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Acoustical Review and Report
For the Existing Worship Space

St Peter Lutheran
Hemlock, MI February 24, 2021

I. Project Goals

The goal of worship architecture, in regards to the acoustical environment, is to provide a setting where the critical aural activities and functions of worship are supported and enhanced. These functions include:

1. The distribution of clear, intelligible speech to all worshipers.
2. The blending of acoustic music (choirs, organ, instruments, etc.) into a rhythmically accurate, well tuned ensemble, and the distribution of that music to all worshipers.
3. The development of a setting where worshipers can hear each other well to support participation together in sung and spoken parts of the service, and so that the music leadership team can hear the participation of the congregation.
4. The development of a setting where echoes, excessive noise, sound focusing, and/or other similar acoustical faults are controlled and suppressed.

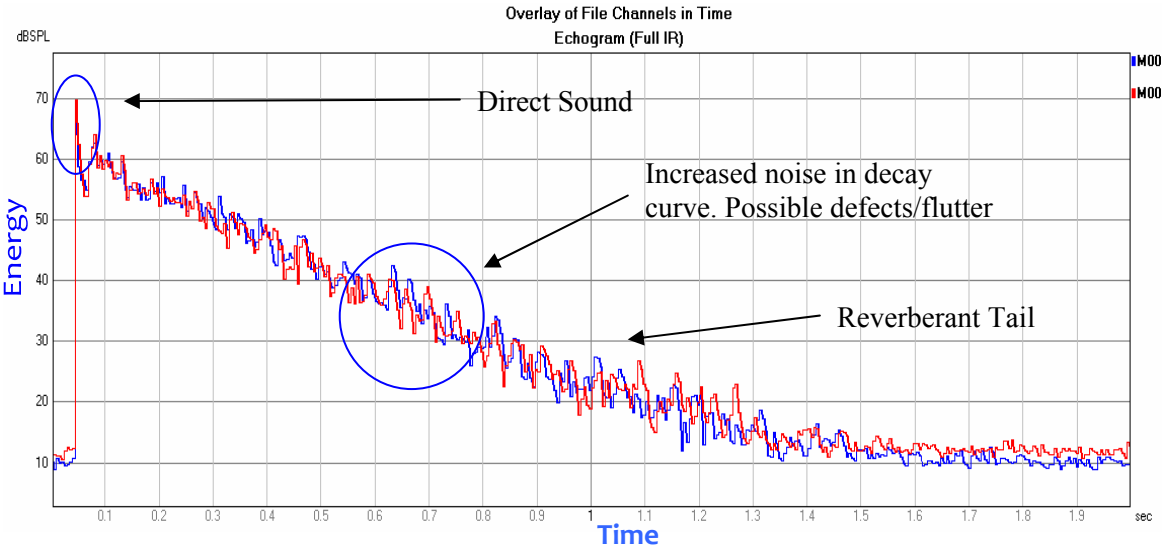
These goals are generally achieved in architectural environments that exhibit desirable design features and elements such as:

A. An adequate ratio of cubic air volume to seating capacity.
B. A non-restrictive geometric shape/form.
C. Good location and proximity of key elements such as singers/instruments, etc.
D. Good ratio of sound reflective to sound absorptive materials, finishes and structures.
E. An appropriate reverberation period.
F. An electronic sound reinforcement system of appropriate equipment design, location and calibration.
G. Adequate sound-isolation from potentially noisy adjacent spaces, outdoor transportation, and/or machinery.
H. The design and location of building systems and equipment (such as heating/air conditioning HVAC systems) for the control and suppression of noise.

II. Analysis of Existing Conditions

1. The geometric form of the building, long axis plan orientation with high side walls and vaulted ceiling with balcony, provides a sufficient amount of cubic air volume which can result in conditions for sound to propagate fully across the entire frequency range. The high steep peak of the ceiling geometry is a limiting factor of potential increase in reverberation period. The geometry creates a condition where the sound energy will decay more than normal due to the proximity of adjacent reflecting surfaces occurring in close succession.

2. The existing reverberation period is much lower than recommended for traditional worship with contemporary elements and/or services. Steps should be taken to increase the room's reverberation.
3. The existing room volume per seat, at 267.50 cu ft per seat, is on the high side of the midpoint of acceptable values for traditional worship spaces (180 cu ft-300 cu ft /seat); The room volume compared to the occupancy is capable of supporting a high reverberation period over the entire frequency spectrum, however there are currently too many sound absorbing surfaces in the room located too close to worshipers to achieve that goal. The room should be tuned by removing and relocating some sound absorbing surfaces to liven the reverberation period.
4. Carpeted existing floor surfaces diminish the projection and distribution from musicians and the congregation and hinders participation as well as support from other congregants. Hard surface flooring material should be considered to achieve optimal results.
5. Most exposed wall and ceiling surface finishes, such as the brick and wood deck ceiling are sufficiently dense enough to support reflections throughout the full frequency spectrum. Plywood soffits running parallel down the length of the upper nave walls have limited capacity for low frequency reflections. These areas should add density or be stiffened to provide support through the full range.
6. Balcony wall surfaces flanking the pipe organ and musicians are not dense enough to provide projection support through the entire frequency spectrum. In addition there is a large void next to the pipe organ and top row of musicians where an abandoned exhaust grille remains. Voids should be filled and walls should be stiffened to aid in musicians' ability to hear those on opposing sides of the balcony space for proper rhythmic and tonal blending, as well as in projection into the nave. The side walls should also be angled to give further aid in musicians' ability to project into the space.
7. Opposing parallel reflective wall surfaces down the length of the nave are causing flutter echoes within the space. This audible slap back or echoes are manifested from sound energy reflections off of large, flat, monolithic and unobstructed wall surfaces; i.e. flat brick nave side wall surfaces, the plywood soffits, as well as opposing gypsum walls in the balcony flanking the pipe organ and musicians. In addition to the stiffening/angling required at some of these wall conditions, sound diffusing features or profiles should be introduced to distribute sound more evenly through the space.



At receiver positions in the mid/rear of the space we see an increase in noise in the background reverberant tail, which may lend itself to produce flutter if the side walls and balcony front are stiffened without adding diffusion. See sheet AC-01.1 and attached echogram data sheet

8. An excess amount of noise was noted coming from the HVAC system; noise is elevated throughout the entire frequency spectrum in particular between 63Hz to 1kHz. The noticeable cause of this excess is likely from a combination of the various machine noise elements, air velocity and restricted supply grilles in the space (broadband Hz).

The following recommendations are provided to achieve the best possible acoustic result for this space, based on our understanding of your needs at this time. Changes and modifications to these recommendations may be considered at any time, per your request.

III. Music Area

Choir and Organ Balcony Design Ideals, Goals and Features:

Acoustic/Music Goals:

- Choir singers and instrumentalists to hear each other well for tuning and rhythmic accuracy
- Choir singers, organist, and instrumentalists to hear organ tone clearly and without obstruction
- Music (choral, organ, instrumental) to project evenly throughout the entire worship space

Acoustic Design Features to achieve Goals:

1. Choir singers in "ensemble" format
2. Choir singers on tiered/raised floor levels
3. Choir singers to have chairs (not pews)
4. Space for director, organ console, piano, and instrumentalists forward of choir singers
5. No singers or instrumentalists under a cantilever, under a too-low ceiling condition, around corners, or in any "dead" tone pocket
6. No obstructions to tonal projection or egress
7. Dense, hard, sound reflective materials
8. Sound diffusing surface profiles (walls) at choir area
9. Preparations for Organ chamber space of sufficient size and access, and with sufficient power, conduit and weight bearing infrastructure for future pipe organ use.

Architectural Acoustic Design Feature Recommendations:

1. Angle balcony walls to 5° in the vertical axis to eliminate parallel reflecting surfaces.
2. Incorporate a sound diffusing (angular/irregular) wall surface profile to the surfaces flanking choir/organ/musicians area

Balcony Area Technical Details:

1. **Maintain hard surface flooring (no carpet) throughout**
2. Current fixed choir riser platforms are recommended for choir singers and should remain.
3. Provide sound reinforcing / diffusive wall to prevent flutter echo from parallel side walls and to help project tone out of balcony. Wall should be built 5° in the vertical axis and made of solid wood/plywood or three layers of gypsum wall board glued and screwed

together and to the structure, staggering the seams. Insulate cavity with 3" mineral wool. See drawings.
4. Balcony solid front railing should be replaced with a spindle railing with a minimum of 50% opening.
5. Provide adequate electrical service to the music area for choir stand/desk lights, instrumental music rack lights, piano humidifier, and other musical-electric equipment
6. Provide sound system infrastructure (microphone jacks, speaker plugs, electrical power) components in the choir/musicians area

Organ Infrastructure/Site Preparation needs for a future Pipe Organ

1. An organ case area must be *dedicated* for the use and installation of organ equipment only: No ducts, pipes or any other equipment or devices can be located within the organ chambers.
2. An organ case area should have no intermediate walls---the entire space should be open and dedicated to organ equipment only.

Weight

Contact potential organ manufacturers for weight bearing requirements.

Climate

Humidity: Relative humidity should not fall below 35% for extended periods. Air ventilation fans may be desirable for pipe organ spaces.

IV. Reverberation Period

Reverberation: Establishing a proper reverberation period is a critical factor in developing desirable acoustical conditions in a worship space.

"Reverberation Period" is the amount of time (in Seconds) that sound energy will linger and travel in a given space. Specifically, it is the amount of time sound energy will take to drop a level of 60 decibels after the source has ceased producing a tone.

