means that sound and noise control is one of today's churches top priority.

So, Where do I start?

Whenever you are starting on a project it works best if you take stock of what you have and what you need. Church acoustics is to a very large extent about helping people to hear what they want to hear. And this is a great place to start. Make a long list of what everybody wants.

Each person may represent a different aspect of the overall sound quality that should be considered when planning to improve the church acoustics. A typical input statement may go something like this:

‘I am ___________ and represent the _________ aspect of the congregational process. I feel that the sound of the________ should be improved so that the ________ can ________better. Probably we should ________but we should be careful not to __________________________.”

Some people will be able to represent more than one aspect, or have more than one suggestion. Each variation of the statement is written as a stand alone statement. A person may be able to write 5 variations on one basic theme.

There is no expectation for anyone to be an acoustic wizard when going through this process. The intent is not to ask them for possible *solutions*, but rather gain their assistance in figuring out what types of *problems* do exist. We ask this because one of the ways people seem to easily express themselves is by talking about their own needs, desires and frustrations.

Each person who is asked to say what they think should be focused on. This last statement serves a number of purposes.

1) It helps people know they have been heard.
2) It provides independent clues to the “problem”.
3) It formalizes the process, giving it validity.
4) It creates a window of time in which to speak.
5) It helps people formalize their concerns.
6) It creates a list for reference.
7) It allows minority positions to be expressed.
8) It facilitates a community version of resolution.

Here are some examples of “Probably.. but” comments:

> “We want to improve the sound but we don’t want to buy more any speakers.”
>
> “We want to hear pastor better but we have to keep the reverberation for congregational singing.”
>
> “The fellowship hall is too noisy for daycare but we also want to be able have choir practice in there.”
>
> “The praise band is just too loud but we love the sound of the church for speaking and singing.”
>
> “We know the large windows contribute to the echoes, but we shouldn’t block out the view with curtains.”

If people don’t explain what problems and concerns they have with a space, then it is pretty hard to fix their space.

Budget

Everyone wants to know how much will it cost. If you are working on a church acoustic committee, the cost estimate is something you have to come up with. There are two versions to a cost estimate. One is to find people to bid the job. The other way is to look at your funding and figure out how much you have to spend.

People always say that they don't know if they can afford an acoustic project because they don't know what one costs. So, as hard as it is, the best thing to do here is to just talk about money. Acoustic projects for churches cost in the thousands of dollars, not hundreds. A small project will be around $1,000. A typical project will be in the $3 to 5,000 range. A fairly large project will run $10 to 15,000 and a big project will cost $25 to 50,000. This is just for the materials to do the job. Converting a big room that sounds like an empty gym into one that sounds like a church will cost about 20 cents per cubic foot. (L x W x H)

To the material costs, there is the cost of installation. This ranges about 10 to 15 % of the material cost.

Now that the basic costs of doing a church acoustic job has been covered, you and the church committee probably don't know any more about your project than when we started. But there is one thing we can depend on, like getting most anything that is good and worthwhile, completing the church acoustic will usually cost more than we wanted to spend. But when you start to use the church again, you'll be proud that you stayed the course and got the job done.

If you are planning new construction, you should figure in about $5 per square foot of building space for acoustics and noise control.

Another way to look at it is to remember that an acoustic/noise control budget for new construction is between 5% and 10% of the cost of construction.

Sometimes it is helpful to talk about what it costs the church to not fix the acoustics. For one, there is the emotional aspect that comes up when people aren't heard. Dissension remains within the committee, unresolved and important issues remain on the table's back burner, year after year. If the church acoustic doesn't get fixed this year, it will come up next year. Sometimes a church will have talked about doing acoustics for a decade, each time tabling the discussion until the next year. People get tired of trying to fix something over and over. If they can't move forward, sometimes they just give up or move on. So there is a moral of the leadership to consider, the idea of having a team, solving problems and moving on to newer and bigger ones.

What else happens when the church has bad acoustics? Basically the church was built for doing something that it isn't able to do. And, if it can't do what it was intended to do, then it is failing to realize it's potential. A church that is held back from reaching it's potential is really a loss for everyone. People have to hear clearly to understand what is being said. Not being able to hear causes frustration. Instead of finding inner peace, frustration blocks the way. As people grow older, hearing often becomes more of an issue. Churches who fail to address the needs of their senior members, may be alienating this important segment of the congregation and all they have to contribute.

Elementary Introduction to Room Acoustics

Before discussing church acoustics, it may be a good idea to cover the basics of big room acoustics:

Sound waves travel in the air and bounce off the walls, floor and ceiling, back into the air again. Any of three things happen when sound it hits a surface. It is either conducted, absorbed or reflected. Conducted sound simply leaves the room. If absorbed, the sound is partially or totally killed. If reflected, it is returned back into the room. Usually all three things happen at the surface.

Conducted sound is simply transmitted through the surface. The lighter the weight and more limp the surface, the more easily it conducts sound. The lower frequencies transmit through a surface more easily. Heavy, stiff walls like concrete hold sound in a room. Lightweight, flexible surfaces, like windows, leak bass out of the room.

Sound absorption is caused by friction as sound moves air through and past the microscopic surfaces of fibrous materials. It works well for the high frequency range but generally is less effective in the bass range.

Sound reflection is what is left. That which is neither conducted through, nor absorbed at the surface, just bounces back into the room. If the surface is flat, then we have a reflection. If the surface is curved or irregularly shaped we have diffusion-the scattering of sound.

While absorption of sound takes place for the most part on the surfaces of the room, the *storage* of sound takes place for the most part in the volume of the room. In general, one can say: Sound lives in the air of a room and dies on it's surface.

Room Size: The bigger the room, the more sound it can hold. Conversely, a sound in a small room will be louder than if played in a big room. Turn up the volume of a radio in a small plaster room. It's plenty loud anywhere in the room. Then move the radio, same volume setting, into a big church and step way back, the radio now seems quiet. Big rooms swallow sound. It takes a lot more sound to fill up a big room than a small room.

