Acoustics for Churches and Chapels

For the Catholic Diocese of Columbus/ Ohio

A Summary of Concerns, Guiding Principles, and Recommendations for Acoustics for the Construction and Renovation of Worship Spaces

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THE CATHOLIC DIOCESE OF COLUMBUS, OHIO

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INTRODUCTION

All the sounds of worship are created by and for the faithful assembled for the sacred liturgy to the glory of God. The assembly must be able to hear those who serve the liturgy with their individual voices: the presider, lectors, cantors, deacons, and music ministers. The assembly must also be able to hear its own corporate voice making the spoken and sung responses. The participation of the assembly declines when individual members of the body of Christ hear only their own solo voices and become self conscious. Participation in the spoken and sung responses increases when the members of the assembly can hear one another. Then the body of Christ is joined in both heart and voice.

Sometimes a mistaken notion is at work in the building and remodeling of churches. It goes like this: Churches that have very "live" acoustics are good for music but distort speech. Since people must be able to hear what is said at Mass, it's better to have a "dry" or "tight" sound in a church so people can hear what is said.

No. The parish doesn't have to sacrifice the beautiful sound music makes in a room that rings in order to have clarity of speech for the readings and presidential prayers. It is possible to hear the reader in a "lively" and "reverberant" church that makes the organ, choir, and other musicians sound beautiful. It's easier and more beneficial to use technology to enhance the clarity of solo voices who read and sing than to "quiet a room down" and, thereby, dampen the corporate voice of the assembly. Moreover, in a "dead room" with the acoustics of a sound studio, all the imperfections of the musicians, no matter how accomplished they may be, come to the surface.

A room designed to deaden all sounds is doomed to kill liturgical participation. (E&A 51)

Even with the best sound reinforcement system (what used to be called a "public address" or "PA" system), some people might not be able to hear adequately because their hearing is inadequate. Included in these guidelines is direction in addressing this pastoral need.

In advocating good acoustics for worship and presenting ways to achieve them, this instruction addresses three primary audiences: (1) pastors and church leaders involved in or considering a building project; (2) church building committees investigating and making decisions for a building project; (3) architects, sound contractors, and other design professionals who will work with pastors and committees and, ultimately, be responsible for incorporating acoustical elements in the design and construction process.

BASIC REQUIREMENTS FOR GOOD ACOUSTICS IN ALL CHURCHES

Appropriate acoustical conditions for worship should include the following provisions:

1. Lively natural acoustics that support and enhance the spoken and sung responses of the assembly.

2. An acoustic environment that gives an audible impression of the presence of others, clearly conveying the experience of public worship.

3. Suitable locations and spatial configurations for the primary sound sources.

4. Good sound isolation to prevent the intrusion of distracting sounds during worship or meditation and to allow privacy and confidentiality where needed.

5. Adequate control of noise produced by building systems within the church such as HVAC, plumbing, and lighting.

6. A high-quality sound reinforcement system.

Meeting these requirements is most effectively and economically accomplished if they are an integral part of the architectural design from the earliest design phases.

ELEMENTS OF GOOD NATURAL ACOUSTICS FOR WORSHIP

"Natural acoustics" refers to the way an architectural space responds to sound without sound reinforcement or electronic enhancement. The natural acoustical qualities of a church must serve speech and music, provide an aural awareness of the presence of the assembly, support the social and communal elements of the faith gathering, foster a sense of the sacredness of the worship space, and help people feel involved and become involved in the liturgical action. The architecture of a worship space can most effectively support good natural acoustics by providing beneficial reflections of sound, and it must do this without introducing acoustical faults such as echoes and focusing of sound.

The most important and well-known element of natural acoustics is reverberation. There are three general reverberation conditions that most commonly occur: (1) a relatively short reverberation that allows clearly intelligible speech but which tends to frustrate and repress music and congregational response; (2) a medium or compromise reverberation that serves all types of speech and music acceptably but usually serves none exceptionally; (3) a long reverberation that imparts a glorious and resounding character for spoken and sung responses of the assembly, pipe organ and traditional choir yet, if excessive, can render speech virtually incomprehensible and reduce contemporary and folk music groups to muddled noise.

These three conditions actually represent three ranges of reverberation conditions. Of these three, this instruction recommends a reverberation that is within the third, longest range: Reverberation

must be as long as possible to enhance the sounds of the assembly and music ministry without being too long for speech clarity or contemporary and ethnic music styles that have become more common in Catholic worship.

To summarize, the design goals for ideal natural acoustics in a church are: (1) reverberation that is supportive of the assembly, encouraging all to participate regardless of talent or training; (2) suitable room response for the most demanding musical elements of a parish's music ministry (be it a guitar ensemble or a pipe organ with all stops out); (3) the prevention or elimination of echoes and sound focusing. The resulting acoustical character will be rich and resounding for all sounds, natural or electronically enhanced. However, there will probably be a need for a carefully designed sound reinforcement system to assure clear intelligibility for the spoken elements of the liturgy.

The following factors are recommended in providing appropriate natural acoustics in the architectural and acoustical design:

1. Provide a reverberation period of at least 2 to 3 seconds.

2. Minimize the amount of sound absorbing materials. In all cases, sound absorbing materials must not be located near the important sources of sound: the assembly, the music ministry, and the presiders and readers. Since all of these sound sources are at floor level, floors cannot be carpeted and pews cannot be covered with upholstery or cushions.

3. Provide sufficient room volume to allow the natural development and support of sound. A volume of 300-400 cubic feet per seat is recommended for churches with seating capacities up to about 800 seats. Larger churches may require greater volume, but smaller churches should not fall substantially below this range. In providing sufficient room volume for acoustics, height is a more important factor than floor area.