The proper reverberation period will support clear, intelligible speech, and balanced, clear and even musical production and projection, as well as facilitate hearing and participation amongst worshipers for their sung and spoken parts of the service. A reverberation period that is too long can render music and speech with confusion and lack of unintelligibility. A reverberation period that is too short can diminish participation by the congregation in sung and spoken service parts. The correct reverberation period is essential to the success of the worship environment.

The function and use of a space determines the appropriate reverberation period. In a space of this size and shape, worship responses, hymn/liturgical singing, and choral/instrumental music is the primary musical form, a reverberation period of approximately 1.80 to 2.00 seconds during unoccupied conditions is desirable.

Conditions influencing the reverberation period include the surface area and relative sound reflecting or sound absorbing qualities of all materials and furnishings in the room, and the cubic air volume and shape of the room. (Generally, a large room with many reflecting surfaces

will have a long reverberation time and a small room with many sound absorbing surfaces will have a short reverberation time.) Note that changes in reverberation period of 0.1 seconds are detectable and noticeable to typical listeners.

Existing Conditions Untreated

Tested Conditions:	Reverberation Time (Seconds)				
Frequency (pitch) →	125Hz (C3)	250Hz (C4)	500Hz (C5)	**1000Hz (C6)**	2000Hz (C7)
	"Bass"	*Middle C*	*Alto-Soprano Range*		*Consonants*
Unoccupied$_{(tested)}$	1.85	1.52	1.47	**1.41**	1.37
50% Occupied$_{(predicted)}$	1.64*	1.34	1.24	**1.18**	1.15
Fully Occupied$_{(predicted}$	1.55*	1.26	1.14	**1.08**	1.05

* Note: actual RT times in this frequency range may vary due to limitations of low frequency calculations in prediction software.

Please see attached reverberation testing sheet for complete test results

Single Number Reverb Time Rating:

Unoccupied **1.40** Seconds
50% Occupied**: 1.21** Seconds
Fully Occupied**: 1.11** Seconds

Reverberation rates in the mid to upper frequencies are currently too low for traditional liturgical and musical functions. Both speech intelligibility and musical clarity are suffering due to sound absorbing surfaces too near to the congregation and covering a significant number of surfaces in the room, acoustical defects that degrade speech intelligibility and understanding. Sound reflections should be increased in the room by removing sound absorbing surfaces and replacing many with sound reflective or diffusing surface profiles. Modest amounts of sound absorbing features should remain at appropriate locations in the space, not too near to worshipers or musicians.

Appendix A: *(Speech Transmission Index (STI)for Untreated Space):*

Target Average Values Goals is between 0.52-0.56 for traditional worship spaces.

Figure 1: At 50% occupancy the entirety of congregation area falls above the target values resulting in an average STI value of 0.63. This average is above the allowable maximum range for a traditional worship spaces and will lean towards better conditions for speech transmission, while only amplified instrumentation and vocal sources may be able to overcome the dryness of the space and the low reverberation period.

Band	STI Range	Examples of typical uses
A+, A	>0.76	Recording Studios
B	0.68-0.76	Theatres, speech auditoria, parliaments, courts
C	0.64-0.68	Teleconference, theatres
D	0.60-0.64	Class rooms, concert halls, multipurpose auditoria
E	0.56-0.60	Contemporary worship spaces, concert halls
F	**0.52-0.56**	**Traditional worship spaces**
G	0.48-0.52	PA in shopping malls, public offices
H	0.44-0.48	PA in difficult acoustic environments
I, J, U	<0.40	Not suitable for PA systems

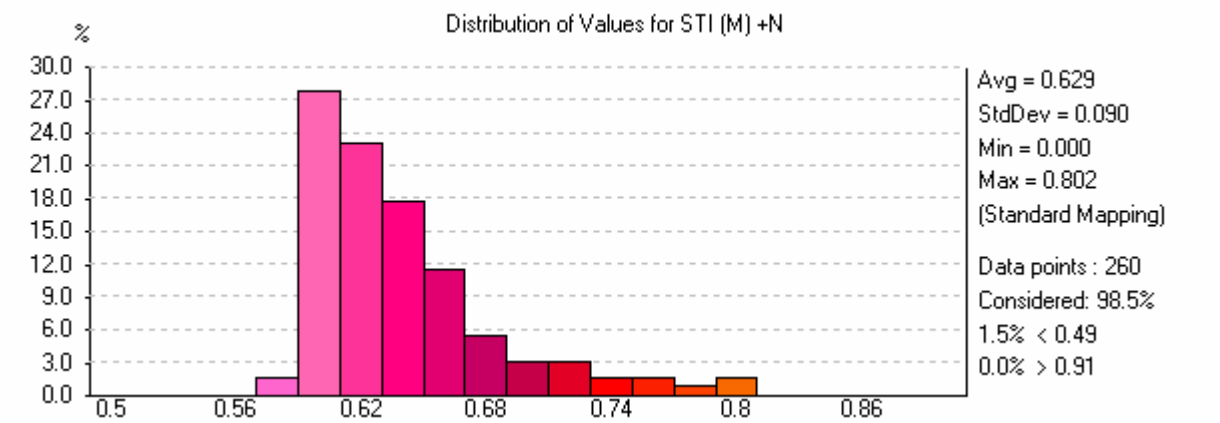
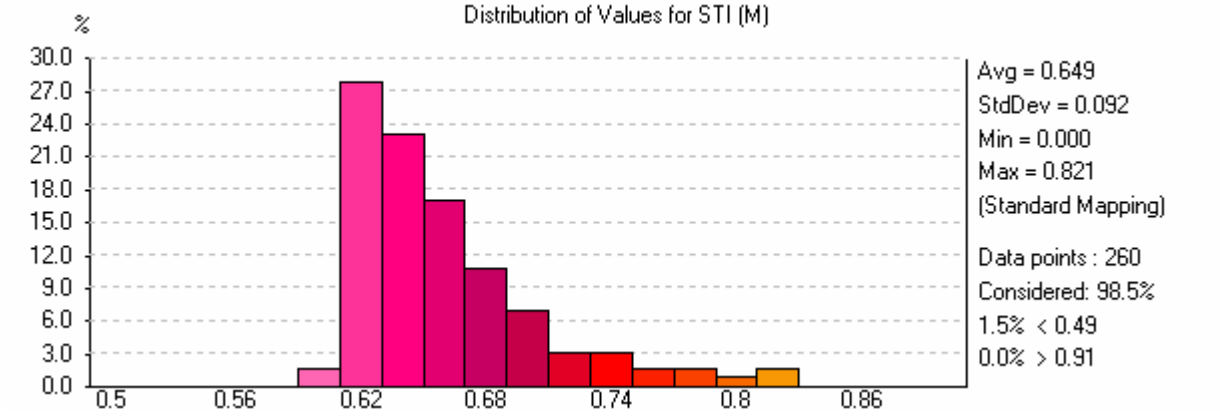


Figure 2: At 100% occupancy 0% of the congregation area falls within the target values for traditional worship resulting in an average STI value of 0.65. This falls well above the allowable maximum range for a traditional worship space.



V. Recommended Modifications

Nave Floor: All existing carpet should be removed. Hard reflective flooring finish should be installed in its place under pews and in central aisle. In the rear and side aisles install 1/8" low pile level loop carpet directly adhered to the sub floor with no pad. Slate to remain in the chancel and chancel apron.

Nave Seating: Existing fully padded pews to be removed. Install new pews or seats with padded seats only and hard backrests.

Nave Soffit Walls: Reinforce existing paneling with an additional layer of plywood or gypsum board, glued and screwed/ nailed together and to the structure, staggering the seams. Install sound diffusing features. (See detail sheet AC-08)

Nave Side Wall Diffusion: Install sound diffusing features on the side walls below the soffits. See drawings for details.

Nave Walls Absorption: Install 280 sq. ft. of 1" absorptive panels in corners of nave. See drawing for location details.

Balcony Walls: Angle balcony side walls 5° off of the vertical axis. Walls should be 3 layers of Gypsum wall board, glued and screwed together and to the structure, staggering the seams. Insulate the cavity with 3" of mineral wool. See drawings for details.

Balcony Front (Railing): Replace solid front balcony with acoustically transparent spindle railing with 50% opening or greater.

Chapel Floor: Remove existing carpet in chapel. Replace with 1/8" low pile level loop carpet directly adhered to the subfloor with no pad.

Chapel Walls: Install 70 sq. ft. of 1" absorptive panels on upper chapel demising wall adjacent to worship space. See drawings for location details.

Ceiling: As existing.

Occupancy Conditions	**Reverberation Time (Seconds)**				
Frequency (pitch) →	125Hz (C3)	250Hz (C4)	500Hz (C5)	**1000Hz (C6)**	2000Hz (C7)
	"Bass"	*Middle C*	*Alto-Soprano Range*		*Consonants*
Unoccupied	2.16*	1.95	1.92	**1.88**	1.83
50 % Occupied	1.94*	1.76	1.68	**1.65**	1.60
Fully Occupied	1.76*	1.60	1.50	**1.47**	1.41

Single Number Reverb Time Rating:
Unoccupied **1.90** Seconds
50% Occupied**: 1.67** Seconds
Fully Occupied**: 1.49** Seconds

* Note: actual RT times in this frequency range may vary due to limitations of low frequency calculations in prediction software.

Please see Appendix B-C for full RT curve and sound transmission index results

Reverberation Period has been increased across the spectrum and will support both speech and music. Speech intelligibility has been maintained without largely reducing the overall value of the space by removing sound absorbing surfaces near to worshipers. Sound diffusing elements have been implemented to protect from potential existing acoustic defects from monolithic opposing wall surfaces. Note that the reverberation period with these recommendations has been increased to a point that when fully occupied is better than the current existing space completely unoccupied. A substantial improvement.