Room Geometry: Two different shaped rooms might have the same cubic volume but different surface areas. If they have the same volume, they both can hold the same amount of sound. But, the room with the larger surface area will have its sound die out faster. Conversely, two different shaped rooms may have the same surface area but different volumes. The room with the larger volume will store more sound, and it will take longer for sound to die out in the larger room. Given the same volume, a room with a low ceiling will sound louder than a room with a high ceiling.

Reverberation is what occurs when sound is *stored*. If we enter a big empty room and fill it with a long shout, then stop and listen, we hear our sound slowly die away. How long the sound takes before it dies away depends on how much sound is *stored* in the room's volume and how much sound is *absorbed* from the room's surface area.

The time it takes for sound to die out is the *Reverb Time* and it is measured in seconds. For a big empty room, it can be estimated by the ratio of Volume to Area.

Reverb Time (seconds) = Volume/Area (feet)

For example, a completely bare sanctuary, 25 feet high with floor space of 60 by 100 feet has a volume of 150,000 cubic feet and a surface area of 20,000 square feet. The reverb time for a good shout in this room will be about:

150,000/20,000 = 7.5 seconds.

A larger room with 400,000 cu/ft and 36,000 sq/ft of surface area would have a reverb time of about 11 seconds, while a smaller room with a volume of 72,000 cu/ft. and 12,000 sq/ft would have an estimated time of 6 seconds.

Bigger rooms have more volume, therefore hold more sound than small rooms. They also have longer free flight times, and less absorbing impacts per second. Big rooms hold sound much longer than small rooms.

Reverberation, however, may not be uniform throughout a room. The shape of a room also affects the sound.

Room Shape: As a general rule of thumb, sound is stored in the high volume part of a room. A room with a small floor area and a high ceiling will seem to sound reverberant overhead. Whereas a high peaked ceiling pushes the reverberant effect down into the congregation.

Vaulted (slanted) ceilings open up the volume of the room larger at one end than the other. A high ceiling over the pastor and low over the congregation causes the reverberance to be up front, near and behind the pastor. If the ceiling is low over the pastor, then the reverberation is located in the back of the hall, which usually sounds better. A room that is very long will have a strong echo off the back wall. The shape of a room also impacts how sound decays and to see it, we consider time of flight. A room might be 60 feet wide, 30 feet high and 120 feet long. Sound travels just under 1200 feet per second. It hits one of the side walls every 60' or 20 times per second, the ceiling or floor every 30' or 40 times per second and one of the end walls every 120' or 10 times per second. Generally, the vertical sound dies out fastest because it hits a surface 4 times more often than sound hitting end walls and twice that of the side walls.

Conclusion

And now we can see the overall object of this lesson. A bigger room takes a disproportionate amount of acoustic work to be fixed, compared to a smaller room. The big room holds more sound and provides proportionally less surface area than a small room. Even more, a big room lets the sound travel farther between successive impacts on it’s surface. This even further slows the erosion of the sound.

But the big rooms do one thing that small rooms can’t do-they hold lots of people, and that means big rooms are here to stay. And when we have one, the best thing we can do is to remember what’s going on in the acoustic life of your big room. Be patient and supportive in the amount of money, time and effort that has to be spent on getting your big room to behave in a reasonable fashion. But fill it up with people and you’ll know why you did it.

Multi-purpose Sanctuary

Even the most basic church is a multi-use facility. The minister speaks and the congregation listens-that's one use. Later, the choir sings and the congregation sings along-that's another use. For speech to be understood by the congregation, a non reverberant room works best. For hymns to be sung by the congregation, a reverberant room works best. It seems that the sanctuary would only be able to satisfy the requirements for one, either speech or singing but certainly not both. This is a fundamental dilemma that plagues the church acoustic committee members.

This tension between what the pastor knows is needed for the sermon to be heard and what the music minister knows is needed for the singing to be engaging, can deadlock any interest in church acoustics for years on end. If the pastor doesn't want to change the acoustics or doesn't want to deal with the stress of the upset music minister caused by changing the acoustics, then every time the subject is mentioned, it gets dropped.

In the olden days, the church was not an either/or proposition-acoustically. In the small country church, the pastor was close to the congregation. So, despite the noisy room, everyone could hear. And it certainly sounded great for singing. But sanctuaries these days aren't so quaint. They are big, wide, deep and tall and they have a carpeted floor. They are so big, that a person's own voice never really returns to them. The only sound they hear is that of their immediate neighbors. These congregation members feel isolated-though standing in a sea of people.

An acoustically designed church should perform both church functions well. It will support both speech and singing, and not one at the expense of the other. The pastor can be happy, knowing that the message is getting through and the music minister begins to rest assured, seeing that the congregation catches fire when singing. A good design of the sanctuary acoustic allows what is supposed to happen, to really happen. Acoustics is a support service, it doesn't get the spotlight. The goal of acoustic design is to bring the space to life-so that, as people use it, they don't even notice anything more than that it sounds good.

Often times, a church with *speech intelligibility* problems will attempt to address the problem by having acoustic materials installed on the walls or ceiling. Only later to discover that they have sacrificed the quality of the singing and music within the church. Though they bought a solution to one problem, they created another in the process. These are mistakes which are costly but avoidable-with the proper guidance from a trained acoustician. Church acoustics are not the same as 'sound control'. Sound control is used in large commercial facilities such as auditoriums, gymnasiums, swimming pools, and the like. The focus there is to just remove the sound. Unlike a church, where you are trying to retain desirable sounds, and remove the undesirables ones.

Church acoustics involves the complex subjects of wave propagation, physics and architectural geometry and should be handled by people qualified in these areas. Before hiring someone to work on the acoustics, it is best to find out what their background is in these subjects.

Gymnatoriums

It is a new era in community churches, and frequently the first building put up is not the sanctuary, it is a gym. Concrete slab, tilt up walls and a steel truss roof. Before it got painted, it could have been mistaken for a warehouse. Ugly? Yes, but it's the cost effective starting point for the new church. And then the reality sets in. No one can hear what is going on. What can be done with 25' high concrete walls and floor space that measures at least 60' by 100'…?

