Integrated Passive and Active Room Acoustics
System design solution for a large worship space

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As presented at ASA Boston - 2017

This case study shows how passive acoustic design which is integrated with active electronic room enhancement creates an “acoustically versatile sanctuary” achieving all the client architectural acoustic goals.

To enhance the architectural achievements of this uplifting and light filled volume, this combined passive and active system allows undetected changes to the room acoustics of the worship space during A/V presentations.

Project Summary
• United Methodist Church of the Resurrection (COR), Leawood, Kansas, additional locations in Olathe, Kansas, downtown Kansas City, Missouri & Blue Springs, Missouri.
• Senior Pastor/ Founder - Rev. Adam Hamilton
• Founded in 1990, COR is the largest United Methodist congregation in the United States, with a membership of over 21,000 and average weekly attendance for all campuses of 11,000 people in 2016.
• In 2014, the church announced plans to build a new sanctuary.
• Architect – John Justas, Principal - HGA Architects and Engineers
• Acoustic Design – Acoustic Distinctions
• Technology Designer / AV Design – IDIBRI
• Construction Manager – McCownGordon
• AV System Integrator – Progressive Electronics
• Sanctuary – Completed in 2017. Flexible seating for 3,500 and AV systems for speech, orchestra, choir, contemporary music, organ, and video production.

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Establishing Acoustic Design Priorities

We used this chart to explain the link between the design considerations, the acoustical criteria and the architectural elements needed to achieve that criteria.

Considerations such as the room shape, room volume, wall surface materials, soffits and balconies and their impact on the room acoustic are reviewed with the client.

The client priorities are arranged in order of magnitude of importance, and the design criteria are weighted matching the client priorities.

### First Priorities
- A sense of majesty, with the sanctuary being a tall vertical space that would draw the congregation upwards.
- Acoustics supportive of preaching, conveying warmth, intimacy and high intelligibility, so that little or no effort is required to hear and understand the message throughout the seating areas.
- Acoustics supportive of congregational participation which would be encouraged with a vibrant, lively atmosphere to foster aliveness. It was important to avoid acoustical visual barriers interfering with the connection between the pastor and those in the audience.
- Acoustics supportive of congregational participation and traditional music. While providing high mid and late energy returns to support traditional music is consistent with the church’s goal for “livelier” acoustics, providing a good acoustical environment for contemporary music would require lower middle and late energy returns.

### Secondary Priorities
- Acoustics supporting congregational participation and traditional music.
- Provide ample late energy to support organ music and choral.
- Support for congregational participation and traditional music.
- Providing a sense of majesty, with the walls and ceiling materials reflecting this.
- Considerations such as the room shape, room volume, wall surface materials, soffits and balconies and their impact on the room acoustic are reviewed with the client.

### Design Priorities

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>ACOUSTICAL CHARACTERISTICS</th>
<th>ARCHITECTURAL ELEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low levels of reverberation, &lt;1.2 second RT typically</td>
<td>Minimised room volume - low ceiling</td>
<td>Sound absorbing wall and ceiling treatments</td>
</tr>
<tr>
<td>High speech intelligibility</td>
<td>Sound reflecting surfaces located close to the congregation, including balconies, soffits, ceiling elements that direct sound back to the platform</td>
<td></td>
</tr>
<tr>
<td>Early sound reflections between members of the congregation</td>
<td>Minimised footprints</td>
<td>Sound reflecting surfaces located close to the congregation, including balconies, soffits, ceiling elements that direct sound back to the platform</td>
</tr>
<tr>
<td>Cathedral-like sound</td>
<td>Large acoustic volume</td>
<td></td>
</tr>
</tbody>
</table>

The project presented a set of conflicting requirements:

1. Thin space needs high ceilings, this project ceiling was 85 ft., therefore it had to be absorptive to avoid late reflections.
2. For similar reasons, the walls also had to be highly absorptive.
3. The sound system would need to be very directional to avoid energizing these surfaces.
4. The visual restriction on having large acoustical elements suspended from the ceiling eliminated the architectural tool to provide early and mid-energies, which are important to support the congregational participation and traditional music.
5. There had to be total clear view of the beautiful stained glass 3 story high by 100 ft. wide. It’s the largest, angular-stained glass display of any church in the world.

Also by making the ceiling and wall surfaces absorptive to achieve control of the late reflections, we diminish most of the ability to support late energy which is especially important to organ music and choral music as well.