4. Provide properly oriented, hard-surfaced materials around sound sources. All surfaces (including floors, walls, and ceilings) near and around presiders, cantors, readers, musicians, and the assembly must have hard surfaces.

5. Avoid or minimize the use of lightweight surface materials such as gypsum board or thin wood panels. If wood paneling is desired, and if it occupies a large area, it should be attached directly over solid, massive structural materials. Do not use suspended acoustical ceilings.

6. In designing new churches, avoid the use of architectural elements that cause echoes, particularly from rear walls. In renovations, existing echoes should be eliminated. In all cases, the preferred method for preventing echoes is to use irregularly shaped surface. Sound-absorptive treatments are to be used only as a last resort and to the minimum extent needed.

7. Avoid the use of curved surfaces where they might tend to focus or concentrate sound in a confined area. There are many exceptions and extenuating factors in this recommendation. Allowances should be made for traditional forms such as rounded apses, barrel vaults, etc., and for architectural creativity—but not to the detriment of acoustics. Here, too, surface

irregularities can sufficiently reduce focusing.

Physical Provisions for Sound Sources

The following guidelines address specific requirements for establishing the necessary spatial relationships, configurations, and architectural elements for good acoustics:

1. The sound sources and listeners in a church include everyone in the gathering.

   Not only the planners and ministers . . . are active in the Liturgy. The entire congregation is an active component. There is no audience, no passive element in the liturgical celebration. This fact alone distinguishes it from most other public assemblies. (E&A 30)

   Because of this, the design of a church must provide good hearing conditions for all present and provide good support for sounds produced in the assembly seating area as well as those from the presiders and music ministry.

2. Good sightlines also establish good sound lines. Insofar as possible, provide direct line-of-sight between and among the three major liturgical areas: (1) the assembly, (2) the altar platform, presiders and readers, and (3) the music center.

3. Architectural features from performance space design, if appropriately and gracefully used, may be beneficial for worship. These include such things as an elevated position for the altar platform or ambo, and hard-surfaced, appropriately oriented surfaces around the altar platform and music center. However, these elements must be appropriate for a church, and they must not treat the assembly as a passive element. In making provisions for the ministries, the involvement and participation of the entire assembly must be maintained as the highest priorities and must not be sacrificed in making provisions for other liturgical areas.

4. The assembly seating area presents few opportunities for creativity in its placement or configuration. There are, however, some common alternatives for seating configurations such as transepts, radial seating, and moveable seating. In all cases, it is necessary to provide appropriate sound-reflective surfaces near and around the seating area to reflect sound energy quickly and strongly back to the assembly. Sloped seating for the congregation may also be helpful if it does not introduce other complications.

   Radial seating plans generally result in a minimum of nearby surrounding surfaces for the assembly. Even so, there are compensating factors in the visual elements: seeing others participating in worship can help a person feel involved and become involved. Because of the acoustical disadvantages, it is even more important to eliminate carpet and pew cushions when radial seating plans are used.

5. The following directive from Environment and Art in Catholic Worship provides further guidance regarding the assembly:

   Benches or chairs for seating the assembly should be so constructed and arranged that they maximize

> *feelings of community and involvement. The arrangement should facilitate a clear view not only of the one who presides and the multiple focal points of reading, preaching, praying, music and movement during the rite, but also of other members of the congregation. (E&A 68)*

6. The music ministry has special acoustical needs for the projection of its sound to support the assembly and encourage participation. Nonetheless, the music ministry is also a part of the assembly and should be configured to acknowledge this:

> *Benches or chairs for the seating of those engaged in the ministry of music, instrumental or choral, should be so constructed and arranged that they have the advantages described above for congregational seating and also that they are clearly part of the assembly. Yet, the ministers of music should be able to sing and play facing the rest of the assembly in order to elicit the participation of the community without distracting from the central action of the liturgy. (E&A 69)*

SOUND ISOLATION

Sound isolation involves the acoustical insulating properties of building elements (walls, doors, etc.) to minimize sound transmission between rooms and other areas. In churches it is important to prevent the intrusion of unwanted sound from outdoors or from other rooms in the building.

Sound isolation must be provided for all spaces within the building where silence, privacy, solemnity, and confidentiality are required for the special needs of the sacred liturgy, prayer, and meditation. The requirements for natural acoustics, listed above, will result in construction that is sufficiently massive to provide a foundation for a suitable level of isolation. There are further considerations that need attention to achieve the desired level of isolation.

1. For new buildings, site selection should consider environmental noise that might intrude during worship services. Locations near airports, train rails, fire stations, etc., may present noise problems that are very costly or impossible to overcome.

2. Stained-glass and conventional windows are poor sound isolators. Large windows should not face noisy areas such as highways, parking lots, etc. Do not locate noise-producing devices (outdoor HVAC equipment, transformers, etc.) near windows.

3. Sound-isolating partitions and construction should be used between areas that may be used concurrently. This might included sound isolation between the church and adjacent spaces, such as quieting rooms for infants, gathering spaces, fellowship halls, rest rooms, etc.

4. Sound-isolating partitions and detailing should be used between rooms where speech confidentiality is needed. This might include reconciliation rooms or a pastor's office used for family counseling or other sensitive matters. Special care should be taken in selecting and installing doors to prevent sound leaks. Under-cut doors (for carpet clearance) and louvered doors (for air circulation) should not be used where sound isolation is important.

MECHANICAL SYSTEM NOISE CONTROL

Mechanical systems in worship spaces must not produce excessive noise that might create distraction and reduce speech intelligibility. Experience has shown that it is not sufficient to simply specify a noise design goal for mechanical systems and leave it at that. To achieve suitably low levels of mechanical system noise, the following guidelines should be followed:

1. The design goal for mechanical systems serving the church must use established design standards such as the Noise Criteria (NC). Recommended design goals are from NC-20 to NC-30: air velocities at air supply and return grilles should not exceed 450 feet per minute. NC-35 is the absolute maximum acceptable level and should be considered only if there are special architectural or financial constraints.