Some congregations intend to leave it as a gym/daycare facility with weekend worship until the sanctuary is built. Others want to use this space as an architectural shell and build the sanctuary inside of it. Yet another wants to convert this space acoustically to a good sanctuary for the present but when the real sanctuary finally does get built, remove most of the acoustics from the gym and relocate it into the sanctuary. And these are just a few of the many plans and options that get considered when a congregation has this type of large room.

Not only is the type of worship an important factor in these spaces, but all too often, the acoustic committee's concern is also about how to support the transitional nature of the space. Conceptually the process starts with making the gym a minimally sensible place to be in. This means that the upper walls and the ceiling must be fit with acoustic materials.

A bare gym has a reverberation time of around 5 to 7 seconds. By adding either ceiling acoustics or upper wall acoustics, the reverb time drops to about 2.5 to 3 seconds.

This is the typical amount of reverb in a standard school gymnasium. This type of acoustics is only suited for sports activities and at that, not very well. Most coaches don't like to work in such a noisy gym.

The next step is to add the second half of the system. If the ceiling was done, then the walls have to be done or visa versa. However, there is more to achieving good listening in a large space than getting the reverb time right. Echoes may be bad, and they are not measured by reverb time.

An echo is the bounce back off an opposing wall-typically the back wall. It is the sound that passes by you, bounces off the wall some 30 to 100 feet away, then washes right back over you. It makes for bad listening and even worse speaking, singing or playing. An echo throws off your timing, distracts you, and causes you to stumble over your words and thoughts.

Echoes and reverberation, both have to be managed. Since acoustic materials are used to achieve both, the first thing to do is to absorb the echoes. Introducing acoustic materials into the room to absorb echoes also acts to reduce the reverberation. Two benefits for the price of one. From there, you can check the reverb time again and add what is still needed to get it to an acceptable level. When both have been completed, then the reverb should drop to about 1.25 to 1.5 seconds. This is a good reverb time for most uses of such a large volume room

Circular Churches

Sometimes the building has been built in a circular pattern. The rear wall will be smoothly curved or it may be made up of flat sections set up along a circular arc. The extent of the arc may range from as much as a 3/4 circle to 1/4 circle. The ceiling of these spaces is usually segmented by beams that converge high above the center of the circular arc. Circular rear walls create a unique and pretty disastrous set of problems and to fix them requires aggressive acoustic effort and materials.

There are two problems with circular sound reflecting surfaces. One is that sound travels very well around the curve of the wall. The other is that sound that starts from a location out somewhere in front of the curve gets reflected back to a focal point, something like a magnifying glass. The location of that focal point moves around, depending on where the sound source moves or is located. Refocused echoes are very loud at the focal point and when you hear it, the sound seems to come from some mysterious place, some odd direction which usually doesn't make any sense.

A traditional flat wall does not focus sound, it lets sound continue to expand and get weaker with distance. But a curved wall does the opposite, the sound gets stronger as it travels away from the wall. With flat walls, acoustic tuning of the space usually gets done only by using a pattern of alternating absorption and wall reflections. This acts to thin and scatter the sound that is bouncing off the flat wall.

When working with churches and most public spaces, the sound reflecting wall is never completely covered with absorption. This causes a "dead acoustic" effect that is very undesirable for people to hear. However, the focusing effect of curved walls is so strong that applying a "normal" amount of sound absorption to the wall barely effects the sound at the focal point. One then adds more and then more again until you find the wall to be completely absorptive. The focal point problem went away but now we have the "dead wall" effect, also a disagreeable sonic effect.

When working with curved walls, the thinning effect of absorption is not enough. Here, two different acoustic functions are needed to get the job done.

1) Some of the sound needs to be absorbed at the surface of the curved wall, as with any back wall.

2) The remaining sound needs to be scattered, reflected in directions away from the focal point.

Whatever sound that is not absorbed on the curved wall needs to be scattered off in some direction away from the focal point. The typical sound scattering device is a curved panel, called a poly. The poly-panel is essentially a thin flat panel that is bent to have a curvature that is reversed to the curve of the wall. A poly only scatters mid and high range sound. The poly must also be a bass trap so that the reflecting low frequencies do not focus. By mixing up the absorption and scattering of sound on curved surfaces, people sitting near the wall still hear a lively wall and those near the focal point don't hear the focused sound. Both seating areas are now comfortable.

Big Rooms with Beam Ceilings

Big rooms seat lots of people and it's great to have a big congregation. But big rooms also have big ceilings and big ceilings have to be held up. Putting posts throughout the congregation is not what people build these days, they prefer the clear span ceiling. But to carry all that weight all that distance, big beams are needed. The beams are so big that they really reflect the sound that hits them. Speakers are usually hung in the ceiling, nested up inside of or just below these big beams. The beams catch the sound emitted from the speakers and redirects it, usually in the wrong direction. Big beams can be big trouble in churches.

When speakers are installed near big beams, the beams intercept and redirect the sound that was emitted in the upper part of the room. Basically the sound will be sent out to travel along side the beams or out to try to cross over the beam. When the sound gets trapped between a pair of beams and travels down their length, the sound between the beams remains very loud. It hasn't been allowed to freely expand out over the whole hall. This channeled sound dumps out at the end of the pair of beams almost as loud as when it began. This hallway echo effect is very bad for quality listening in the seated areas below the far end of the beam.

If the sound is sent off instead, across the beams, a completely different effect develops. The sound can't hurdle the beams. It is reflected back towards where it came from, only to find another beam, broadside waiting for it. Like a handball, the sound is reflected back and forth between the two beams over and over again. This creates a reverberant effect overhead, right by the speaker.

This reverberation isn't like the more familiar, room reverberation which takes around 2 seconds to build up strength. This cross-beam type of reverberation is very strong and takes place very fast. So fast, people can't separate the cross-beam reverberation from the voice of the speaker. It almost sounds like there is something wrong with the speaker. In fact, this is one of the main reasons people buy new speakers, because they couldn't understand what the old ones were saying. Little did anyone suspect that it wasn't the speakers that were bad at all, it was the fact that the speaker was hung close to a pair of big beams.