Appendix B: *(Reverberation Graphs):*

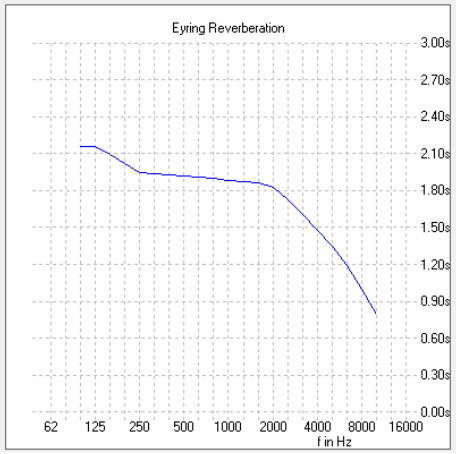
Pews Unoccupied

Project
Hall : St. Peter Luitheran Town : Hemlock, MI
Version : Proposed conditions RT desired : 2 s

Geometry
Room Surface : 2567.13 m²
Volume : 3413.54 m³

Absorption
Avg. Abs. Area : 275.52 m²
Avg. Abs. Coeff. : 0.11

Mean Free Path
Length : 5.32 m
Time : 0.02 s



Band	RTime [s]
100 Hz	2.16
125 Hz	2.16
160 Hz	2.09
200 Hz	2.02
250 Hz	1.95
315 Hz	1.94
400 Hz	1.93
500 Hz	1.92
630 Hz	1.91
800 Hz	1.9
1000 Hz	1.88
1250 Hz	1.88
1600 Hz	1.86
2000 Hz	1.83
2500 Hz	1.73
3150 Hz	1.61
4000 Hz	1.47
5000 Hz	1.35
6300 Hz	1.19
8000 Hz	1
10000 Hz	0.79

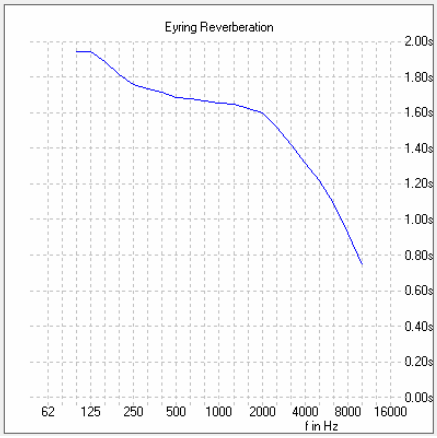
Pews 50% Occupied

Project
Hall : St. Peter Luitheran Town : Hemlock, MI
Version : Proposed conditions RT desired : 2 s

Geometry
Room Surface : 2567.13 m²
Volume : 3413.54 m³

Absorption
Avg. Abs. Area : 312.1 m²
Avg. Abs. Coeff. : 0.12

Mean Free Path
Length : 5.32 m
Time : 0.02 s



Band	RTime [s]
100 Hz	1.94
125 Hz	1.94
160 Hz	1.89
200 Hz	1.82
250 Hz	1.76
315 Hz	1.73
400 Hz	1.71
500 Hz	1.68
630 Hz	1.68
800 Hz	1.66
1000 Hz	1.65
1250 Hz	1.64
1600 Hz	1.62
2000 Hz	1.6
2500 Hz	1.52
3150 Hz	1.42
4000 Hz	1.31
5000 Hz	1.22
6300 Hz	1.09
8000 Hz	0.93
10000 Hz	0.75

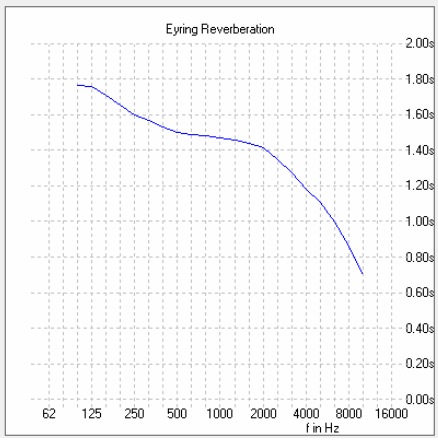
Pews 100% Occupied

Project
Hall : St. Peter Luitheran Town : Hemlock, MI
Version : Proposed conditions RT desired : 2 s

Geometry
Room Surface : 2567.13 m²
Volume : 3413.54 m³

Absorption
Avg. Abs. Area : 348.67 m²
Avg. Abs. Coeff. : 0.14

Mean Free Path
Length : 5.32 m
Time : 0.02 s



Band	RTime [s]
100 Hz	1.76
125 Hz	1.76
160 Hz	1.71
200 Hz	1.65
250 Hz	1.6
315 Hz	1.57
400 Hz	1.53
500 Hz	1.5
630 Hz	1.49
800 Hz	1.48
1000 Hz	1.47
1250 Hz	1.46
1600 Hz	1.44
2000 Hz	1.41
2500 Hz	1.35
3150 Hz	1.27
4000 Hz	1.18
5000 Hz	1.11
6300 Hz	1
8000 Hz	0.86
10000 Hz	0.7

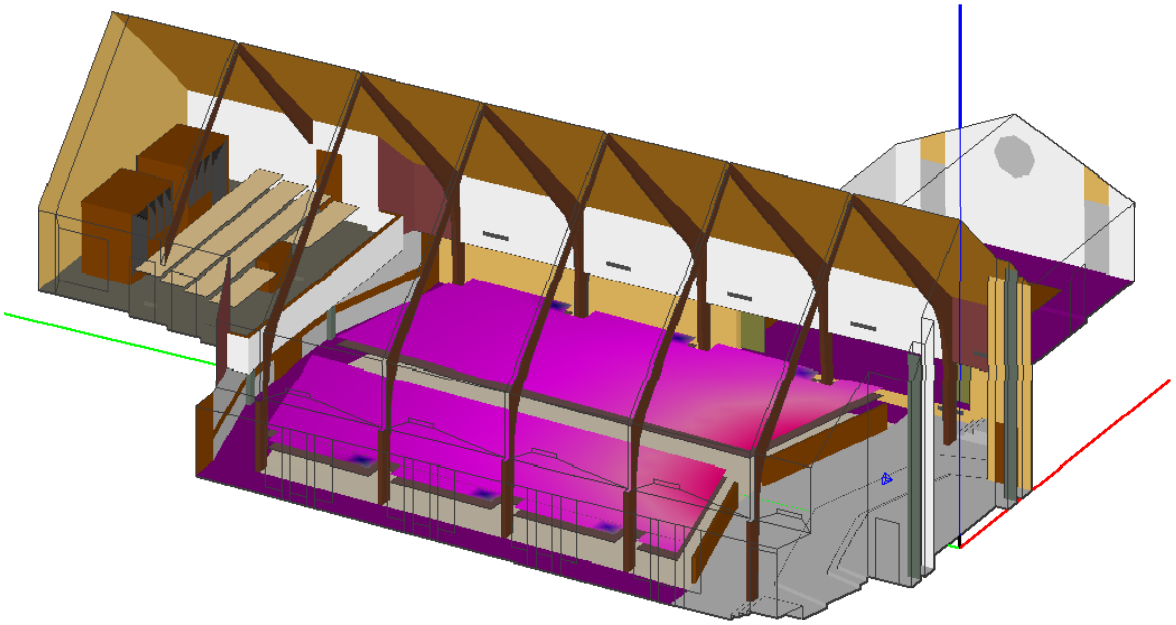
Appendix C: *(Speech Transmission Index (STI)):*

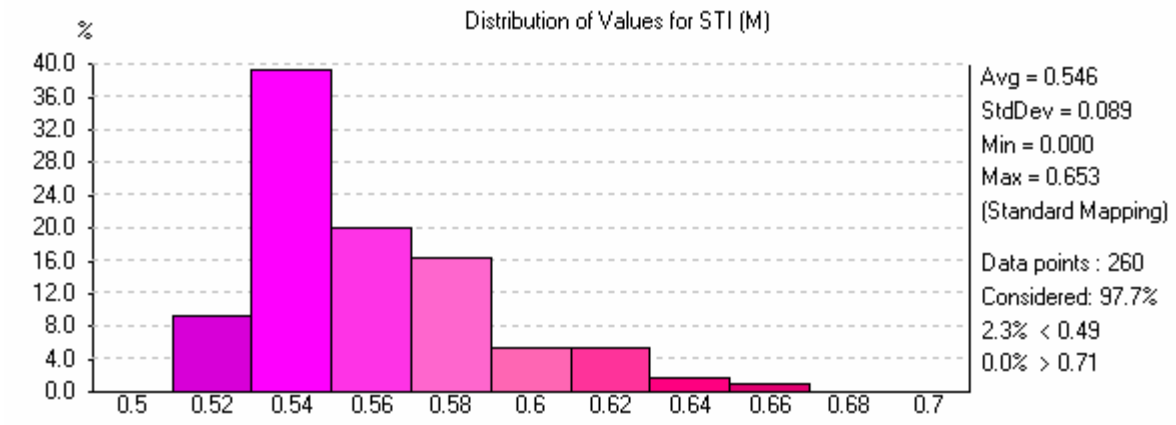
Target Average Values Goal is between 0.52-0.56 for traditional worship.

Figure 1: At 50% occupancy 48% of the congregation area falls within the target values with another 35% lying just on the high side of the recommended values resulting in an average STI value of 0.55 which is a well balanced value recommended for a traditional worship style.