### Active Variable Acoustics Option

The need for electronic active variable acoustic enhancement was evident to change the acoustics of the space for each use. Acoustic Distinctions had prior experience with Acoustic Control Systems (ACS) with headquarters in the Netherlands, and ACS worked with the Acoustic Distinctions from the early stages for the proper application of their technology.

In an ACS electronic-variable acoustic system, the program material is captured with highly directional microphones and manipulated using advanced digital signal processing technology and custom developed reverberation algorithms to process the microphone signals generating late reflection fields and enhanced early reflections.

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**Figure 1: Acoustic design priorities**

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Conflicting Requirements

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<tr>
<th>Architectural goal of having a seating “thin” space.</th>
<th>Versus</th>
<th>Support for congregational participation and traditional music.</th>
<th>Versus</th>
<th>Provide ample late energy to support organ music and choral.</th>
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The processed signals are then emitted in the space from strategically placed loudspeakers enhancing the acoustic behavior of the room.

This system can for example virtually reduce the height of the ceiling or make the walls feel closer by manipulating the parameters of the signal processing.

Signal Flow for the ACS Variable Acoustics System

With the ACS system, multiple directional microphones are positioned relatively close to source areas. Signals are routed to speakers mimicking the natural arrival and intensity of would be reflections from architectural elements.

Issues like coloration, image control, and feedback are avoided by using multiple directional sample microphones and a large processing matrix in building the independent playback channels.

Positioning Microphones and Loudspeakers

The relationships between the positions of individual microphones and loudspeakers are established to determine the natural boundary conditions. As a result, a signal is created sent to a particular loudspeaker, and all speakers together build the desired field of reflections.

This includes taking into consideration the preservation of the natural boundaries within the hall as basis for timing and making sure the generated reflections never arrive before the direct sound.

There are however exceptions, for example if you would like to make a hall sound larger you can manipulate the timing to serve this purpose, you can also virtually create a reflector by reducing the timing of reflections, or mask an echo by filling in slightly differently timed reflections around it as we implemented some of that in this case.

In total there are
- 40 microphones
- 40 microphone level inputs
- 124 discrete processed outputs
- 124 loudspeakers
- 2x 24 channel early reflection matrix
- 2x 24 channel reverberation matrix

Figure 3: Schematic locations of speakers and microphones – elevation

Figure 2: Signal flow for the ACS Variable Acoustics System
Final System Adjustments – Operational Pre-Sets

Six presets were made available to the user which allowed the room to have reverberation time range from 1.9 sec at system standby to 4.8 sec at preset 6.

The AV operator can instantaneously switch between the adjacent presets with a push of a button during the service. The changes are very subtle, and not noticeable to the congregation.

During preaching, the room’s natural acoustics are well controlled to create acoustics supportive of preaching, conveying intimacy. The highly directional sound system provides for excellent sound reinforcement of the speech signal in all seating areas, with minimal “spill” of sound energy onto the room’s wall and ceiling surfaces to minimize the excitation of late-arriving sound reflections from the room’s wall and ceiling surfaces. The room’s naturally controlled acoustics along the high-controlled high-power sound reinforcement system also provided excellent sound quality for the contemporary music program.

During times of the service when the congregation is asked to participate in worship, the active variable acoustics system is switched on. Similarly, during traditional music presentations, the active variable acoustics system is switched on.

Measurement Results

In Figure 6 on page 14, we see an energy time curve of a measurement taken near the center of the sanctuary with the electronic system on standby and in the same location with the system on preset two (2.4 sec) we can clearly see the early, mid, and late energies added by the ACS system.

Conclusion

Active variable acoustic systems can be an effective solution when cost or architectural constraints prohibit the room’s natural acoustics from supporting the prioritized program of use, and when the acoustical environment that best supports the activity in that space changes quickly; in this case, during a worship service. continued on page 14...
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In an active variable acoustic system, there are no visual changes associated with changes in the room’s acoustics.

Additional References –

United Methodist - Church of the Resurrection, Leawood
http://cor.org/leawood/

HGA Architects and Engineers - Feature on Church of the Resurrection

Acoustic Distinctions – Acoustics Design
http://www.acousticdistinctions.com/

IDIBRI – Technology Designer
http://www.idibri.com/

Acoustic Control Systems – Variable Acoustics System
https://www.acs.eu/

Progressive Electronics – AV Integrator
http://peik.com/

McownGordon - Construction Manager
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