2. For churches with special needs for low noise levels (e.g., for music performance, recording, broadcasting, etc.), levels of NC-20 to NC-25 are more appropriate. Where there is a substantial music program supported by investments in a costly pipe organ or piano, the lower NC values are recommended.

3. To provide effective noise control at the lowest costs, planning for noise control should be done in the early design stages. Space planning, remote locations for mechanical equipment, adequate space for equipment, and duct routing are all important. Roof-top mechanical units should not be located above the church, fellowship hall, or other noise sensitive rooms.

4. Mechanical units mounted on the roof of a church often pose insurmountable noise control problems. If this is unavoidable, unit sizes should not exceed 10 tons. Vibration isolation curbs must be used, and additional noise control measures may be required.

5. Outdoor mechanical units should not be located near windows, especially stained-glass windows. Take care to prevent the projection of mechanical noise to the surrounding neighborhood.

6. Plumbing noise can be minimized by locating high-pressure and high-volume plumbing pipes and toilet facilities as far from the church as practical. Use vibration isolating pipe supports and attachments for plumbing near the church area.

7. Transformers, fluorescent lights, audio and video equipment, ceiling fans, etc., can produce objectionable hums. Sufficient care must be taken in design, equipment selection, and installation to prevent intrusive electrical noise.

SOUND REINFORCEMENT SYSTEMS

A well-designed, high-quality sound reinforcement system is often a critical element for providing speech clarity in the church acoustical environment: Even with uplifting music and resounding assembly response, if the assembly cannot understand the words of the sacred liturgy, the total

acoustical environment is a failure. Sound reinforcement systems for churches must be properly designed, for providing speech clarity in an environment that must also enhance music and assembly responses can be difficult. This design process is often further challenged by architectural and aesthetic priorities that strive to minimize the visual intrusion of loudspeaker components. Considering these difficulties, a sound reinforcement system must be included in the building or renovation plans during the early design stages.

If reinforcement for music is also needed, the functions and capabilities must be factored into the design to allow for graceful integration of sound components and ease of operation. Because of the great diversity of musical expression now appearing in Catholic liturgies, the following guidelines are primarily concerned with speech clarity and traditional music forms. (Note: Special sound system capabilities for the unique needs of individual music ministries are too complex and varied for discussion here.)

1. The most important function of a sound reinforcement system is to provide excellent speech intelligibility. It must do this within the reverberant environment needed to support the assembly and music ministry. Care must be taken in the design and use of sound systems so that the assembly's voice is not overpowered or made less significant by amplified sounds.

2. Excessive reverberation can reduce speech intelligibility. It is not uncommon to find churches treated with excessive amounts of sound absorbing materials to reduce reverberation with the intent of ensuring speech clarity. This may enhance speech clarity and allow the use of a simpler and less expensive sound system, but it often creates a reverberation that is too short for music and congregational response. It is much better to design the sound system to function properly with a longer reverberation, one that supports all the elements of liturgy.

3. For proper sound system design, the designer must know the reverberation time. In a new church this can be predicted in advance from architectural drawings. In an existing church, reverberation can be measured. With this information, the sound system can be designed specifically to work within the reverberant environment.

4. Echoes can greatly reduce speech clarity. Echoes must be prevented in the architectural and acoustical design of a new church and eliminated in existing churches. Echo-producing surfaces can be readily identified by an acoustical consultant or sound system designer. These surfaces can be reoriented, reshaped, or treated to eliminate the echoes.

5. The preferred loudspeaker design is a central cluster. This may be composed of several loudspeaker horns assembled into a single array or of several cabinets that house the necessary components. One major advantage of the central cluster design is directional realism: the audible impression that sound is coming from the talker rather than from the loudspeaker. There are other loudspeaker configurations that may be appropriate under certain conditions, but these must be evaluated on a case-by-case basis.

6. Loudspeakers can be large and unsightly. The architectural design should plan for the visual integration of loudspeaker elements in the earliest stages of design.

7. Traditional music (vocal and instrumental) should require no amplification. The natural acoustics of the church should be adequate to support voices and traditional instruments. It may be necessary in some cases to provide supplemental electronic support or enhancement for cantors or small choirs, but this should be done with great care to preserve the purity of natural vocal sounds and to prevent overpowering the assembly.

8. Many music ministries use more modern instruments such as electronic keyboards, amplified guitars, etc.: instruments that cannot be heard without amplification. This often requires sound system capabilities that are far beyond those provided by a basic speech reinforcement system. In some cases, a multi-purpose reinforcement system with full music capabilities can be used; in other cases, the music ministry may use a dedicated music reinforcement system. In either case, it is necessary to insure that there is sufficient control of loudness to prevent music groups from overpowering the congregation. There is often a fine line between supporting congregational singing and overpowering the assembly. To prevent this, it is essential that amplified music ministries be provided with adequate monitoring capabilities so they can hear and judge their own loudness.

9. A hearing assistive system should be provided for the hearing impaired. The most common systems use a transmitter to provide an electronic signal that is picked up by a small wireless receiver and tiny earphone worn by those needing hearing assistance.

ACOUSTICS AND THE DESIGN/BUILDING PROCESS

This instruction presents the major concerns and priorities for acoustics in church building and renovation projects. These must be evaluated in conjunction with other concerns and priorities. But, it is important to consider acoustics issues early in the project since they may have significant architectural and financial implications. It should not be assumed that acoustical factors will increase costs: Proper acoustics design can actually save money both in the short and long term.