Fig. 1

Band	STI Range	Examples of typical uses
A+, A	>0.76	Recording Studios
B	0.68-0.76	Theatres, speech auditoria, parliaments, courts
C	0.64-0.68	Teleconference, theatres
D	0.60-0.64	Class rooms, concert halls, multipurpose auditoria
E	0.56-0.60	Contemporary worship spaces, concert halls
F	**0.52-0.56**	**Traditional worship spaces**
G	0.48-0.52	PA in shopping malls, public offices
H	0.44-0.48	PA in difficult acoustic environments
I, J, U	<0.40	Not suitable for PA systems





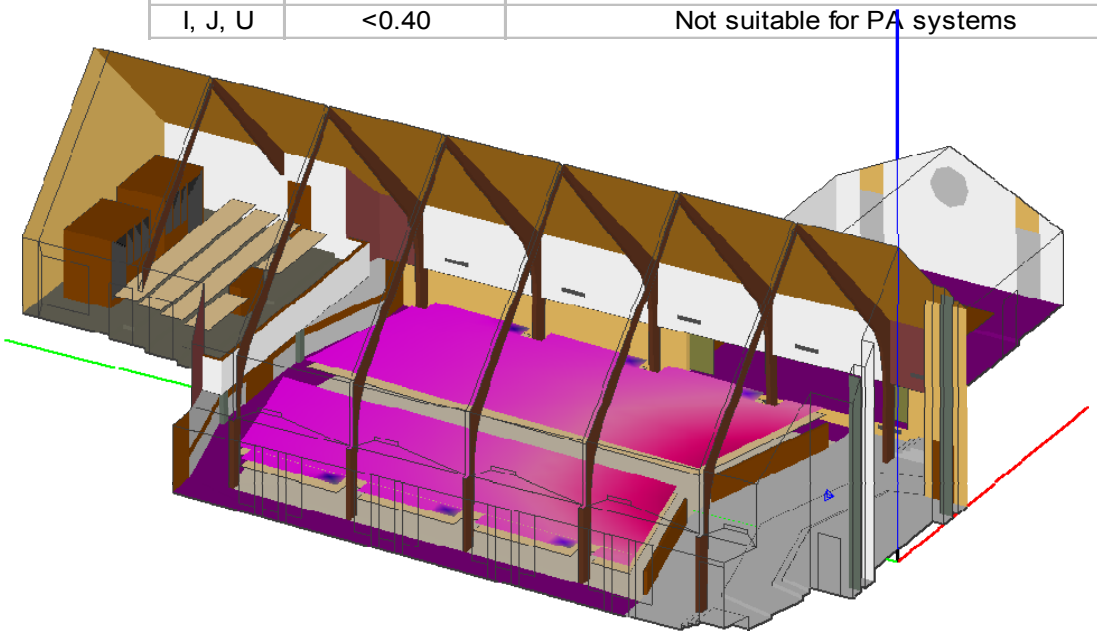
Appendix C:*(cont'd) (Speech Transmission Index (STI)):*

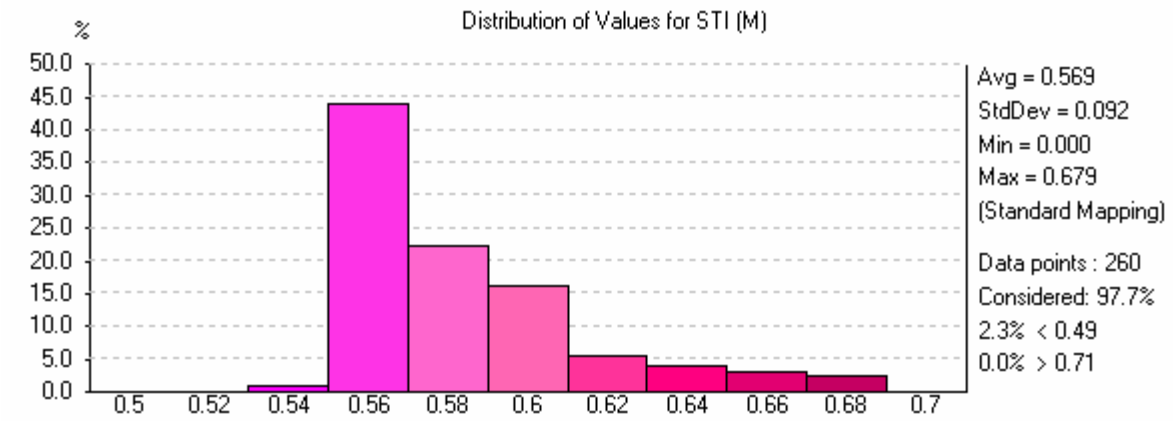
Target Average Values Goal is between 0.52-0.56 for traditional worship.

Figure 2: At 100% occupancy 46% of the congregation area falls within the target values with another 35% lying just on the high side of the recommended values resulting in an average STI of 0.57. Note that recommended modifications have positively impacted the space, as this average STI value is just on the high side of purely traditional worship space. The limiting factor here is the nearness of the seating to the chancel

Fig. 2

Band	STI Range	Examples of typical uses
A+, A	>0.76	Recording Studios
B	0.68-0.76	Theatres, speech auditoria, parliaments, courts
C	0.64-0.68	Teleconference, theatres
D	0.60-0.64	Class rooms, concert halls, multipurpose auditoria
E	0.56-0.60	Contemporary worship spaces, concert halls
F	**0.52-0.56**	**Traditional worship spaces**
G	0.48-0.52	PA in shopping malls, public offices
H	0.44-0.48	PA in difficult acoustic environments
I, J, U	<0.40	Not suitable for PA systems





VI. Re-Design & Material Recommendations

1. **Flooring**: Floor materials in the worship space should be majority hard surface and sound reflective; especially chancel platform, apron, choir balcony area, and under congregation seating. Stained concrete, or various porcelain, ceramic, slate, stone, and other tile or wood options are acceptable and many are available with skid resistant, textured, or non slip coatings. Existing carpet should be removed and a *1/8" low pile level loop carpet* is acceptable to be reinstalled in nave side and rear aisles and chapel. See drawings for details.
2. **Seating:** Existing fully upholstered pew seating should be replaced with pews/chairs with padded seats only and hard backrests
3. **Walls:** Any **NEW** interior wall surfaces should be primarily hard, dense, and sound reflective to generate the musical support and a desirable "warm" reflective support. Non-porous Masonry, Reinforced Gypsum Wall Board, Plaster, Wood Paneling, or equivalents can be used. (Any wood paneling or trim must be reinforced/strengthened in order to provide low frequency/bass reinforcement, reverberation, and balance.) Layers must be glued & screwed to form one composite panel. Materials options include:
    a. Two layers staggered seams, min 5/8" gypsum board total 1-1/4" thickness, glued and screwed/nailed together and to studs/joists/bracing 16" o.c. max) AND/OR
        i. **Note: (Min 3 layers 5/8" gypsum wall board in balcony)**
    b. Min. 1-1/2" wood paneling assembly (layered plywood or plywood and MDF Board) on studs/joists/bracing 16" o.c. AND/OR
    c. Non-porous or painted/sealed masonry veneer AND/OR
    d. Equivalents can be evaluated upon request

Note regarding glued layers: the glue is necessary to form one heavy, composite, reflective surface, rather than two thinner resonating surfaces. The drywall contractor will need special instruction regarding this issue. Glue must be standard construction adhesive applied in continuous beads in a zig zag pattern across the panel and perimeter with 4"-6"max. between beads, or a thin, even layer to entire gypsum wallboard surface. Do not use resilient compound products in this application. All layers should be rotated and offset.

1) **Balcony Side Walls:** Angle balcony walls to 5° in the vertical axis to eliminate parallel reflecting surfaces. Walls should be constructed of 3 layers of gypsum wall board, glued and screwed together, staggering seams. Or a similarly dense finish surface. See drawings for details.
2) **Nave Soffit Walls**: Reinforce existing paneling with an additional layer of plywood or gypsum board, glued and screwed/ nailed together and to the structure, staggering the seams. Fill in the vertical reveals with heavy insulation, wood or blocking. See drawings for details.

4. **Wall Absorption Treatment Options:**

Sound absorbing panels must be added to the upper side walls of the nave and on the chapel side of the demising wall to balance the removal of the some of the carpet and to

even the tone and 'fine tune' the reverberation period of the space. Note the information below regarding treatment material options and sources.

1) **Nave Wall Absorption:** Install 280 sq. ft. of 1" thick sound absorbing material to the back bay of the nave soffits, on the gypsum board walls that wrap around to the balcony, and on the soffit of the bay closest to the chancel. See drawings for location and details.

2) **Chapel Wall Absorption:** Install 70 sq. ft. of 1" thick sound absorbing material to the chapel side of the demising wall between the nave and chapel. See drawing for location and details.