Big beams are very high up off the ground so working on them ends up being a high wire act. No one likes to be high up off the ground and the more time up in the air, the increased odds of something going wrong. But, no matter how many reasons there might be to simply hang a sound panel on the wall, there is only one way to deal with bad acoustics from big beams-and that is to add acoustics to the beams, way up there.

The good news is that if the acoustic fabric has a similar color, close to the that of the beams, no one notices the acoustic material that has been added to the hall. They don't see it but they sure hear it. And when it comes to church acoustics, the best opportunity for success is a design that incorporates easily, that no one would notice and that works. The way the church looks is important to people, and usually they are resistant to changing the aesthetics to a large degree.

The Praise Band vs. the Pipe Organ

It is not uncommon these days to see the choir being replaced by a praise band. Here is a building that might have been built to support a pipe organ and choir now being asked to support a praise band with it's electric bass guitar, kick drum, rhythm guitar and cymbals, not to mention lead and backup singers.

The idea of a rock band in a church sounds good from one point of view. The music minister is dedicated to engaging the congregation to worship through music. And if it's a rock band, so be it. But the acoustics of most churches won't support the sound of a rock band. Most auditoriums or civic halls won't support that type of sound either. Before we begin to wonder about outfitting a church for the purpose of supporting a praise band we should spend some time just pondering what is so different about the type of sound that comes from a rock band that causes so much problems for many otherwise good acoustic spaces.

The first thing is, that the rock band has power-lots of acoustic power. Microphones, amplifiers and speakers. When you look at the stage area of a rock band, even before the performers and the instruments arrive, you see mics, cables, amps and lots of loudspeakers. But stand back and look again, over half of these speakers, called monitors, are pointed right back at the musicians themselves.

Let's say this again more slowly. It is so loud on the stage of a rock band that the musicians can't hear each other. So each musician sets up their own personal loudspeaker just a few feet away, points it straight at them and turns up the volume.

With a church rock band, there is a tremendous amount of sound power being pumped into the sanctuary. A big pipe organ also pumps a lot of sound into the sanctuary. But there is a difference, a big difference. Speed. Pipe organs change notes slowly but notes in a rock band change quickly.

A pipe organ likes a slow hall, one with a long reverb time. The lingering sounds of the last note are mixed with the new sounds of the next note. Fantastic falling chords of reverberant sounds are generated by this. Pipe organ music is even written to include the after glow of the sounds mixing together in the hall. The accompanist to pipe organ is the hall acoustic.

The rock band likes a fast hall, one with a short reverb time. The amplified power is strong and the note sequences come rapidly. The staccato of the drummer, the attack transients of the rapidly plucked bass guitar string, the fast fret work of the lead guitar and the dynamic vocal lines-all get jumbled together into a sonic mess-if the hall can't keep up, because it's too slow. The enemy to the rock band is the hall acoustic.

We can quiet the acoustic level in the hall by reducing the amount of sound being delivered to the hall. This is done by making the *stage* acoustically dead. When the stage is dead, the congregation only hears the sound that is projected forward, intended for them to hear. When the band plays in a dead stage, the on-stage noise levels go way down, and that means the band turns down their monitors. This reduces even more the amount of on-stage noise-a good thing.

Folk Music in Church

On the opposite end of the scale for church music is the folk music. A guitar and a song. A soloist. An unaccompanied choir. Simple, beautiful, and not necessarily amplified. This type of sound may not be loud enough for everyone to hear well, and it certainly is worth hearing.

Small acoustic groups, the soloist, a duet or ensemble are playing out into a hall that is usually the wrong shape and way too dead to be heard well enough. The classically designed recital hall is long, mildly low and narrow, and well suited for small acoustic venues. The stage walls and ceiling have a megaphone shape.

This design is not much different than that of a country church but it is greatly different than the wide, high volume urban churches we see today. Sometimes we can't have it all and a compromise is in order. But before we can strike a compromise, we have to go over the priorities of an acoustic performance.

The acoustic performance does not put out much sound power. The sound, therefore, should be projected out into the congregation seating area. The performers would be best heard if they were set up in an acoustic shell, the megaphone effect. Any sound that would have been wasted going off in the wrong direction, up, down, backwards or sideways is reflected out into the congregation.

The only problem with this is that the acoustic performers also have to hear themselves and each other, no different than with the rock band. So, there must be included in the acoustic shell some amount of reflection that keeps the sound of the performers hanging around the performers.

Acoustic shells are usually thought of as being useful in projecting sound. But here, we also need the shell to contain some of the sound. It is a delicate balance between projection and containment that gets a shell to work correctly. A choral shell has the same job to do. The choir is an acoustic ensemble. They need to hear each other while they are singing. If they sing out in the open there are no reflections to help them keep in sync, both in tone and rhythm. When shopping for a shell or a shell design, there are two functions that have to be provided:

1) The performers get to hear each other and themselves
2) The congregation gets to hear the rest of the sound.

The acoustic performances need the opposite kind of stage than the amplified performers need. Acoustic performers need a live stage and rock performers need a dead stage. But all performers need to hear themselves and each other very well.

The surface of a live acoustic shell has a lot to do with the sound of the performance. The wrong material, such as metal, will impart a 'tinny' or 'metallic' signature to the sound. Plastic and fiberglass tends to be 'drummy'. On the other hand, wood is warm and organic-which is a good reason why acoustic instruments are normally made from it.

The Traditional Church

This church is not the large cathedral, it will be long and narrow with a high peaked roof overhead and usually a balcony in the back. The size ranges from small, 25 feet wide to big, 60' wide but their length is always 2 to 3 times as wide, and the peak is as high as the width. The ceiling is often wooden with beams, but those built recently are found sometimes with just plain sheetrock finish. They are delicately balanced, clear sounding enough for speech and reverberant enough for singing, when occupied. Generally there is not much sound absorption material in the room.

