ACOUSTIC ENVIRONMENTS

Acoustic study of Performance/Theatre Space proposed for 36 Newtown Avenue

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Pt. 1 INTRODUCTION

This report is a study of acoustic performance within the proposed cinema and performance venue development at 36 Newtown Avenue. The proposed structure is to house three cinemas with one being a multipurpose performance venue space seating up to 140 people. The report explores potential acoustic issues that could occur in this larger, main cinema/ performance space that have the potential to impact occupant comfort or detract from their experience. This investigation includes analysis of the insulation needed to prevent noise pollution from this structure. Acoustic performance of the space is simulated using INSUL and CATT Acoustic to establish design recommendations.

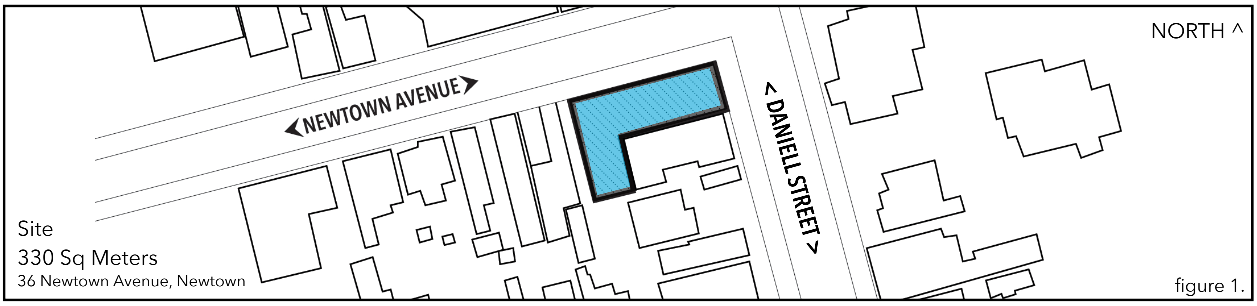


figure 1.

LIST OF COMFORT / PERFORMANCE DESIGN GOALS

- Events at the performance complex must not acoustically disrupt the existing urban, residential setting. Common building elements such as party walls must be constructed to prevent 'undue noise transmission' as per council bylaw (BCG6). This dictates that audible noise levels generated from the cinema then entering neighboring domestic buildings must be less then 30dBA during the day and 22dBA after 8pm (WCC) (Chan, 4).

- Quiet performance speaking should be clearly audible over all background noise. Listening to soft music and/or speech in the 140 seat multipurpose performance venue requires the background noise level to be between 25-30 dBA (Auralex). This also demands that the spaces STI (Speech Transmission Index) value is 0.7 or greater (excellent, STO ED3) (Rossing, 239).

- For ideal sound quality and occupant enjoyment the Cinema/Performance space reverberation time shall be between 0.4 and 0.6 seconds when the space is a cinema and 1.1 - 1.4 when the space is being used for musical events (Rossing, 129) (AAE). Furthermore to reduce erratic acoustic behavior impacting on ones experience at the cinema the preferred noise criteria curve (PNC) of the cinema space is 10 - 20 based on steady background noise definitions (Chan, 4).

- Acoustic transmission will be further controlled by defining an sound transmission class (STC) of at least 65 (AAE) for the walls, floor and ceiling. Furthermore any air gap between materials rated of this quality must also be either sealed or brought up to this level. This will ensure that the stacked cinema design does not impact ones experience of the performance, especially when each theatre is in session (AAE) (ASC).

- To prevent occupant discomfort and safeguard from illness the sound transmission class of walls, floors and ceilings shall be no less than STL55 as per NZBC G6, 3. The impact insulation class of floors shall be no less than STL55. (NZBC G6)

- To provide adequate privacy for occupants and a comfortable feeling 'non-science' is considered. Ensuring that no space is over 'controlled' will ensure that the building feels active and alive while maintaining strict sound qualities when needed (Cinema/Performance Spaces) hence the minimum sound level in the cinema is set to 25dB (ASC).

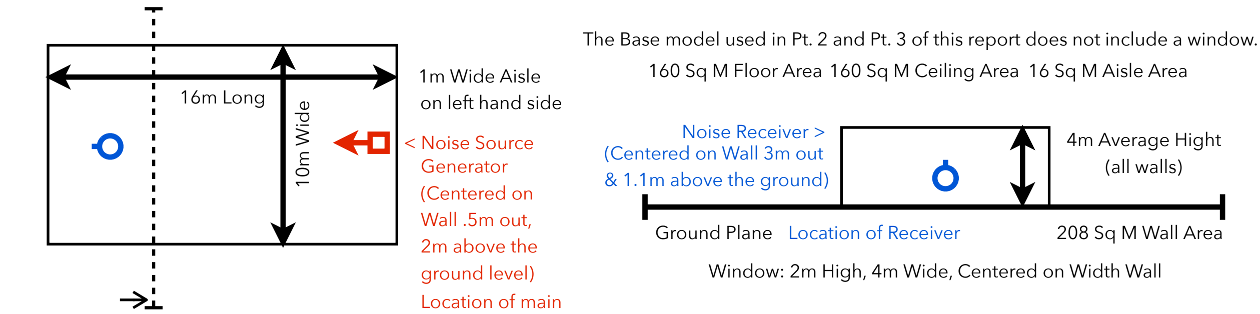
Checklist/Summary of Assessment Criteria:

figure 2.