1" Fabric Wrapped Wall Panels:

a. ***Respond A Series***, economical, all-purpose acoustical wall panel available from CONWED Designscape, Granville, OH, russell.leighton@owenscorning.com. Phone (800) 932-2383, fax (740) 312-7009, http://conweddesignscape.com/products/wall-panels/, OR,

b. ***FabricMate*** inexpensive, Site-Fabricated Acoustical Wall system.Suitable for flat or curved walls and/or custom shapes available from Fabricmate Systems Inc. Ventura, CA 93003, Phone: 866.622.2996, www.fabricmate.com, OR,

c. ***Acousti-Panels AP*** fabric wrapped fiberglass wall panels with hardened edge available from Golterman & Sabo, St. Louis, MO, 800.737.0307, https://www.gsacoustics.com/acoustical-panel.aspx, OR,

d. ***MPC Inc. Silent Wall® SW100***, metal frame, cloth covered fiberglass panel, manufactured by MPC Inc, Westlake, OH, Tel. 440-835-1450, www.mpcsilentwall.com , sales@mpcsilentwall.com, OR,

e. ***Hardside Panels,*** fabric wrapped panel with chemically hardened edges Kinetics Noise Control, 6300 Irelan Place Dublin, OH 43017, 1.614.889.0480, http://www.kineticsnoise.com/interiors/hardsidepanel.html, OR,

f. ***Acoustical Panel AP*** general purpose sound absorbing panel with fabric or vinyl finish available from Decoustics Limited, 61 Royal Group Crescent, Woodbridge, ON, L4H 1X9, Canada. Phone: 1-800-387-3809, fax: 905-652-2505 https://decoustics.com/products/fabric/, OR,

g. ***Whisper Walls®*** Decorative stretched fabric acoustic panels., Aurora, Colorado 80014 , Toll-free: 800-527-7817, Fax: 303-671-0606, www.WhisperWalls.com, OR,

h. ***Fabritec*** cloth covered sound absorptive wall panels available from Pinta Acoustic, Inc. Minneapolis, MN 55430 USA Toll-Free: (800) 662-0032, http://www.pinta-acoustic.com/en/home/products/acoustic-wall-panels.html, OR,

i. ***Sound Quality, S-2000***, fabric wrapped acoustical wall panels available from Sound Seal Architectural Products, Agawam, MA 01001, Tel: 413.789.1770, http://www.soundseal.com/soundquality/s2000.shtml, OR,

j. ***Applique Wall Panels,*** Kinetics Noise Control, 6300 Irelan Place Dublin, OH 43017, 1.614.889.0480, https://kineticsnoise.com/interiors/appliquepanels.html , toneill@noiseproblems.com, OR,

k. ***Sonora™ Panels*** by Acoustics First Corporation, Richmond, VA 23230, Tel: 804-342-2900 Fax: 804-342-1107, info@acousticsfirst.com, http://www.acousticsfirst.com/sonora-wall-panels.htm, OR,

l. ***"PS-80AL***" Acoustical Panel, manufactured by PSI (Panel Solutions, Inc.) P.O. Box 11, 100 East Diamond Avenue, Hazleton, PA 18201, (570) 459-3490, http://www.panelsolutions.com/ps80al.htm, OR,

m. ***1" Classic*** Fabric Wall and Ceiling Systems suitable for curved walls from NovaWall® Alexandria, VA 22304 , Phone: 800-695-6682 , www.novawall.com, OR,

n. ***Architectural Solutions™ Type 600, 700, or 800*** 2" Fabric wrapped sound absorption panels from Certainteed Corporation, Valley Forge, PA 19482, Tel: 800-233-8990, Fax: 610-341-7571, www.certainteed.com, OR,

o. Equivalents can be provided/evaluated upon request

Wood Faced Options:

May Require Sound Absorptive Core Material

a. ***Pinecrest Solid Wood Grilles***, beautiful, detailed wood grille panels, available from Pinecrest, St. Paul, MN 55127, Phone: 800-443-5357, http://www.pinecrestinc.com/grillesnew.php

b. ***Alto Acoustical Wood Planking System*** tongue and groove installation over fiberglass core with a variety of hardwood finishes available from Kinetics Noise Control, 6300 Irelan Place Dublin, OH 43017, 1.614.889.0480, https://kineticsnoise.com/interiors/alto.html

c. ***Series 1000s Wood Grille***, Wood dowel and grille system from 9Wood, Springfield, OR., PHONE: 888.767.9990, FAX: 541.988.9998, https://www.9wood.com/series/index/1000 ccoury@9wood.com, OR,

d. ***Topakustik® or Topperfo®*** wood faced perforated panels available from RPG Inc., 651-C commerce Drive, Upper Marlboro, MD 20774, 301-249-0044, http://www.topakustikusa.com/products/topperfo/ OR,

e. ***Wood Trends*** genuine wood ceiling plank treatment available from Sound Seal, Agawam, MA 01001 , Phone: 1-413-789-1770 https://www.woodtrends.com/index.html

f. ***Aluratone®*** or ***Panel Grilles*** acoustical wood ceiling and wall systems available from Rulon Company, St Augustine, FL 32092, phone: 800.227.8566, https://rulonco.com/products/

g. ***Perforated Wood Ceiling*** systems available from Ceilings Plus, Los Angeles, CA 90040, Phone: 323-724-8166, http://www.ceilingsplus.com/products/flutes/perfWood.htm

h. ***Madero*** natural wood veneered acoustical finishes available from Decoustics Limited, 61 Royal Group Crescent, Woodbridge, ON, L4H 1X9, Canada. Phone: 1-800-387-3809, fax: 416-675-5546 www.decoustics.com

i. ***Metro Wood Panels***, durable, acoustically absorbent panel with a faux wood finish, manufactured by Wall Technology, Inc. Granville, OH. 43023, Tel. 800.932.2383. http://www.walltechnology.com/products/ OR

j. ***New World™ Perforated Panels*** Real wood veneer panels with balancing veneer back. Standard product available with class A fire retardant core, lays into standard 15/16" or 9/16" T bar ceiling grid. Standard wood species are: red oak, maple, ash or cherry. Available from Architectural Surfaces, Inc. Chaska, MN 55318, Toll Free: 1.800.221.5496 http://www.architecturalsurfaces.net/new-world/

k. ***Woodgrille™*** Modular 2' wide panels lay into standard T-bar suspension systems. System provides 100% upward accessibility. Rail spacing available for 9/16" or 15/16" grid suspension systems. Available from Architectural Surfaces, Inc. Chaska, MN 55318, Toll Free: 1.800.221.5496 http://www.architecturalsurfaces.net/woodgrille/

l. Equivalents can be provided/evaluated upon request

5. **<u>Diffusion Options - Nave side walls and side soffits</u>**

Sound diffusing treatments must be added to the nave side walls both on the soffits and on the brick side walls under the soffits to maintain the correct reverberation period in the space, and to suppress echo type reflections that have the possibility to manifest from additional sound sources (congregation projection) and to allow sound energy to distribute evenly throughout the space.

a) **Nave Side Wall Diffusion:** Install sound diffusing elements or surface articulation along flat monolithic long axis side wall surfaces of the soffits and on the brick wall under the soffits. *See drawings for treatment application locations and sample profiles.* Note the information below regarding treatment material options and sources.

Finish materials should be mostly hard, dense, and sound reflective and provide a distinct alternating non regular pattern of surface articulation with multiple depth changes. These forms should cover a substantial area of otherwise flat monolithic surfaces. The surface articulation should comprise of a composite pattern of cavity depths with a minimum depth of 4" between form levels and a minimum of 3 different depths to be incorporated into a composite pattern. Any hollow cavities created must be filled with mineral wool insulation. Surface profile configuration should be minimally flat, with as small a parallel area as possible facing the opposing wall surface. See drawings for samples. Specific additional designs can be developed upon request.

Above: Samples of sound diffusing feature designs: A: Geometric, B: Screen, C: Rail & Stile, D: Composite Pattern.

Alternatively, there are a few commercially available geometric sound diffusers.

Diffusion Options

a. ***Space Array*** modular 2-dimensional diffuser available from Kinetics Noise Control, 6300 Irelan Place Dublin, OH 43017, 1.800.959.1229, http://www.kineticsnoise.com, OR,

b. ***Geometric Diffusers*** thermo-molder co-polymer radius and pyramid diffusers available from Kinetics Noise Control, 6300 Irelan Place Dublin, OH 43017, 1.800.959.1229, http://www.kineticsnoise.com/interiors/geometric.html, OR,

c. **Golden Pyramid Diffuser,** available from RPG Inc., 651-C commerce Drive, Upper Marlboro, MD 20774, 301-249-0044, https://rpgacoustic.com/pyramid-golden/ OR,

d. "**Modffusor**" available from RPG Diffusor Systems, Inc. 651-C Commerce Drive, Upper Marlboro, MD 20774, Tel: 301-249-0044, www.rpginc.com. OR,

e. **Omniffusor**, available from RPG Inc., 651-C commerce Drive, Upper Marlboro, MD 20774, 301-249-0044, www.rpginc.com, OR,

f. ***Curvalon®*** Custom Curved Wood Veneered Panels available from Rulon Company, St Augustine, FL 32092, phone: 800.227.8566 http://www.rulonco.com/product-curvalon.php, OR,

g. ***Respond Diffusers*** Barrel and pyramidal diffusers scatter and blend sounds for a broad range of frequencies and improve the quality of music environments. Available from CONWED Designscape, Ladysmith, WI, russell.leighton@owenscorning.com. Phone (800) 932-2383, fax (800) 833-4798, http://conweddesignscape.com/products/wall-panels/, OR,

h. Equivalents can be provided/evaluated upon request

VII. HVAC & Mechanical System Noise

The Heating Ventilation and Air Conditioning systems serving the worship space should be designed/treated to suppress noise and must conform to **Noise Criteria rating (NC) 20-25**. Current HVAC Noise Levels are **NC 34.9** within the main worship space. This is approximately 9.9 dB louder than the maximum desired. (See the attached Noise Test Results sheet). Due to the logarithmic nature of sound measurements, an increase of 3 decibels in measured sound will result in a noticeable increase of the perceived loudness of a sound, and an increase of 10 decibels will be perceived as doubly as loud. This 9.9 dB excess translates to noise levels just over twice as loud as desired and will mask speech clarity and musical definition causing the congregation to struggle to perceive both accurately. The noticeable cause of this excess is the HVAC system, likely from a combination of the various machine noise elements, air velocity and restricted supply grilles in the space (broadband Hz). Existing HVAC and fans contributed to the noise in the space especially between the frequencies of 63Hz to 1kHz.