This design is time proven. The high peak ceiling acts like an overhead reverb chamber, which, with its megaphone shape, keeps pushing the reverb down into the seated congregation area where it is both heard and absorbed. The side walls are narrow and the pastor speaks from a raised platform. This allows much of the side traveling sound to keep reflecting back and forth over the congregation, adding early reflections to improve intelligibility. These rooms are great for natural acoustic speaking. If an overhead speaker is used, is should be adjusted quiet enough to only reinforce the natural voice of the pastor-but not overpower him.

Areas for improvement are to angle the side walls slightly near the front of the church to project more sound to the back. What the front side walls otherwise do is to keep the sound bouncing back and forth between the side walls but not moving down the hall. This lingering sound up front blurs the articulation. Or, if the overall sound is loud enough due to the smallness of the church or due to amplified sound being used, this blurring effect can be eliminated by adding a small amount of distributed absorption along the front side walls. This is particularly important to do when musicians are performing in the front end of this hall.

A simple hand clap from the front of the church will demonstrate if an echo is present. If it is, then is should be eliminated. The echo will usually bounce off the back wall. Try and estimate the amount of time the echo takes to return. If the church is 60' long, the echo should arrive in about 1/8th second. Generally a distribution of sound absorbing items and sound scattering items needs to be located on the rear wall. Frequently it is the back wall of the balcony that is causing the echo. Once the back wall is improved, the face of the balcony might be noticed as also contributing it’s own echo and also quite distracting.

The roof peak over the pastor catches the upward moving sound, compresses it with its megaphone shape and then reflects the sound right back down. The lower range of the voice is usually the problem here and improvements are made by adding low frequency sound absorption up in the peak. Also, the central cluster speakers are typically hung high over the pastor but down from the peak. The high frequencies (the “sss” sounds) are easily directed into the congregation by the speaker’s horn. But the low frequencies go in all directions with equal strength. If the speaker is located some 20 to 30 feet off the front wall of the church, this creates a bass reverb zone between the lectern and the alter. Low frequency, bass trap type sound absorption located in the peak and ceiling area is the only way to get rid of the muddy sound in the front end of these rooms.

The Acoustic Church

Despite the multi-media wave of electronics that washes over many churches, there is also the opposite effect, the natural acoustic movement is making inroads into the church community as well. Some churches are turning off the microphones and unplugging the speakers. They are going back to natural acoustics. They are finding themselves feeling overwhelmed with processed sound. That something human is lost when a voice is transcribed into electronic circuitry and then rebroadcast.

Sometimes the congregation discovers this mood quite by accident. In the middle of the sermon, the body mic becomes unplugged, a battery runs out or even something worse. All of a sudden, there is no audio power. The pastor is there and the congregation is there but there is no audio. The service must go on. And it does. The pastor raises the voice a bit and people listen a little more carefully and it is amazing, no one needed a microphone after all. And that's not all, people actually hear better when speakers are natural.

There are many reasons why people hear natural speech better than amplified speech. The most important benefit derived when listening to a natural speaker is that the sound of their voice comes directly from the position of their mouth. The brain is used to this kind of communication. Listening people naturally reinforce the sounds they are listening to with lip reading.

Conversely, when people hear the voice of the minister coming out of a box hanging some 30' in the air, their brain can't put the two events together. The motion picture industry found this out long age and they work hard, using 3 speakers behind the screen, to keep the sound of the actors seeming to come out of their mouths even though they move all over the screen. People hate it when the voice of the speaker doesn't come from the speaker.
Yet, visual/acoustic dissection of the pastor is commonplace in the church setting.

Another problem exists with the use of a large microphone on a stand. Now the movement of the mouth is completely obscured from everybody who is watching. Even if we wanted to try to lip read, we can't. The microphone is in the way. What we actually see most of the time in church is our favorite people with a shiny chunks of metal shoved in front of their mouths.

There is another benefit to natural speaking. A raised voice has a different intonation, imparting a different meaning, than a calm voice. A raised voice imparts a sense of earnest effort with a touch of urgency. A microphone takes the intonations of a calm voice and gives them the loudness of a raised voice, which doesn't make natural sense. The raised natural voice is easier to understand because the articulation is more paced and the pitch is raised. A calm voice has a low intonation and easily mumbles. It stays in the hall too long, sounding boomy and making things harder to understand.

How to proceed from here

Although this has been a brief overview, we hope you have gained a better understanding of the impact of acoustics within a church. Perhaps with this new found information, you are ready to begin an acoustic upgrade project for your own facility. Here is a quick checklist you can use to insure you've gathered the necessary data, needed for a quality evaluation.

- ☐ **Get feedback** from concerned members of your congregation via questionnaires and/or meetings. (See Appendix A)
- ☐ **Determine what the core sound problems are** in the church. What are you truly trying to accomplish?
- ☐ **Estimate what you are willing to spend-**have a budget range in mind. Make sure there is a commitment to fix the problem- otherwise your efforts are just in vain.
- ☐ **Obtain blueprints** or have drawings made of the floor plan, ceiling and wall elevations, to be able to send to an expert for evaluation. (See Appendix C)
- ☐ **Take photos** and/or video of the interior of the church to include with your analysis package. (See Appendix D)
- ☐ **Perform an RT-60 (Reverb) Test**, and include the results or tape with your package. (See Appendix E).

Now, with this information in hand, you are ready to select someone you trust is qualified to help you with the project. Be certain they have a background in church work and are educated in the field of acoustics & voicing rooms. Don't be afraid to ask for credentials and a list of references.

APPENDIX A:

Acoustics & Sound Quality Questionnaire

We would appreciate your feedback and comments regarding the quality of sound within the church. Specifically, how well you are able to *hear* and *understand* the different parts of the service and also the *quality* of the sound.

When the minister is speaking to the congregation, it should be comfortable to hear and listen. At our church it is:

- ☐ Easy to hear what is being said.
- ☐ Fair to hear, but could be improved.
- ☐ Difficult to hear what is being said.