An important first step is to review the proposed building project with Diocesan authorities. Diocesan officials will make recommendations on whether an acoustician is needed and, if so, to what extent. If an acoustics consultant is needed, the Diocese will provide information to help the parish select a consultant. In addition, the Diocese will provide a checklist to guide the parish, architect, and consultant regarding the Diocese's expectations of the consultant's responsibilities including documents and submittals required and critical checkpoints. The following items provide further details on the consultant's involvement in a typical church building project.

1. The Consultant should attend pre-design and/or programming meetings with the architect and other design team members including the mechanical and electrical engineers. Along with these meetings, it is highly recommended that the acoustician attend representative liturgies and meet with the pastor, liturgists, music ministers, and building committee.

2. A Schematic Design (SD) Acoustics Report must be submitted at the conclusion of the SD Phase. This should be based on Pre-design/Programming information and budgets. The report will include a summary of project-specific acoustical issues and concerns including

recommendations for room acoustics, room volumes, dimensions, geometry, seating configurations, reverberation times, mechanical system noise design goals, etc. These should also include special concerns such as musical instruments and music center location, preliminary sound system functional description for speech and music, and any unusual acoustical requirements unique to the project. Potential design problems should also be identified including such things as mechanical room location and size, loudspeaker integration, etc.

3. A Design Development (DD) Acoustics Report and Drawing Review must be submitted at the conclusion of the DD Phase. All items addressed in the SD Report should be reviewed for proper design progress and implementation including the resolution of all problems identified in the SD Report. It is also essential to clearly indicate that mechanical noise criteria have been communicated to the Mechanical Engineer and that meeting these criteria is feasible and affordable based on the planned mechanical design. The Sound Reinforcement System specification should be included with the DD Report including a budget estimate and loudspeaker sketches clearly showing the size and location(s) of all loudspeaker elements.

4. A Construction Documents (CD) Acoustics Report and drawing review is recommended to verify that all the items in the SD and DD Reports have been properly addressed and specified in the final documents. If there has been significant cost-cutting or value-engineering during the CD Phase, it is essential that the CD Report identify any problems or compromises that could result in acoustical performance that would not meet established criteria.

5. A final Acoustics Report is to be issued upon the completion of a check-out and inspection visit at the end of construction. The report should include documentation of measurement showing that all acoustical criteria have been met. A punch list should be included listing all deficiencies and giving recommendations for corrective measures. The final checkout must also include a complete performance verification of the sound reinforcement system.

AN ACOUSTICS CHECKLIST FOR A TYPICAL CHURCH BUILDING PROCESS

The following checklist of acoustics items and checkpoints assumes that an Acoustics Consultant has been selected and that the acoustics effort includes the four fundamental facets of church acoustics: (1) Natural/Architectural Acoustics; (2) Sound Isolation; (3) Mechanical System Noise and Vibration Control; (4) Sound Reinforcement System Design and Specification.

Pre-Design and Programming Phases

- The Acoustics Consultant (AC) attends a Design Team Kick-off Meeting with all key members of the design team and receives preliminary information and documents including a program statement and budget information.
- The AC attends at least two representative liturgies.

Schematic Design Phase

- The AC submits an SD Acoustics Report, based on a review of the final (or 90%) submittal package, including project-specific design criteria such as room geometry (volume, dimensions, etc.), reverberation time, background noise criteria (NC or RC values), sound

isolation criteria (STC values), etc.
- The AC submits a functional description of the Sound Reinforcement System.

Design Development Phase
- The AC submits a DD Acoustics Report, based on a review of the final (or 95%) DD submittal package, including verification of proper design progress, a formal statement on mechanical system noise control effort and collaboration with the ME, outline specifications for acoustical items to be included in the project specification manual, etc.
- The AC submits the Sound System Specification including preliminary floor plans for conduit and device locations, and preliminary sketches of loudspeakers and locations.

Construction Documents Phase
- The AC submits a final CD Acoustics Report, based on a review of the final (or 95%) CD submittal package. The AC should verify that all necessary aspects of the acoustics design have been be fully addressed in the Construction Drawings and Specifications.
- Ideally, the Sound System Specification will be bid separately from the general bids to eliminate cost mark-ups by the General and Electrical Contractors, but coordination issues among the trades must be clearly specified. The AC will submit a recommendation for the selection of a Sound Contractor to install the sound system as specified in the Sound System Specification. The recommendation will be based on bid responses.

Construction Phase
- The AC responds to submittals and change orders as needed. If appropriate, the AC may visit the construction site for inspection of the installation of special systems and devices.

Final Construction Evaluation
- The AC will perform a complete check-out of the completed building and measure all specified acoustical criteria such as reverberation, sound isolation, NC levels, etc. The AC will also perform a complete performance verification of the Sound System and verify that all necessary documents (manuals, as-built wiring and block diagrams, warranties, etc.) have been submitted. A punch list and recommendations should also be included.

APPENDIX A - ANNOTATED BIBLIOGRAPHY

BOOKS, BOOKLETS, AND PAMPHLETS

Acoustical Society of America. *Acoustics of Worship Spaces*. New York: The American Institute of Physics, Inc, 1985.

Based on a Poster Session at the 1983 Meeting of the Acoustical Society, this book presents posters (one-page of photos, floor plans, and sections) plus a one-page description for each of 43 worship spaces in the U.S., Canada, Mexico, and Japan. Acousticians, architects, building committees, clergy, choir and music directors, and sound system designers are among the intended audience. A preface includes four articles on various aspects of church acoustics.

Alien Organ Company. *Organ Planning Kit*. Macungie, PA: Alien Organ Company, 1992.

This manufacturer's booklet gives a comparison of important features of pipe and electronic organs, plus information on planning, installing, and maintaining organs, acoustical considerations, location, and space requirements.

The American Guild of Organists, Committee on Acoustics and Architecture. *Acoustics in Worship Spaces*. New York: The American Guild of Organists.

