# Integrated Passive and Active Room Acoustics

## System design solution for a large worship space

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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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*Church of the Resurrection Sanctuary with HD Video Screen and 93 Ft W x 35 Ft H Stained Glass "Resurrection Window"*

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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.

| PROGRAM | ACOUSTICAL CHARACTERISTICS | ARCHITECTURAL ELEMENTS NEEDED TO CREATE THIS |
|---|---|---|
| TRADITIONAL MUSIC WITH ORCHESTRA & CHOIR | Balance of early arriving sound reflections and late arriving reverberant energy, resulting in high levels of clarity and long reverberation times, 1.8 to 22 second RT | Generally rectangular in plan<br>Compact/efficient layout with low floor rate<br>Sound reflecting surfaces located close to audience and platform-balconies, soffits, ceiling elements |
| CONTEMPORARY MUSIC AMPLIFIED | Low levels of reverberation, <1.2 second RT typically<br>Minimize discrete echoes from speakers back to platform | Minimized room volume - low ceiling<br>Sound absorptive wall and ceiling treatments<br>Wall shaping to avoid echo and late arriving sound energy |
| PREACHING | High speech intelligibility<br>Acoustic feedback from the room/ congregation<br>Acoustic and visual intimacy between preacher and congregation | Minimized footprint<br>Sound reflecting surfaces located close to the congregation, including balconies, soffits, ceiling elements that direct sound back to the platform |
| CONGREGATIONAL PARTICIPATION | Early sound reflections between members of the congreation | Minimized footprint<br>Sound reflecting surfaces located close to the congregation, including balconies, soffits, ceiling elements that direct sound back to the platform |
| THIN SPACE HIGH AESTHETIC | Cathedral-like sound<br>Highly reverberant >3 second RT possible<br>Poor speech intelligibility | Large acoustic volume<br>Tall ceilings<br>Sound reflective materials (wood, stone, concrete, glass) |

*Figure 1: Acoustic design 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 alertness. It was important to avoid acoustical visual barriers interfering with the connection between the pastor and those in the room.

## Secondary Priorities

- Acoustics supporting traditional music, contemporary music and organ.

There are multiple services each Sunday and the music style is different in each service. The acoustics needed to support both contemporary 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.

These three secondary priorities supporting music each required a different type of acoustic support.

### Conflicting Requirements

Architectural goal of having a soaring "thin" space.

*Versus*

Support for congregational participation and traditional music.

*Versus*

Provide ample late energy to support organ music and choral

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, singular 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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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.

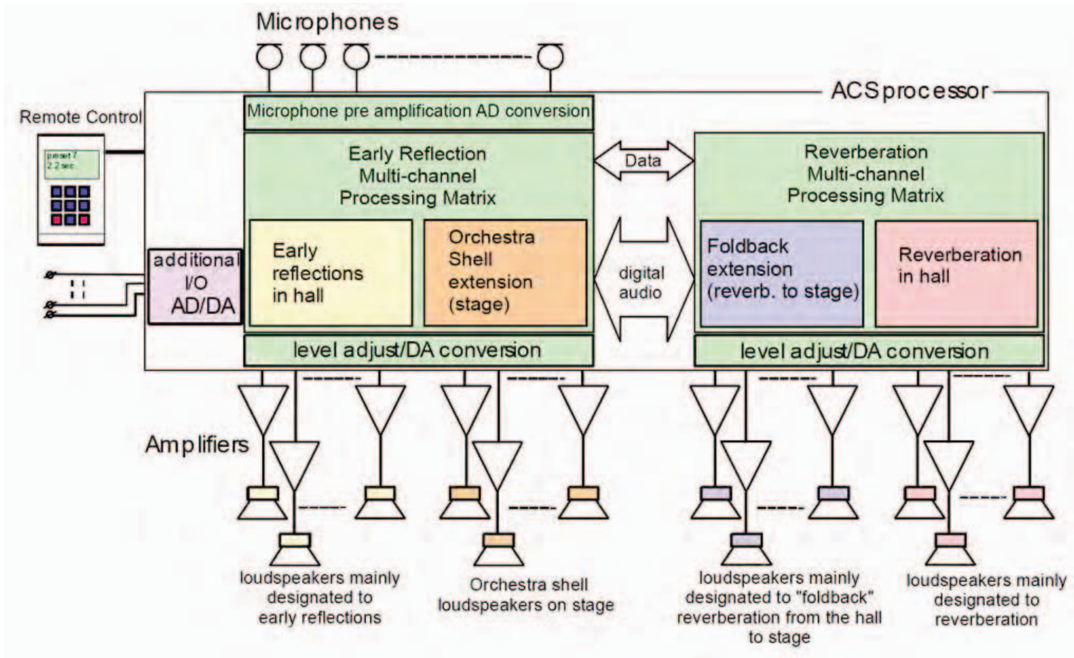
This includes taking into consideration the preservation of the natural boundaries within the hall as basis for timing and making sure the generated reflections never arrive before the direct sound.