The choir and organ music should seem to *fill* the church with sound and easily be heard from all locations. At our church:

- ☐ I feel it is quite good.
- ☐ It is okay, but could be improved.
- ☐ Does not seem to be the case.

When the congregation is singing together, it should be full and involving. At our church it is:

- ☐ Easy to hear the *whole* congregation
- ☐ Fair to hear, but could be improved.
- ☐ Feel like I'm singing by myself

The 'praise band' should be able to play at a comfortable volume level and all instruments can be heard easily. At our church:

- ☐ This seems to be the case.
- ☐ It is okay, but could be improved.
- ☐ Does not seem to be the case.

Comments: (Please write in any specific sound related issues you feel need to be addressed. Or, what is best and worst about the sound in our church)

(OPTIONAL)

Name ____

Phone ____

APPENDIX B:

The ASC Format for Acoustical Analysis

The information submitted using the following guidelines will give us the details we need in order to properly design an acoustic treatment for your church facility. Simplicity, clarity and accuracy are all we require.

When your package arrives at ASC, a designer in our engineering department will run an analysis of your room, and determine what is required to address the specific concerns of your church. Within a few weeks, you will receive a report of our findings, along with a cost estimation for an acoustic control kit.

To do a proper analysis, there are a few things we require:

1. Floor Plans: Send us a copy of the plan of your room. Architect's drawings, or verified blueprints are fine. (Make sure the room has not been modified since the drawings) If you do not have these, then a simple fold-out line drawing will do. (Please see "Drawing a Floor Plan" on the following page.)
2. Pictures and/or Video: They say a picture is worth a thousand words. It is much easier for us to conceptualize your space when looking at the real thing, along with the floor plans. (Please see the "Photographing your Room" on the following pages.)
3. RT-60 Test: (optional) Although we are able to do mathematical calculations of the room's theoretical reverberation, sometimes it is helpful to have an actual test done of the sound decay in the room. (Please see the "Doing an RT-60 Test" following pages.)

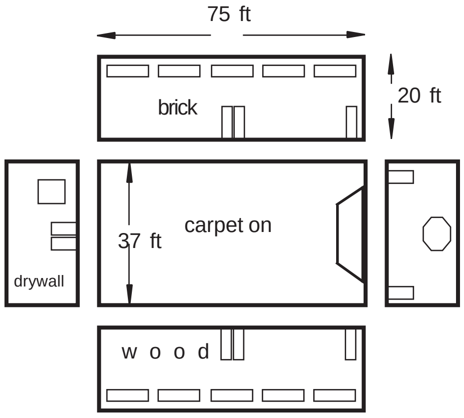
APPENDIX C:

DRAWING A FLOOR PLAN

Floor/Walls and Materials:

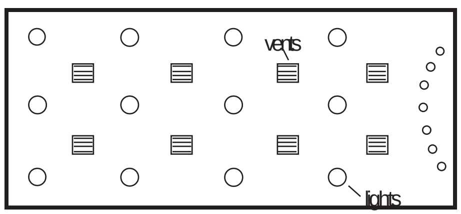
Please draw out the floor & walls as close to scale as possible. Use a fold-out view as shown (each elevation can be on separate paper) Please place and indicate the following items:

-Actual Dimensions
-Doors & windows
-Closets
-Alcoves

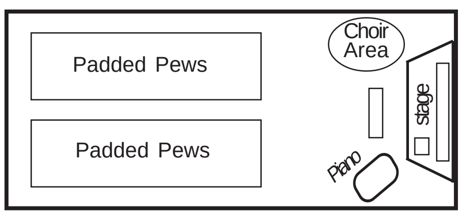


Note: Always indicate on your drawings what the surface material is composed of. For example: Carpeting over concrete, drywall, brick, plaster, acoustic ceiling tiles, wood paneling, glass blocks, etc..

Ceiling: Plan should reflect placement of lights, beams, sprinklers, vents, speakers, etc..



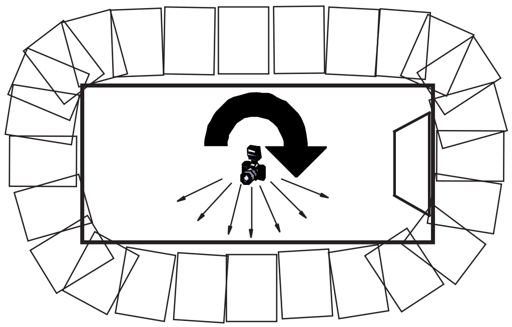
C) **Furnishing:** Make a Xerox copy of the floor plan. Use this copy to indicate the general location of seating, equipment, counters, pianos, organs, speakers,etc.



APPENDIX D:

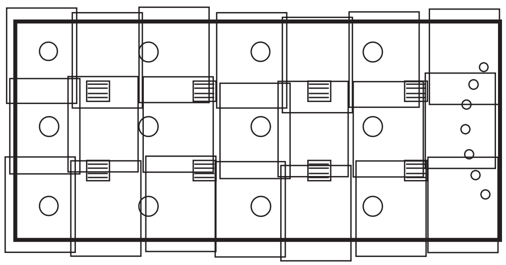
PHOTOGRAPHING YOUR ROOM

360° Panorama: For us to get a global overview of your entire room, it is best to have a 360° view of it. This is done by taking a series of overlapping photos.



-Stand in the center of the room
-Shoot vertical shots (portrait)
-Slightly overlap each picture
-If the room is small, stand against the opposite wall to get as much of the wall as possible.
-If the room has high walls, you may need to take extra shots.
-For best results, use a tripod.

Ceiling: For the ceiling, a panorama does not work. Instead, try to take overlapping pictures that can be reassembled to provide good visual representation of the ceiling.



Details: Take additional photos of any complex areas such as alcoves, curved walls, balconies, etc...

Note: Always indicate on the backside of your pictures what the picture is of. Peace Valley Church-South Wall #1, #2, #3, #4; East Wall #1, #2, #3., etc. Please put your pictures in the correct order, and number them.