A pamphlet by the now defunct AGO Committee on Acoustics and Architecture that covers a range of acoustical issues with emphasis on providing acoustics suitable for a pipe organ including size, room geometry, and finish materials.

Associated Pipe Organ Builders of America. *American Organ Building*. New York: The American Guild of Organists, 1976.

A collection of essays by American organ builders covering various facets of organ building for the lay reader including one chapter devoted to acoustical issues. (SR)

Associated Pipe Organ Builders of America. *Planning Space for Pipe Organs*. New York: The American Guild of Organists, 1992.

A booklet covering space planning for pipe organs in churches with sections devoted to acoustics, room geometry, and finish materials. There is a succinct overview of organ fundamentals including basic concepts and terminology.

Day, Thomas. *Why Catholics Can't Sing*. New York: The Crossroads Publishing Co., 1993.

This thought provoking and controversial book, subtitled "The Culture of Catholicism and the Triumph of Bad Taste," does not deal directly with acoustics, but does explore rekated factors such as the all-to-common overamplification of cantors and songleaders that can overshadow the assembly rather than encourage it to participate in hymn singing.

Eiche, Jon F., ed. *The Guide to Sound Systems for Worship*. Milwaukee: Hal Leonard Publishing Co., 1990.

This 190-page book, published by a leading sound system manufacturer, provides a thorough discussion of sound systems in worship spaces. Early chapters present an overview of the church sound system and discuss where and how to buy a system, and basic acoustics. There are also chapters devoted to virtually every common piece of audio equipment used in church systems including microphones, mixers, amplifiers, equalizers and loudspeakers. Finally, there is information for the do-it-yourself congregation that explains installing, operating, and trouble-shooting a sound system. This is a highly recommended book for every church sound system operator and for those seeking a comprehensive understanding of church audio systems.

Ferguson, John A., and Joy E. Lawrence. *A Musician's Guide to Church Music*. New York: The Pilgrim Press.

A multifaceted discussion of issues in church music with some statement of general principles of proper acoustics relating to organ, congregational singing, choir, and speech. (SR)

Fesperman, John, *Hymnal Studies Four: Organ Planning, Asking the Right Questions.* New York: The Church Hymnal Corporation, 1984.

The entire booklet is a discussion of the design, planning, selection, and use of a church organ with reference to the mechanical action pipe organ. The acoustics section describes basic principles of acoustical design in churches. (SR)

Geerdes, Harold P. Worship Space Acoustics. Washington, DC: The Pastoral Press, 1989.

A booklet written by a practicing acoustical consultant and music educator that covers the full gamut of acoustical considerations for the worship environment including a discussion of sound reinforcement systems.

Liturgy Training Publications. Meeting House Essays: Acoustics for Liturgy. Chicago: Archdiocese of Chicago, 1991.

A collection of articles, originally published in *The Hymn* (July 1990) devoted to acoustics for congregational singing, but touching on virtually all aspects of acoustics for worship. This collection of 6 essays addresses acoustics from the perspective of the acoustician, the architect, the liturgical musician, the organ builder, the theologian, and the pastor.

Lovelace, Austin C., and William C. Rice. Music and Worship in the Church. New York: Abingdon Press.

This resource explores the many facets of organizing and conducting church music. The influence of the acoustical environment on musical production, conducting, organ playing and space planning is presented. (SR)

Neuchterlein, Louis B. A Handbook of Church Music. St. Louis: Concordia Publishing House.

Chapter 4, "The Music of the Congregation: The Importance of Acoustics for Congregational Worship," addresses acoustics for the congregation or assembly.

Ogasapian, John K. Church Organs—A Guide to Selection and Purchase. American Guild of Organists and The Organ Historical Society, 1990.

This book is written for church organ committees charged with choosing a new organ or rebuilding an existing organ. It assumes that most committee members are not organists and, therefore, provides essential information and terminology for the layperson. It presents thorough discussions of all major considerations in the organ decision process including architectural and acoustical requirements, organ types, selecting a builder, and maintenance issues. While some statements about acoustics are debatable, this is an excellent reference for anyone interested in understanding the complexity and variety of the organ, and for those responsible for making a major purchasing decision.

Riedel, Scott R. Acoustics in the Worship Space. St. Louis: Concordia Publishing House, 1986.

A practical and moderately technical booklet of acoustics for speech, singing, and organ with suggestions for room design. (SR)

Riley, George R. *Worship Space Sound Systems.* Washington, DC: The Pastoral Press, 1994.

A brief, generally non-technical, but comprehensive summary of sound systems for churches. It is ideally suited for the parish building committee considering a new or unproved sound system and discusses general system design and all basic system components. Especially useful (and candid) is a chapter dealing with contractors and consultants.

Sovik, Edward A. Architecture for Worship. Minneapolis: Augsburg Publishing House, 1973.

A short book on theology, theory, and practice of designing buildings for worship with thoughtful discussions on acoustics, music facilities, organs, and choirs. (SR)

Year, Tim. Microphone Selection and Application for Church Sound Systems. Evanston, IL: Shure, 1991.

This 36-page booklet, published by a leading manufacturer of microphones, provides a good summary of the use of microphonesfor the varied needs of a worship space. Most of the presentation is not too technical and will be of use to church building committees. Some of the applications and techniques discussed will be useful to church music directors and sound system operators.

Wicks Organ Company. A Technical Guide to the Pipe Organ. Highland, IL: Wicks Organ Co.

An informative brochure that provides general information about pipe organs including placement, environment, and basic technical information.

JOURNAL, PERIODICAL, AND MAGAZINE ARTICLES

Barthel, Alan. "Observations on Hymn Singing in Canada." The American. Organist 22, No. 8 (Aug. 1988): 57.

A discussion of the decline of interest and enthusiasm in hymn singing suggesting that poor acoustics is part of the problem.