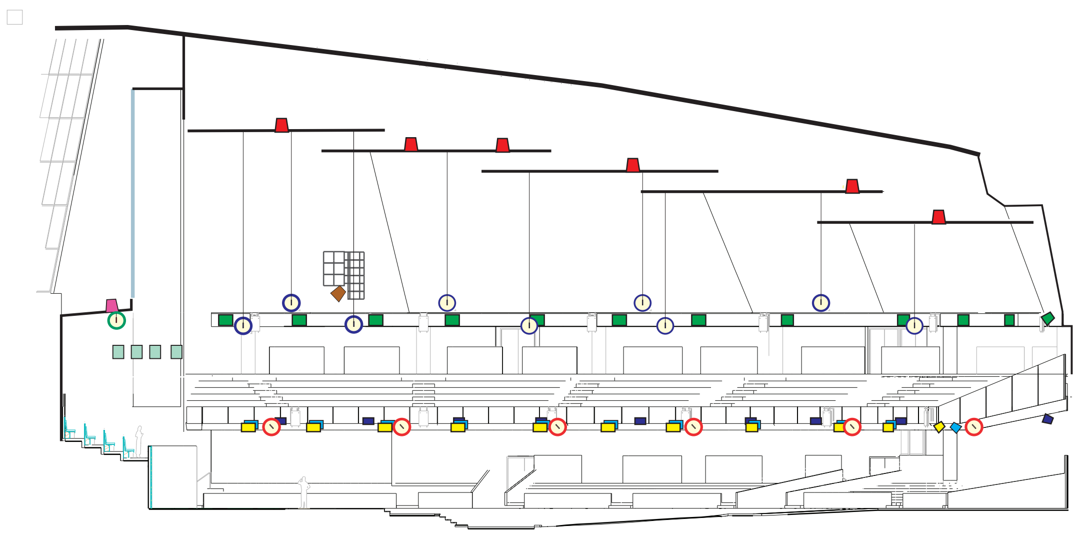
There are however exceptions, for example if you would like to make a hall sound larger you can manipulate the timing to serve this purpose, you can also virtually create a reflector by reducing the timing of reflections, or mask an echo by filling in slightly differently timed reflections around it 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 2: Signal flow for the ACS Variable Acoustics System*



- Microphones hanging above chancel, hall and balcony
- Microphones hanging above choir loft
- Microphones aimed under balcony
- Main ceiling loudspeakers
- Loudspeakers surrounding the hall
- Organ chamber loudspeakers aimed to the hall
- Loudspeakers under PA cluster, aimed to chancel and choir loft
- Loudspeakers above choir loft
- Balcony face loudspeakers aiming inwards, to main floor
- Balcony face loudspeakers aimed under balcony
- Under balcony reverberation fill in loudspeakers

*Figure 3: Schematic locations of speakers and microphones – elevation*

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## Final System Adjustments – Operational Pre-Sets

Six presets were made available to the user which allowed the room to have reverb 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.