Video: *A camcorder can be used to photograph the room as well. Ideally, we prefer to have both a video and still photographs, as they each have their own advantages. When you videotape, please pan the camera very slowly. We are often looking at details, and they can go by too quickly. Avoid shooting directly at bright objects such as lights and windows. Shoot them at an angle. Also, please provide a narration of what is being shot. Use thE same guidelines as above.*

APPENDIX E:

DOING AN (RT-60) TEST

There are two types of reverb tests, one is a quick & simple measurement and the other is to record it to send in to an acoustic engineer for a more accurate analysis.

Simple Reverb Test is done using 10" balloons and a stop watch. One person stands in the middle of the room, whose air conditioner is off, with a stop watch and the other up near the front, under a loud speaker with the balloon held high overhead and a pin. Practice the count down "3-2-1-POP" a couple times to get coordinated-but clap instead of popping balloons. Start the stop watch with the pop and stop it when you cannot hear the reverberant sound from the balloon any longer. Repeat two more times and take the average value to get the approximate room reverb time in seconds.

Recorded Reverb Time Test requires a Radio Shack sound meter, (which you will also use as your input microphone) a tripod, an audio cable with RCA ends and a tape recorder with a "line input". Do not use a recorder with AGC (automatic gain control). Before you go to the church, be sure to hook everything up and prove to yourself that you can make a recording that sounds good and be sure to completely read the sound meter manual.

The set up is as noted above, trading the stop watch for recording equipment. Set the sound meter to 70 dB, C (fast or slow). Plug the *Audio Out* of the meter into *Line In* of the recorder. Start recording, talk into the mic, set zero VU if possible while identifying the test. Follow with 5 seconds of silence. While remaining silent, pop the balloon (no count down) and keep recording for 10 sec after you no longer hear the balloon reverb. Repeat this same test 2 more times, popping the balloon in a different location for each test. Clearly label your tape with the organization name, contact and phone number.

APPENDIX F:

GLOSSARY OF ACOUSTIC TERMS

Acoustics:
The science that studies the waves that are conducted through matter due to the motion of the matter. Usually air is the material that most people think of when it comes to acoustic waves. But acoustic waves exist in all matter. Architectural acoustics, is the study of acoustics when the air is contained in a room. Church acoustics is a sub-division of architectural acoustics.

Sound (waves):
Pressure fluctuations in the air that are heard when an acoustic wave passes by. They are usually caused by objects in the air that quickly change position or a stream of air that quickly changes position. Sound escapes away from the sound source as an expanding spherical wave that travels at the speed of 1130 feet per second, traveling about 1 1/8th of a foot each one thousandths of a second (millisecond).

Sound Level:
The measure of the strength of sound. Units are decibels (dB) and usually measured with a dB meter. The threshold of quiet sound is zero dB and the onset of painful sound is 100 dB. Conversations are at 50 dB, whispers at 30 dB and shouting is 70 dB. When the sound strength of something doubles, it increases by 3 dB, or halved, it drops by 3 dB.

Loudness:
The apparent strength of the sound to the listener. A change in 1 dB is just barely noticed as a change in loudness. Something twice as loud is actually 10 dB stronger, (10 times stronger). Something half as loud is 10 dB weaker, (1/10th as strong).

Direct Sound: (direct signal):
The part of a sound wave that travels directly along the line of sight path between the speaker or sound source and the listener. The *dry* or actual sound.

Reflections:
Sound waves that strike a surface and bounce off are reflected sounds. They bounce off the wall, changing directions but keeping the same angle off the wall as they had when they approached the wall.

Early Reflections:
Reflections that are heard within 1/20 of a second of the direct sound are called early reflections. Early reflections cannot be distinguished from direct signals, they merge with the direct sound to form one composite sound. This combining effect can cause the sound of the direct signal to change in tonal characteristics and apparent direction.

Late reflections (Echoes):
A distinct reflection that arrives at the listener later than 1/20th of a second after the direct sound is heard. The listener can identify from where an echo comes. An echo does not change the tonal characteristics of the direct sound.

Flutter Echo:
This type of echo is most easily heard as one claps their hands out in front of them, while standing in a hallway. The sound "zings" and its tone depends on how many times a second the reflection passes by the listener's head. In a hall 8' wide, the clap will expand out, hit the wall and return 143 times a second and the zing will sound like a 143 Hz buzzy tone. Not a real sound, just a pseudo-tone.

Reverberation: For sound in a large room, reverberation begins at about 1/5 second following the direct sound. It is due to the accumulation of many reflections, compounding one upon the other, so much that the sound no longer seems composed of echoes but rather just a sound of noise, a din of chaos that has no discrete direction and no discrete timing.

Diffusion:
Reflections off of a non flat surface that causes the sound wave to become more quickly disorganized than if off a flat surface is a diffusive surface. Diffusion decreases the time it takes for echoes to become converted to reverberation. The beautiful gothic churches of the old world have very diffusive or sound scattering surfaces. That is part of the sonic beauty of those spaces.

Decay:
The dying out of sound. Usually referring to the steady decline in the loudness of the reverberation.

Decay Rate: (RT-60)
The time (in seconds) it takes for reverberation to change from very loud to imperceptibly quiet, a total sound level difference of 60 dB. For a living room the RT-60 might be 1 second but in a gym, it might be 4 seconds.

Absorption:
The loss of sound energy that occurs when the sound wave strikes a fibrous surface. The fibers provide acoustic friction for the sound wave. The wave does not slow down due to the friction, it keeps it's same speed but it *does* lose energy and get quieter.

NRC Rating:
(Noise Reduction Coefficient) A rating for absorption. It gives the % efficiency for a surface to absorb sound. If a surface is 30% absorptive, then only 70% of the incident sound is reflected back into the room.

Noise: (Background Noise)
The unwanted, undesirable and usually interfering sounds present in a listening space, typically due to an air conditioner or other conversations.