The NC rating of specific HVAC systems is a function of the cumulative effect and relationship of all system components and elements.

Common sources of complaints due to unwanted mechanical system noise include:

- Duct-borne Fan Noise from Air Handling Units
- Structure Borne Vibration From Air Handling Units

- Air Turbulence noise due to small duct sizes & high air velocity
- Hissing or Whistling from restrictive air diffusers (do not balance airflow at diffuser) or VAV units
- Tones or droning noise from A/C compressors
- Radiators or metal air diffusers that click/pop as they expand and contract with the heating cycle
- Noise from toilet pipe/plumbing in adjacent spaces

Note typical and general methods of achieving a successful NC rating may include, but are not limited to the following:

1. **Use min. two 90° lined turns in any ducts between HVAC equipment and the receiving room.**
2. **Maintain low air flow/fan speeds (less than 800ft/min)**
3. Maintain large (oversized) duct dimensions
4. **Provide air delivery vents/grilles with minimal vibration and obstruction: solid construction, felted/resilient edging & gaskets, wide openings, small veins. All Grilles and diffusers (air devices) should be selected to have a catalog Noise Criteria (NC) Rating of NC 18 or less for a single diffuser.**
5. Use centrifugal fans with airfoil-shaped blades; avoid centrifugal fans with forward curved blades.
6. Variable Air Volume Boxes (VAV) and fan-powered boxes should not be located over or adjacent to worship space. These units must be placed near a non-critical listening space, such as a hallway or storage area.
7. No restroom plumbing runs should couple to worship space wall Gyp. Bd. or Studs. Isolate any water piping from the building walls and structure using foam rubber wrapping or resilient clamps and hangers.
8. **Do not place HVAC air handling units or chillers on Rooftop above or adjacent to worship space. Place any exterior equipment at least 30ft from any worship space windows.**
9. Mount all compressors, air handling units and other HVAC equipment on spring isolators, to prevent structure-borne noise transmission. Acceptable materials include:
   - ***Floor-Mounted Vibration Isolation Spring Isolators and Neoprene/Fiberglass Isolators*** from Kinetics Noise Control, 6300 Irelan Place Dublin, OH 43017, 1.800.959.1229, http://www.kineticsnoise.com/hvac/floor.html
   - ***Model KIP Fiberglass Isolators*** from Kinetics Noise Control, 6300 Irelan Place Dublin, OH 43017, 1.800.959.1229, http://www.kineticsnoise.com/hvac/kip.html
   - Or Equivalents.
10. Consider Installing HVAC Silencers/Attenuators: *http://www.vibro-acoustics.com/HVACNoiseControl/HVACNoiseControl.htm*
    - ***Film Lined Silencers*** that limit glass fiber erosion and moisture/dirt penetration by Vibro-Acoustics. Toronto, Ontario M1X 1A2, Phone: (416) 291-7371, Email: info@vibro-acoustics.com , Website: www.vibro-acoustics.com

- ***Quiet Duct ™ HVAC Silencers*** available from IAC America, Bronx, New York 10462-5599, Tel: 718-931-8000, www.industrialacoustics.com
- ***Sound Attenuators*** and ***Industrial Silencers*** for HVAC Noise Control available from Metal Form Manufacturing Inc. Phoenix, Az 85043 Tel: 602.233.1211 http://www.mfmca.com/sound_attenuators.html
- Or Equivalents.

11. Consider installing 1" sound absorptive, internal liners on all supply and return ductwork: Typical materials include:
    - ***Permacote Linacoustic R-300*** Rigid Fiber Glass Plenum Liner Board by Johns Manville Insulation Systems, Denver, CO 50217, Tel: 800-654-3103, pic@jm.com, www.jmairhandling.com
    - ***"ToughGard" # 30-33-003***, or "ToughGard R" #30-33-002 Duct Liner, available from CertainTeed Corp., Valley Forge, PA 19482, 1-800-233-8990, www.certainteed.com. Or equivalents.
    - ***QuietR® AcoustiTEX™*** Duct Liner from Owens Corning Insulating systems, LLC - Toledo, Ohio, USA 43659 1-800-GET-PINK , www.owenscorning.com

IX. Sound System

As a general note, modern worship space sound systems should be adaptable to a set variety of uses, with a mobile control unit using preset scenes based on the worship style and activity, and an equipment rack outside of the main worship space in order to be more accessible to a wide variety of staff and/or volunteer operators.

Please note that with a change in the reverberation period of the room, any existing sound system equipment will need to be re-tuned to work with the improved characteristics of the room. Sound or video system design is not included within this Acoustic Consultation contract agreement. We can provide EASE models and other acoustic calculation data to your chosen A/V vendor or design consultant, without charge, if desired. Contact local A/V provider for sound system adjustments to accommodate the revised room acoustic setting. If assistance is required for satisfactory performance, please contact us.

Acoustical Review and Report
For the Existing Worship Space

St. Peter Lutheran Hemlock, MI
Acoustical Report Summary Checklist – February 24, 2021

The following checklist/review is intended to facilitate a thorough execution of our acoustical recommendations. Detailed measures for achieving each of the following points are provided in the full February 24, 2021 Acoustical Report. Please note that while individual items are listed below, this report is to serve as an entire holistic design for the acoustical improvement of the space. In order for the goals outlined in the report to be achieved, **ALL** items addressed in the report must be accomplished.

- Nave Floor: All existing carpet should be removed. Hard reflective flooring finish should be installed in its place. In the rear and side aisles install 1/8" low pile level loop carpet directly adhered to the subfloor with no pad. Slate to remain in the chancel and chancel apron.
- Nave Seating: New pews or seats with padded seats only and hard backrests.
- Nave Soffit Walls: Reinforce existing paneling with an additional layer of plywood or gypsum board, glued and screwed/ nailed together and to the structure, staggering the seams. Install sound diffusing features.
- Nave Side Wall Diffusion: Install sound diffusing features on the side walls below the soffits. See drawings for details.
- Nave Walls Absorption: Install 280 sq. ft. of 1" absorptive panels in corners of nave. See drawing for location details.
- Balcony Walls: Angle balcony side walls 5° in the vertical axis. Walls should be 3 layers of Gypsum wall board, glued and screwed together and to the structure, staggering the seams. Insulate the cavity with 3" of mineral wool. See drawings for details.
- Balcony Front (Railing): Replace solid front balcony with acoustically transparent spindle railing with 50% opening or greater.
- Chapel Floor: Remove existing carpet in chapel. Replace with 1/8" low pile level loop carpet directly adhered to the sub floor with no pad.
- Chapel Walls: Install 70 sq. ft. of 1" absorptive panels on upper chapel demising wall adjacent to worship space. See drawings for location details.
- Ceiling: As existing.
- Adopt measure to prevent unwanted noise from HVAC and other mechanical systems
- Adopt Pipe Organ site preparations and follow recommendations of chosen organ builder.
- Sound control unit should be mobile with equipment rack outside of main worship space for operator ease.
- Existing audio system should be re-tuned per the recommendations of chosen A/V system designer/provider.

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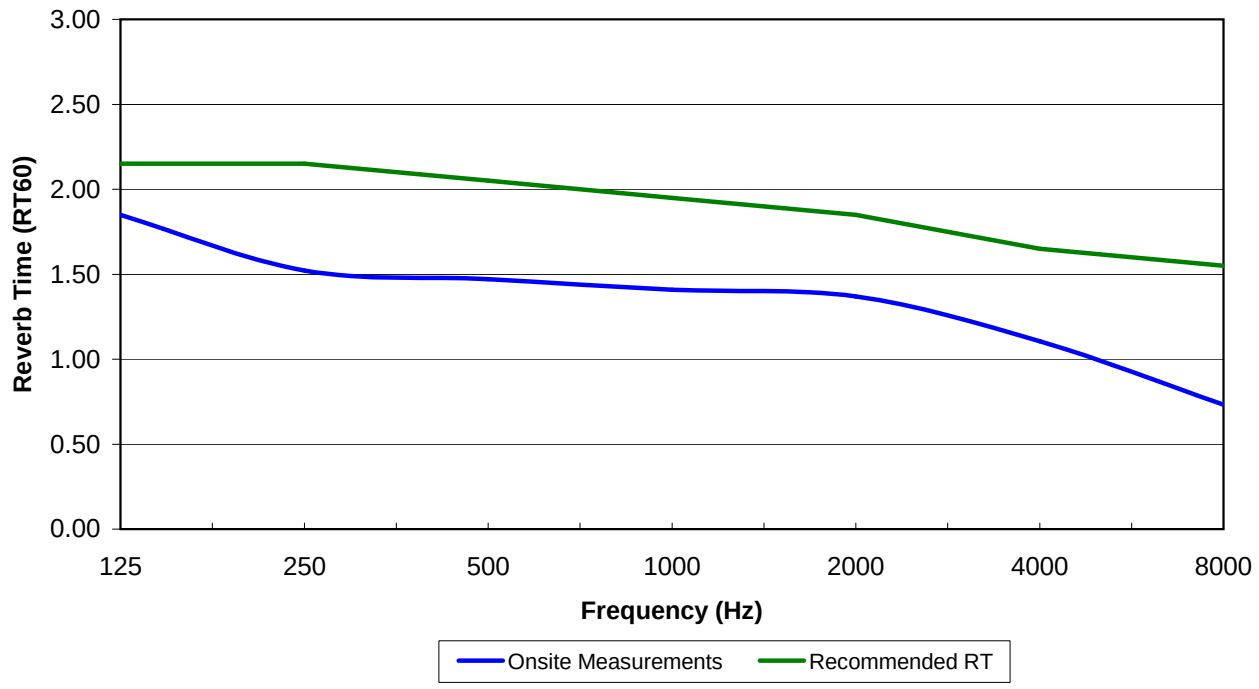
hear the difference.