Bethards, Jack. "Don't Give Up on Acoustics." The American Organist 20, No. 9 (Sep. 1988): 75.

An article appropriate for musicians, clergy, and laity encouraging all to strive for acoustical quality and improvement. Practical ideas and suggestions are presented. (SR)

Bozeman, Jr., George. "The Sounds of Mystery: Practical Remarks on the Acoustics of Religious Space." Faith and Form: Journal of the Interfaith Forum on Religion, Art and Architecture 22 (Spring 1989): 34.

A discussion of how the worship environment appeals to multiple senses, highlighting acoustics. Non-technical practical examples are given. (SR)

Clutz, Charles N. "Acoustics Reassessed: An Opportunity." The American Organist!]., No. 12 (Dec. 1987): 70.

A case study of the acoustical renovation of All Saints Church in Brookline, Massachusetts. (SR)

Doschek, Anthony. "Room Acoustics." The Diapason (Mar. 1978): 10.

A scientific and technical discussion of acoustics and room design. (SR)

Fleisher, Dennis. "Acoustics for Congregational Singing." The Hymn 41 (July 1990): 7.

An essay dealing with fundamental acoustical design issues that influence congregational singing.

Fleisher, Dennis. "Finding the Parish's Voice: The Acoustics Crawl." *Environment & Art Letter* (Oct. 1994): 78.

A discussion of a process whereby a church building committee can identify the acoustical qualities desired for a new or renovated church. The process will not only help the parish discover the acoustical qualities that are compatible with its worship style, but will provide tangible examples to facilitate communication with the acoustical consultant.

Foster, Thomas. "Acoustics in Worship Spaces: Preparing for Sound Improvement." *The American Organist* 15, No. 9 (Sep. 1981): 60.
A brief account of the acoustical renovations at All Saints Episcopal Church in Beverly Hills, California. (SR)

Geerdes, Harold P. "A Guide to Getting a Good Sound System." *Environment & Art Letter* (Sep. 1992): 50.
This article provides a concise summary of sound system issues for churches. All aspects, from fundamental design concerns through budgeting and the bidding process, are presented by an experienced practitioner in worship space acoustics.

Geerdes, Harold P. "How to Select an Acoustical Consultant." Environment & Art Letter (May 1994): 28.
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Gerike, Henry. "And All My Senses." Lutheran Worship Notes 9 (Spring 1987): 1.
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A brief discussion of acoustical improvements made at St. Thomas Church in New York City. (SR)

Held, David. "Singing: The Role of Congregational Singing in the Church." *Issues in Christian Education* 16, No. 3 (Summer 1982).
A discussion of the history and theology of hymn singing with notes on the need for fine acoustical environments. (SR)

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Jung, Henry. "Are Perfect Church Acoustics Possible?" *Faith and Form: Journal of the Interfaith Forum on Religion, Art and Architecture* 14 (Spring 1980): 15.
An introductory article on using electronic reinforcement to clarify speech in an environment that is reverberant for music. (SR)

Klepper, David L. "Sound Systems in Reverberant Rooms for Worship." *J. Audio Eng. Soc.*, 18, No. 4 (Aug. 1970).
A fairly technical article. But there is an excellent and very readable table with accompanying illustrations that reviews six fundamental loudspeaker design formats including clusters, distributed systems, and pew back systems.

Little, Edward M. "Acoustics Can Be Good." *The Diapason* (Dec. 1963).
A discussion of the use of electronic sound systems to clarify speech in rooms with generous reverberation. (SR)

Mahoney, Robert F. "Tailoring Acoustics to Worship Environments." *The Creator Magazine,* (Sep. 1986): 27.

Major, Douglas R. "Making Music." *The Living Church* 185, No. 20 (Nov. 1982): 12.
A short discussion of musical performance considering factors such as the conductor, composition, and acoustics. (SR)

Maple, Howard. "A Joyful Noise." *The Construction Specifier* (Jun. 1994): 76.
A complete but concise summary of the entire process involved in selecting, installing, and maintaining a pipe organ in a worship space. In addition to many well-known aspects of the organ planning process, the author discusses more mundane but critical issues such as HVAC noise and climate control, space planning, situating the organ, floor loads, electrical service, wind duct provisions, and maintenance. The author is the executive secretary of the American Institute of Organ builders.

Owen, Barbara. "Memos to the Organ Committee." *The Journal of Church Music*, (Apr. 1985).
Recommendations to the beginning church organ committee with comments on the importance of acoustics and planning. (SR)

Riedel, Scott R. "Acoustics in the Worship Space." *The Diapason*, I (May 1983): 10; II (May 1984): 10; III Jan. 1986): 10; IV (May 1987): 19; V (Apr. 1988): 16; VI (Apr. 1990).
Six essays on the theory of acoustics for worship with practical and technical suggestions and examples. Essay IV speaks of the influence of carpeting in the worship environment, essay V explains the acoustical phenomenon of echo, and essay VI describes the acoustical effect of padded pews. (SR)

Schalk, Carl. "A Lament for Resounding Praise." *The Christian Century*. (Mar. 23, 1983): 269.
An essay describing the effects of acoustics on worship. (SR)

Visser, Pieter. "Acoustics." *The American Organist'12,*, No. 3 (Mar. 1988): 76.
This text of a lecture given by Visser to the National Council of Acoustical Consultants in April 1985, is an overview of the acoustical requirements of organs and churches, citing specific examples. (SR)

Visser, Pieter. "Theology of Acoustics." *The American Organists* 17, No. 6 (Jun. 1983): 37.
A personal account of the effect of acoustics on worship. (SR) *(SR) Indicates review comments written by Scott Riedel. All other comments are written by Dennis Fleisher.*

APPENDIX B - GLOSSARY

***Automatic Microphone Mixer*—**A sound system component that provides some, but not total, automation of the sound mixing ordinarily done by a sound system operator. These systems automatically turn on microphones that are in use and turn off those that are not in use. Some also have threshold capabilities that help to boost the level of quiet talkers and reduce the level of loud talkers. Automatic mixers can help reduce feedback, especially in reverberant churches.

dB — See *Decibel.*

Cps — Cycles per second. See *Hern.*

Cardioid Microphone — *A* microphone that has increased sensitivity to sound coming from only one direction: the front. Cardioid microphones also have a reduced sensitivity to sounds coming from the rear (handle) end of the microphone. Cardioid mikes help reduce the potential for feedback and reduce the pickup of unwanted sounds (such as noise from the assembly).