Noise Floor:
The strength of the background noise, measured in dB. It is difficult to understand what is being said in a room with a high noise floor.

Signal-to-Noise Ratio (S/N ratio):
The difference in sound level (dB) between the desired sound and the noise floor.

Articulation:
The clarity of a sound, particularly a message conveyed by sound, such that it can be easily and completely understood. A slurred sound may be well heard but the message it carries may still not be well understood, it is inarticulate. Also, a clear and distinct sound may be drowned out by a nearby louder noise, rendering the message not understandable, inarticulate. Echoes also cause articulation problems. Articulation is most often measured in some form of a desired signal to unwanted noise ratio.

Intelligibility:
A measure of the clarity of sound based on the comprehension of the message being conveyed by sound. A "cat, bat, tat, rat... type of recognition test. The conversational version of Articulation.

Bright/Lively:
The condition of sound in which there is an abundance of treble range reflections giving the feeling of "brightness" or "liveliness" to the sound. Sound in a tile bathroom or kitchen is bright. Too much can seem harsh and irritating.

Dark/Dead:
The condition of sound in a room when there is a lack of reflections and a lack of reverberance. Too much can seem lack-luster and uneasy feeling.

Boomy:
The condition of sound in a room when the lower frequencies, particularly the male voice range is excessively reverberant.

Psychoacoustics:
The study and science of how the human comprehends and makes sense out of the sounds they hear. The difference between an early reflection and a late (echo) reflection, is an example of psychoacoustics. The blending of the early reflections with the direct sound is another.

Audiology:
The science and practice of amplifying or otherwise improving how well a person hears sound.

Frequency (Hertz, Hz, cps):
A single sound pulse as from a fire cracker has sound energy but no tone. Tones are sounds that come from voices or instruments which have a repetitive pressure pulse characteristic. The number of repeat times per second that a sound has is called it's frequency. It's unit of measurement is cycles per second (cps) also called Hz (Hertz). Similar to *pitch* in musical terms.

Sound Spectrum:
The sound level measured at different frequencies. Most tones are composed of more than one frequency, a combination of frequencies, as in a musical chord. The sound spectrum would measure the strength of each frequency and display that graph as a plot of Sound Level vs. Frequency, also known as a sound spectrum. The "color" of sound is used as emphasis in the spectrum.

Sonic Color:
The shift in emphasis of a complex sound within it's spectral range. A neutral color is the preferred natural sound but sometimes sound can have a warm color, an emphasis on lower frequencies or a cold color, an emphasis on higher frequencies or a nasal color, an emphasis on midrange frequencies.

Ultrasonics:
Sound whose frequency range is above that of human hearing, above 20,000 Hz.

Infrasonics:
Sound whose frequency range is below that of human hearing, below 20 Hz.

Octave:
Sound that exists within a limited frequency range, between a lower set frequency and a set upper frequency. The difference between the lower and upper frequency is specified to be equal to the lower frequency. The octave sequence for the note "C" starts at 31 Hz and continues thru 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1k Hz, 2k Hz, 4k Hz, 8k Hz and ends at 16k Hz. (k = thousand)

Voicing:
The process of defining the desirable condition of sound in an acoustic space. It integrates the direct, early and late reflections with the reverberation, including a sense of timing and direction for each into an appropriate and desirable acoustic condition for the listener. It combines both the art and science of sound. It requires an understanding of the purpose to be served by each acoustic space. As an art form, it recognizes the aesthetic side of sound, the impression that most people prefer to have of each particular type of sound that exists in some particular place. As a science, it is based on psychoacoustics.

Acoustician:
An acoustical engineer who is trained and experienced in voicing rooms.

Acoustical Engineer:
One formally educated, experienced in the science and practice of acoustics.

Sound Engineer:
Someone trained in setting up microphones and speakers.

Acoustic Contractor:
Someone trained and experienced in installing acoustic tiles and wall panels.

Acoustic Consultant:
Someone, not formally trained, experienced in providing acoustical services.

Acoustic Designer:
Someone, not formally trained, who prepares blueprints for acoustic projects.

Sound Designer:
One who envisions and directs the way sound plays out of a stage.

Acoustic Sciences Corporation
(ASC)

Founded in 1984, Acoustic Sciences Corporation has been providing acoustic analysis, design and sound control products for critical listening environments for the past 17 years. The staff of over 20 employees includes professionals with backgrounds in acoustics, engineering, physics, architecture, music, audio recording, industrial technologies, computer-aided design, 3D modeling, and project management.

Acoustic Sciences has received awards for outstanding product design from such notable entities as the Academy for the Advancement of Audio, TEC Music Awards, Golden Note Awards, Mix Magazine and Stereophile Magazine.

Our leadership in acoustics is recognized globally, having done work with such prestigious names as Dolby Labs, Skywalker Sound, Sony Music, Disney, CBS Studios-as well as celebrities such Herbie Hancock, Amy Grant, Sting, Barbara Streisand, Tom Petty and Pete Townsend.

ASC is unique in the field of acoustics, as it is one of the few companies which offers complete turn-key solutions. From analysis by qualified engineers & acousticians, to custom product designs, to final product fabrication-you are insured a solution tailored precisely to your specific needs.

Notes:

About the Author

Arthur Noxon is the principal Acoustician and President of Acoustic Sciences Corporation. He currently resides in Eugene, Oregon. He holds two master's degrees-one in physics and the other in mechanical engineering, and is a licensed Acoustic Engineer.

Mr. Noxon has worked in the field of acoustics for over 25 years. In 1984, he founded Acoustic Sciences Corporation-a research, design and manufacturing company dedicated to the advancement of acoustic control in critical listening environments.

He holds five patents on acoustic control devices, and has designed and engineered over 70 products for the sound and noise control field. The focus of his work has been with music related applications-mainly recording studios, churches, hi-fi audio, home theaters and performance halls.

Mr. Noxon has authored, and contributed to, more than 20 articles and technical papers for national magazines and professional journals. He is frequently invited to give lectures and talks on acoustics at conferences and conventions throughout the country.