Reverberation Time Measurement

reference: ISO 3382:1997(E)

Hall:	St. Peter's Lutheran - Hemlock, MI	Walls:	Gyspum/ wood paneling
Test Date:	November 20, 2020	Ceiling:	Wood ceiling deck
Engineer:	Craig Schaefer	Floor:	Stone and some carpet
Rm. Volume:	108,273 Ft^3	Seating:	Pews, padded seats and backrests
Tested Occupancy:	Fully Unoccupied		

Plotted Data:



Single Number Rating	
Reverberation Time $T_{30,mid}$ =	1.4 seconds
Recommended RT=	2.0 seconds

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Reverberation Time Measurement

reference: ISO 3382:1997(E)

Hall:	St. Peter's Lutheran, Hemlock, MI	Sound Signal:	Pink Noise Decay
Test Date:	November 20, 2020	Sound Source:	Riedel Sound System
Engineer:	Craig Schaefer	Source Position:	Mounted in Chancel
		Microphone Height:	4 ft. (Approx.)

Onsite Measurements

T30 (Reverberation Time)

	Pos. R01	Pos. R02	Pos. R03	Pos. R05	Pos. R08	*S.D. σ =*	Average	*Recommended RT*
125	1.92	1.97	1.79	1.72	1.87	*0.10*	1.85	125 2.15
250	1.52	1.52	1.57	1.49	1.52	*0.03*	1.52	250 2.15
500	1.53	1.47	1.48	1.45	1.44	*0.04*	1.47	500 2.05
1000	1.40	1.44	1.43	1.40	1.38	*0.03*	1.41	1000 1.95
2000	1.38	1.38	1.39	1.38	1.33	*0.02*	1.37	2000 1.85
4000	1.11	1.12	1.14	1.11	1.06	*0.03*	1.11	4000 1.65
8000	0.71	0.76	0.77	0.73	0.70	*0.03*	0.73	8000 1.55

EDT (Early Decay Time)

							Average
125	1.49	1.64	1.70	1.87	1.65	*0.13*	1.67
250	1.52	1.49	1.40	1.36	1.93	*0.23*	1.54
500	1.59	1.62	1.60	1.62	1.62	*0.01*	1.61
1000	1.42	1.58	1.52	1.60	1.44	*0.08*	1.51
2000	1.64	1.58	1.69	1.59	1.45	*0.09*	1.59
4000	1.21	1.31	1.37	1.10	0.99	*0.15*	1.19
8000	1.12	0.95	1.37	0.65	0.56	*0.34*	0.93

STI (Speech Transmission Index

					Average	*Recommended STI*
0.63	0.58	0.61	0.57	0.57	0.59	0.52-0.56

C_{50} (Definition / Speech)

				Average	*Recommended* C_{50}
3.90	1.00	3.10	0.30	0.90	1.84	≥ -2 dB

C_{80} (Clarity / Music)

				Average	*Recommended* C_{80}
5.60	2.50	5.00	2.60	3.50	3.84	≥ -5 dB

** signifies a decoupled space*

Bass Ratio (Warmth)

Reference: Leo Beranek, 1996

$BR_{existing}$= 1.0

Recommended Bass Ratio:

Traditional: *1.1 to 1.3 For Traditional Liturgy, Choir, Organ, and Classical Instruments*

Contemporary: *.9 to 1.0 For Drums, Bass Guitar, Keyboards, etc.*

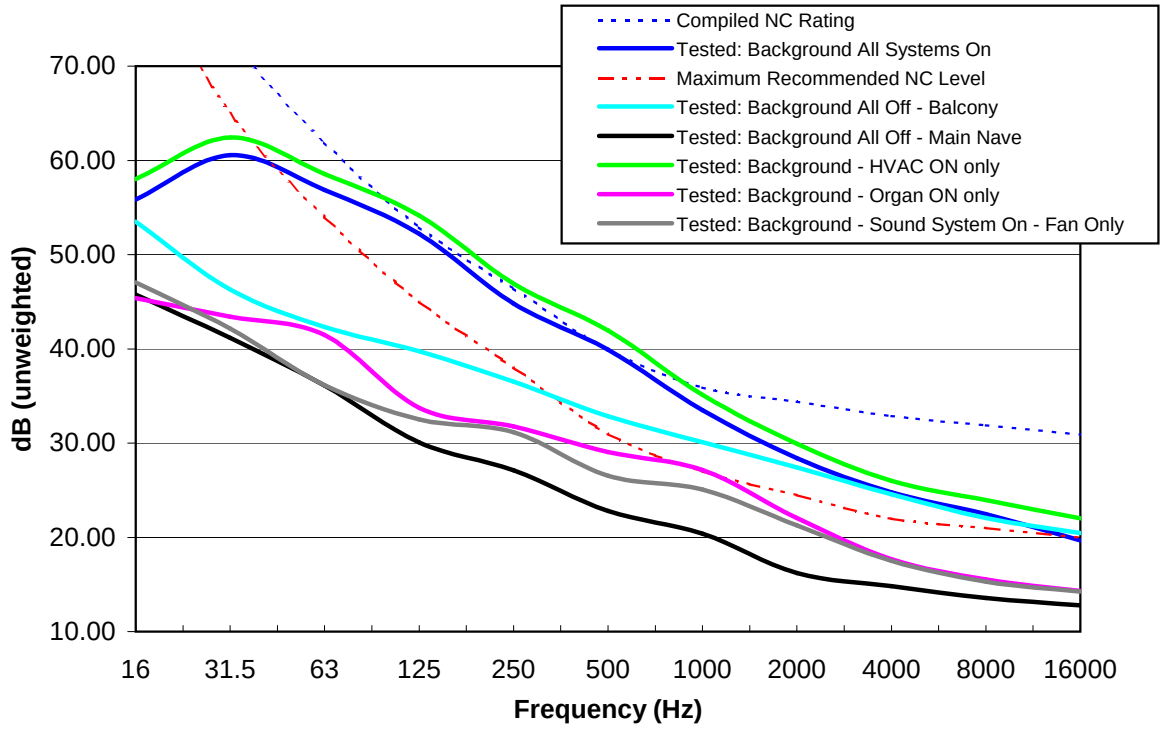
Measurement Apparatus

Testing & Analysis Software:	EASERA (TDS) Version 1.1.3 by Software Design Ahnert GmbH Germany
Microphones:	Brüel & Kjær Type 4003 Omni directional Microphones (Consecutive Pair)
	Brüel & Kjær Type 2812 Two Channel Microphone Power Supply
Audio Interface:	Focusrite Scarlett 2i2 interface to EASERA. Sound source Pink Noise

Noise Test Results and NC Rating

St Peter's Lutheran, Hemlock, MI		Building:	Main Worship Space
Test Date:	November 20, 2020	Reverb Time:	1.4 sec
Rm. Volume:	108,273 Ft^3	Engineer:	Craig Schaefer
Rm. Notes:	HVAC is the most notable source of noise in the space. Appears to be a combination of machine and air turbulance.		

Plotted Data:



Compiled NC Rating

NC 34.9

Perceived Loudness

Δ Level(dB)	Reaction
1	Just Noticeable
3	Noticeable
6	Substantial
10	**Doubling (or Halving)**

Maximum Recommended NC Levels

Recording Studios	NC 10-20
Concert Halls	NC 15-20
Music Rooms	NC 20-25
Traditional Worship	**NC 20-25**
Theaters	NC 25-30
Conference Rooms	NC 25-30
Classrooms	NC 25-30
Contemporary Worship	NC 30-35
Cinemas	NC 30-35
Bedrooms	NC 30-35
Swimming Pools	NC 35-40
Restaurant/Bar	NC 40-45

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Testing Data Sheet

	0	Building:	Main Worship Space
Test Date:	November 20, 2020	Reverb Time:	sec
Rm. Volume:	108,273.00 Ft^3	Engineer:	Craig Schaefer
Rm. Notes:	HVAC is the most notable source of noise in the space. Appears to be a combination of machine and air turbulance.		

Tested: Background All Off - Balcony

HZ	Pos. A	Pos. B	Pos. C	*Average*
16	52.60	54.90	53.00	53.50
31.5	47.00	45.50	46.40	46.30
63	43.60	41.10	42.30	42.33
125	41.00	38.70	39.50	39.73
250	37.90	35.20	36.50	36.53
500	35.00	31.30	32.30	32.87
1000	**31.50**	**28.70**	**30.10**	**30.10**
2000	28.80	26.50	27.00	27.43
4000	26.20	23.80	23.70	24.57
8000	23.70	21.40	21.10	22.07
16000	21.80	19.90	19.70	20.47

Tested: Background All Off - Main Nave

Pos. A	Pos. B	Pos. C	*Average*	HZ
47.70	44.50	45.10	45.77	16
42.40	39.70	41.40	41.17	31.5
37.60	34.70	36.00	36.10	63
30.70	29.50	30.00	30.07	125
28.30	26.00	27.00	27.10	250
22.90	22.60	22.90	22.80	500
22.00	**19.00**	**20.20**	**20.40**	**1000**
14.50	16.30	17.80	16.20	2000
14.30	14.30	15.90	14.83	4000
14.00	12.50	14.20	13.57	8000
12.70	12.50	13.20	12.80	16000