Central Cluster Loudspeaker System — An arrangement of loudspeakers with all the primary speakers located together in a single array in a central position usually immediately above the sanctuary or chancel. This single array may be composed of several horns and cabinets, but the total assembly of speakers behaves as a single sound source. Among the major advantages of a central cluster system is directional realism: the impression that amplified sound is coming from the talker, not the loudspeaker array. A major disadvantage is that the cluster can be quite large and, with its central location, present a significant visual element.

Decibel — The most common unit of sound level (loudness) measurement. Zero decibels is the threshold of hearing, the quietest sound that most people can hear under ideal conditions.

Diffusion—The scattering of sound. Usually diffusion refers to the evenness of sound distribu- tion in a room: good diffusion results in no hot spot or dead spots. Also, diffusion is a way to prevent echoes by scattering sound with surface irregularities rather than by absorbing it.

Distributed Loudspeaker System — A loudspeaker system composed of several loudspeakers located at multiple locations throughout the church seating area. Often distributed systems are made up of relatively small loudspeaker cabinets located on side walls or structural building columns, a configuration commonly found in highly reverberant European cathedrals. Because they place loudspeakers fairly close to the listeners, distributed systems provide a high degree of sound control and, usually, excellent intelligibility. However, they often give the impression that sound is coming from the loudspeakers, not the talker.

Echo — A discrete reflection of sound from a hard sound reflective surface resulting in an audible repetition of a sound. See also *Reverberation.*

Electro-pneumatic Organ — A type of pipe organ in which each pipe is connected to the keyboard

through a combination of electronic and pneumatic components. Because of this, electro-pneumatic organs can have their consoles (keyboards) placed at a distance from the pipes.
This often allows better configurations for music areas.

Feedback — A high-frequency audible squeal produced by a sound system when the sound from a loudspeaker is picked up by a microphone, creating a continuous loop or feedback path. If the system loudness is sufficiently high, this loop allows sound to be re-amplified resulting in the wellknown, and often ear-shattering, squealing sound.

Feedback Eliminator — A special sound system component that is designed to prevent feed- back, even when feedback conditions are present. See *Feedback*. While older versions of feed- back eliminators were of questionable value, newer products, designed and introduced in the 1990s can provide excellent, though not infallible, feedback suppression.

Focusing — A concentration of sound energy usually produced by convex curved surfaces. The concentration of sound in a small area is accompanied by a decrease of sound in other areas. As a result, sound focusing usually leads to poor uniformity and distribution of sound heard as "hot" spots and "dead" spots throughout the listening area.

Foldback Speakers — See *Monitor Speakers*.

Hearing Assistive System — An supplemental device for sound reinforcement systems that provides special capabilities for those with hearing impairments. Typically, these systems have a transmitter (radio-frequency or infra-red) that broadcasts a signal within the church. This signal can be picked up by small, inconspicuous wireless receivers with an earphone, carried by those with hearing impairments, allowing them to clearly hear all signals carried by the sound system.

Hertz — The unit of sound frequency: cycles per second.

HVAC—Heating, Ventilating, and Air-Conditioning systems. HVAC systems often cause excessive noise in churches. One special problem with HVAC noise is that it is very effective at reducing speech clarity, a potentially serious problem in a church. However, subtle HVAC system noise can provide a useful masking effect. See *Masking*.

Masking — The covering up or obscuring of one sound with another sound. Some effective masking can be provided by a properly designed HVAC system. This may be useful in a church to convey a sense of isolation and quiet by minimizing the intrusive effects of unwanted sounds such as conversation from a gathering space or sporadic outdoor noise. However, excessive masking can severely reduce speech intelligibility.

Monitor Speakers — Loudspeakers, usually relatively small, used to project sound back to the sound sources, i.e., the talkers or musicians producing the sound. Often, those producing sounds in a church (presider, readers, and musicians) are located behind the main loudspeakers and can- not hear the amplified sound they are producing. Monitor or foldback speakers project sound to those

producing the sound so that they can hear their amplified sound and more accurately judge and control their own loudness levels.

Omnidirectional Microphone—A microphone that picks up sounds equally from all directions. There are certain advantages to omni's (as they are often called): they are less sensitive to the direction and distance of a talker. This reduces changes in loudness caused when a talker moves relative to the microphone. However, they also tend to pick up unwanted sounds such as noise from the assembly.

NC — See *Noise Criteria.*

Noise Criteria—A standardized system of rating the ambient noise level (usually from HVAC equipment) in a room. The NC value is roughly 10 points lower than the corresponding decibel level. NC-30 is a typical level for a quiet church. NC-20 to NC-25 might be more appropriate for a church with a strong traditional music program or with special needs for recording or broadcast. See also *Room Criteria.*

Noise—Unwanted or distracting sound. However, some noises can be useful: See *Masking.*

RC— See *Room Criteria.*

Rank — A set of organ pipes producing the same tone quality but with each pipe at a different pitch. There are usually 58 to 61 pipes per rank: one for each key on the keyboard.