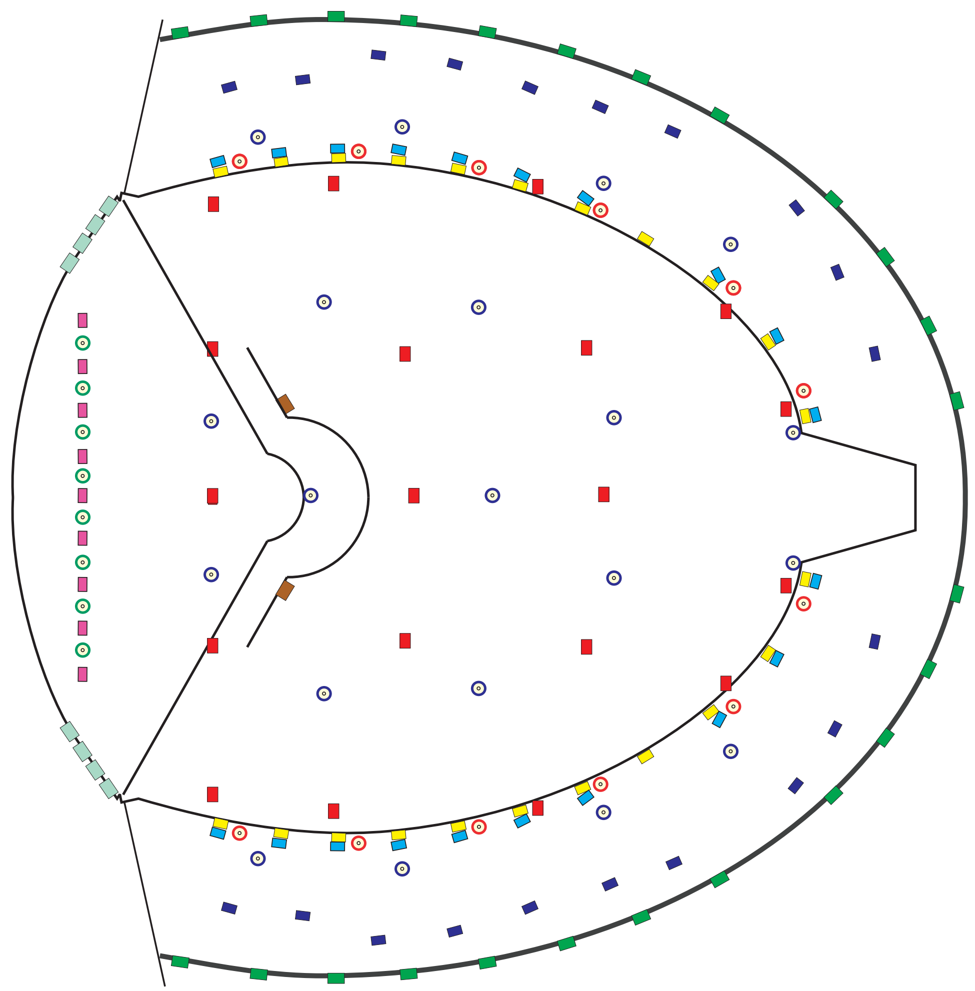

*Figure 4: Schematic Locations of Speakers and Microphones - Plan*

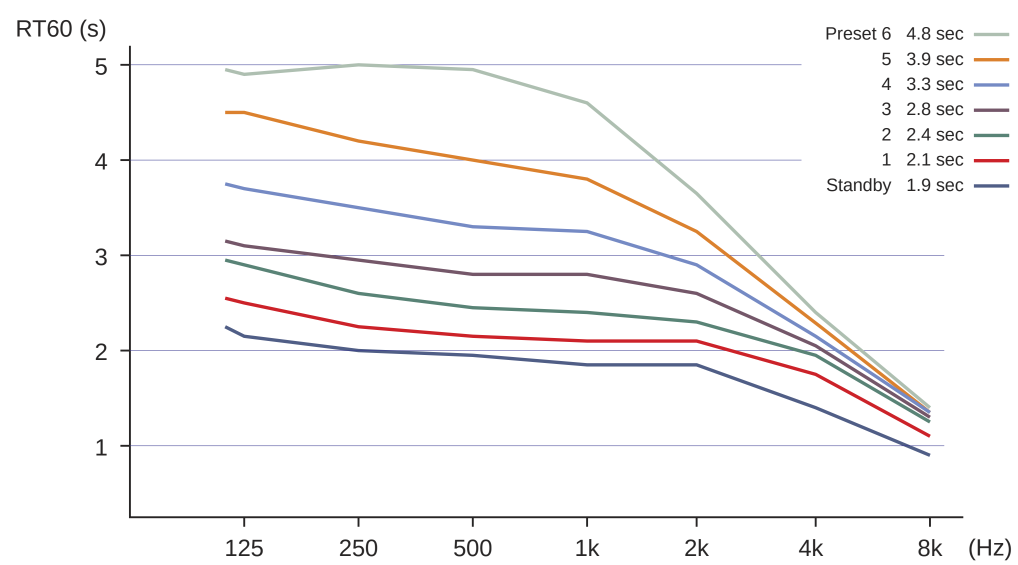


*Figure 5: Final System Adjustments – Operational Pre-Sets*

## 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 stand by 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.

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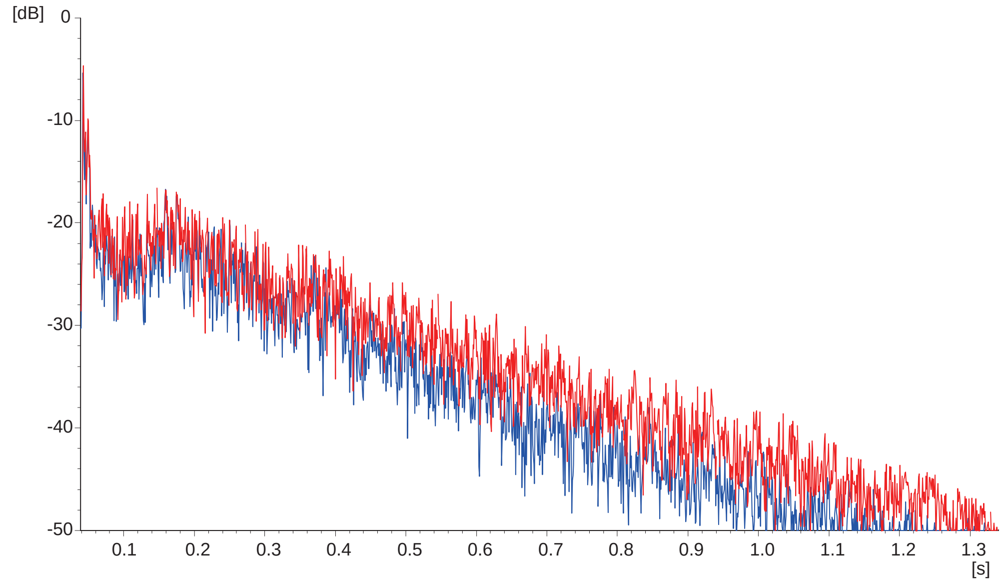
*Figure 6: Energy Time Curve*
*Allpass HZ*

*ACS off*

*ACS present 2*



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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

http://inside.hga.com/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://peikc.com/

McownGordon - Construction Manager

http://mccowngordon.com/