Tested: Background All Systems On

HZ	Pos. A	Pos. B	Pos. C	*Average*
16	55.20	55.80	56.50	55.83
31.5	58.90	60.60	62.20	60.57
63	55.70	55.20	59.70	56.87
125	50.80	50.70	55.10	52.20
250	44.20	43.90	46.30	44.80
500	39.40	39.50	40.80	39.90
1000	**33.00**	**32.80**	**34.70**	33.50
2000	29.30	27.40	28.50	28.40
4000	27.30	23.70	23.30	24.77
8000	27.00	20.70	19.70	22.47
16000	22.10	18.70	18.20	19.67

Tested: Background - HVAC ON only

Pos. A	Pos. B	Pos. C	*Average*	HZ
58.50	55.30	60.20	58.00	16
63.40	59.50	64.40	62.43	31.5
57.40	57.60	60.70	58.57	63
53.10	52.70	56.60	54.13	125
46.10	46.50	48.10	46.90	250
41.50	41.30	43.10	41.97	500
34.10	**34.40**	**36.90**	**35.13**	**1000**
27.20	30.40	32.20	29.93	2000
21.80	27.20	29.00	26.00	4000
20.70	24.80	26.40	23.97	8000
18.20	23.00	24.90	22.03	16000

Tested: Background - Organ ON only

HZ	Pos. A	Pos. B	Pos. C	*Average*
16	49.10	44.10	42.90	45.37
31.5	44.80	42.40	43.00	43.40
63	41.80	41.60	41.00	41.47
125	35.30	34.40	31.50	33.73
250	34.00	33.80	27.50	31.77
500	30.40	30.90	25.80	29.03
1000	**28.20**	**28.70**	**24.50**	**27.13**
2000	22.90	23.60	19.70	22.07
4000	18.20	19.70	15.10	17.67
8000	16.00	17.40	13.20	15.53
16000	14.40	15.90	12.60	14.30

Tested: Background - Sound System On - Fan Only

Pos. A	Pos. B	Pos. C	*Average*	HZ
46.40	46.60	48.10	47.03	16
42.30	42.30	41.90	42.17	31.5
35.00	37.60	35.80	36.13	63
31.60	33.20	32.70	32.50	125
31.20	31.50	30.80	31.17	250
24.60	26.30	28.70	26.53	500
24.00	**24.70**	**26.50**	**25.07**	**1000**
21.10	21.60	21.10	21.27	2000
16.80	18.10	17.60	17.50	4000
14.70	15.90	15.30	15.30	8000
13.50	14.80	14.40	14.23	16000

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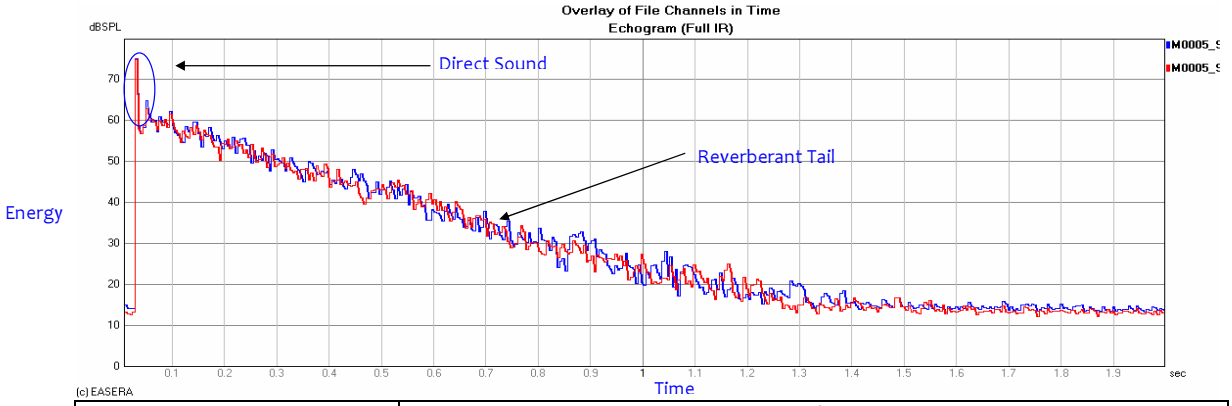
Echograms and Echo Determination

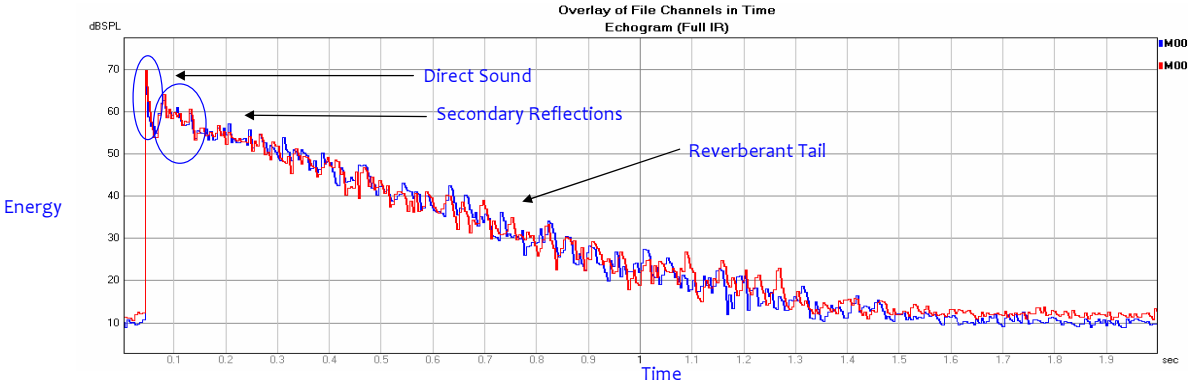
St. Peter's Lutheran - Hemlock, MI		Sound Signal:	Pink Noise Decay
Test Date:	November 20, 2020	Sound Source:	Riedel Sound System
Engineer:	Craig Schaefer	Source Position:	Mounted Over Sanctuary
Rm. Notes:			

Receiver 03



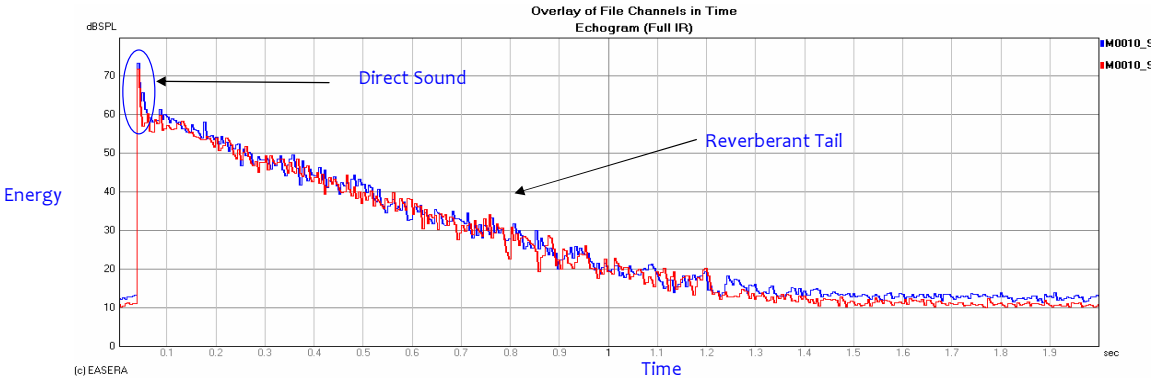
Notes:	Single High Intensity Direct Sound Instance, no secondary reflections to support the direct sound, smooth reverberant tail

Receiver 05



Notes:	At recevier positions in the mid/rear of the space we see an increase in noise in the background reverberant tail, which may lend itself to produce flutter if the side walls and balcony front are stiffened without adding diffusion.

Receiver 07



Notes:	Strong direct sound arrives in the chapel, but there are no secondary reflections to support the direct sound, smooth reverberant tail.

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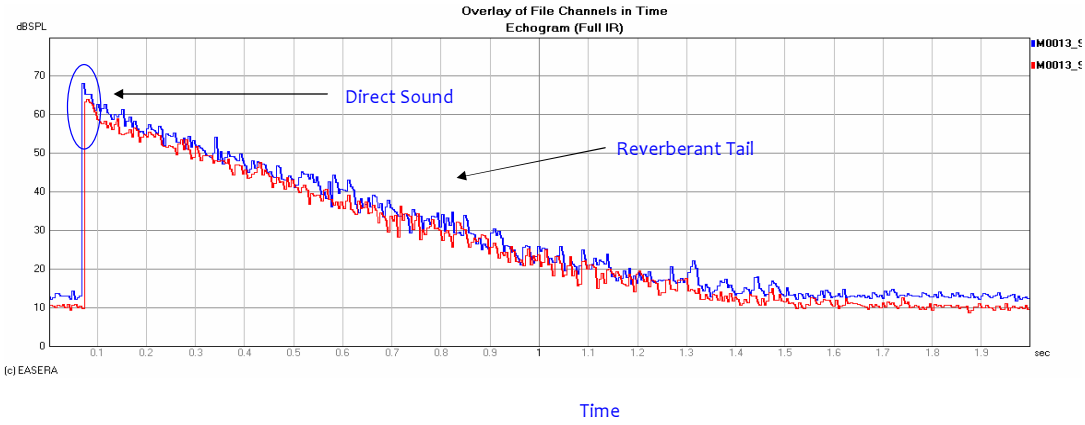
Echograms and Echo Determination

St. Peter's Lutheran - Hemlock, MI		Sound Signal:	Pink Noise Decay
Test Date:	November 20, 2020	Sound Source:	Riedel Sound System
Engineer:	Craig Schaefer	Source Position:	Mounted Over Sanctuary
Rm. Notes:			

Receiver 09



Notes:	Balcony Position: Balcony seating experiences low level direct sound which is nearly indisguisable from the reflected sound.

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