Reverberation Time — The time it takes for a sound to decrease by 60 dB after the sound is abruptly stopped. In a typical home or office the reverberation time is less than 0.5 second. A reverberation time of 2 to 3 seconds is appropriate for most Catholic churches. Large cathedrals can have reverberation times of 6 seconds or more.

Room Criteria — A standardized system of rating the ambient noise level (usually from HVAC) in a room. Both the Room Criteria and Noise Criteria systems have been in use during the past several years, but, as of 1991, the Room Criteria system is the preferred method. For most pur- poses, the Room Criteria and Noise Criteria are equivalent. See also *Noise Criteria.*

RT, RT60 — Abbreviations for*Reverberation Time.*

Sound Transmission Class — A rating system used to rate the sound insulation performance of a material or assembly. The Sound Transmission Class is most commonly used to rate the sound insulation provided by common building partitions. Typical walls (gypsum board on studs) are in the range of STC-40 to STC-50. The STC number is roughly the number of decibels that a sound would be reduced when passing through a partition.

STC— See *Sound Transmission Class.*

Stop — A rank of organ pipes. Note, however, some stops can be made up of more than one rank (or set) of pipes (such as a mixture or mutation) to produce a special or distinctive tone quality.

T60 — Another abbreviation for *Reverberation Time*.

Tracker Organ — A type of pipe organ in which each pipe is connected to the keyboard through mechanical levers and components; the primary mechanical connecting links are called "trackers." Because of this, tracker organs are also called "mechanical action" organs. Tracker organs have their consoles (keyboards) attached to the cabinetry that houses the pipes.

Unidirectional Microphone — A type of microphone that has increased sensitivity to sound coming from only one direction: usually the front. A cardioid microphones is one type of unidirectional microphone, but there are other microphones that have an even more confined pick up pattern. See also Cardioid Microphone.

Wireless Microphone — A microphone that can send its signal without a wire and plug connect- ing it directly to the sound system equipment. The signal is usually carried by radio waves. The radio transmitter can be built into the microphone body or can be a separate small box usually concealed under the clothing of the microphone user.

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APPENDIX C - SELECTING AN ACOUSTICS CONSULTANT

The renovation or construction of a church involves the collaboration of many design and building professionals. Because of the critical role of acoustics, the architect must have a complete appreciation of the acoustical issues for worship and be able to implement them effectively in the design and construction of the building. Because of the highly specialized nature of church acoustics, it is often necessary to engage an acoustics consultant. The following items offer some guidance in selecting an acoustics consultant:

1. The consultant should be involved in the design process as early as possible, preferably during programming, but not later than the early Schematic Design phase.

2. The consultant can be engaged by the church or the architect. In either case, the church must receive copies of all acoustical reports.

3. The consultant should be selected on the basis of experience in church building projects. Experience and credentials in other types of buildings my not be a suitable indication of the consultant's abilities and sensitivities to worship space acoustics.

4. The consultant should have no direct affiliation with or be a vendor for manufacturers of acoustical materials, sound equipment, etc.

5. The consultant should be knowledgeable about Catholic worship, be sensitive to the priorities of Catholic liturgy, and actively investigate the unique elements of the parish's expressions of public worship.

6. The consultant (or consulting firm) should provide consulting and design services in room acoustics, sound isolation, mechanical system noise and vibration control, and sound reinforcement systems.

If the consultant is hired by the architect, the parish should verify that requirements from the above items have been addressed. If the church wishes to hire its own consultant, the following additional items will assist the selection process:

1. Get the names of qualified firms or individuals from the diocese, from references involving other successful projects, or from a consultant's registry such as the National Council of Acoustical Consultants (NCAC). If using a registry, be sure to select from those who specialize in churches.

2. Send a Request for Qualifications (RFQ) or Request for Proposal (RFP) to prospective candidates. The consultant's submittal should include:

   • A complete company profile of qualifications, experience, and services offered;

- A list of past projects including dates of completion;

- Names and phone numbers of three references (preferably pastors, music ministers, architects, etc.) who have been involved directly with the consultant on comparable projects in the past five years;

- An itemized, project-specific scope of work indicating the consultant's involvement in the required elements of church acoustics and design;

- A fee estimate, insofar as possible, based on information provided by the church. This might include the following: a preliminary program statement, project schedule, and construction budget; preliminary design sketches (existing drawings for a renovation); details of special music requirements (such as a pipe organ, large choir, etc.) and all other pertinent information.

After an initial screening and thorough verification of credentials and references, it is appropriate to interview finalists. The parish should ask direct and probing questions to develop a comfort level with the consultant's experience, personality, level of involvement, commitment to good acoustics for worship, etc. For example:

- Does the consultant have sufficient time and personnel available to complete the project on schedule?

- What reimbursable expenses are involved , and what is the estimated maximum cost of these reimbursable?

- How will the consultant determine the acoustical criteria for this specific project?

- How will the consultant address the primacy of the assembly and specific elements of the music ministry unique to the parish?

- What specific actions will the consultant take should the acoustics be unsatisfactory? Will there be additional fees? By what criteria will "acceptability" be judged?

If the consultant is hired by the church (rather than by the architect) the consul tant is, effectively, the church's representative and advocate for acoustics. It is, therefore, important that the parish be confident of the consultant's abilities and dedication in this role.

The selection of a consultant should not be based solely on the proposed consulting fee. More important factors include, but are not limited to, the following:

- The consultant's knowledge and experience in acoustics and understanding of the unique requirements of church acoustics and Catholic liturgy;

- The consultant's record of successful projects (quality rather than quantity);
- The consultant's ability to meet schedules and work within budgets;
- The consultant 's commitment to excellence and ability to be an advocate for acoustical priorities on behalf of the church;
- The consultant's willingness to devote sufficient time to the project, to be an active design team member, and to study and respond to the particular elements of the parish's identity and religious expression.