1	Undue Noise Transmission	dBA (<22)	**4**	Maximum Background Noise	dBA (<30)
2	Performance Speech Quality	STI (0.7+)	**5**	Minimum Background Noise	dBA (>25)
3	Space Reverberation/Clarity	RT (.4-.6s)	**6**	Acoustic Behavior	PNC (10-20)

BASE BUILDING MODEL SPECIFICATIONS

The following is documentation of the base building that is used to generate simulations of how sound might react within the space. NB. That this remains unchanged unless started for all trials.



Cinema Space Plan
Construction Parameters of Cinema Space...

Cinema Space Average Section
Construction and Parameters of Cinema Space...

figure 3.

- **Walls:** *150mm Cast in Situ Concrete panels - Joints Sealed - Left Exposed.*

    - Informed Acoustic Properties: (Total Area: 200m^2)

    STC48, Issues with low frequency noise reduction, especially at 62.5 Hz where it it almost totally ineffective. By commercial building standards where STC50 is the code requirement this is close.

- **Ceiling:** *Timber Joists (190x90 at 800 Cntrs)/ 10mm standard GIB plasterboard on bottom side with R3.5 Ceiling Pink Batts (160mm Thick) and 17mm Ecoply Sheet Decking Material above.*

    - Informed Acoustic Properties: (Total Area: 160m^2)

    STC47, Very similar performance to the walls but because of the smaller surface area this building element contributes less to overall performance.

- **Floor:** *Ground floor utilizing an insulated concrete pad on grade (300mm thick).*

    - Informed Acoustic Properties: (Total Area: 160m^2)

    STC59, Exceptional Performance. The thickness and density of the material is highly effective at reducing low frequency sound while still maintaing performance at high frequencies.

- **Glazing:** 6mm thick commercial dual glass panels with a 15mm spacing between panels.

    - Informed Acoustic Properties: (Total Area: 8m^2)

    STC35, As this glazing type is optimized for thermal retention the closeness of the two glass panels do not lend themselves well to acoustic control.

Respective Coefficients of Absorption of Building Elements								
figure 4.	**62.5Hz**	**125Hz**	**250Hz**	**500Hz**	**1000Hz**	**2000Hz**	**4000Hz**	*Ref.*
Walls	-	0.01	0.02	0.04	0.06	0.08	0.10	(CTC, 24)
Floors	-	0.01	0.02	0.05	0.08	0.06	0.06	(CTC, 14)
Ceiling	-	0.20	0.20	0.10	0.10	0.04	0.02	(CTC, 17)
Glazing	-	0.15	0.05	0.03	0.03	0.02	0.02	(CTC, 17)
Audience (full)	0.30	0.39	0.57	0.80	0.94	0.94	1.00	Rossing, 395

BASE MODEL PERFORMANCE; ACOUSTIC CONTROL (USING INSUL FOR SIMULATIONS)

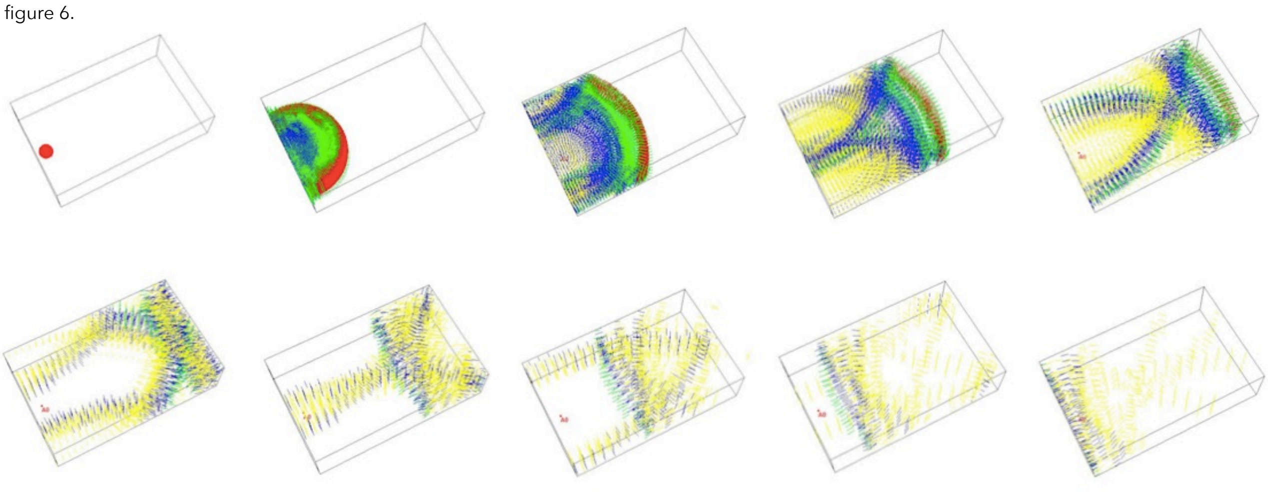
INSUL 7 was used to simulate the effective transmission loss of external traffic noise entering the main performance/cinema space and identify key sound control issues... (See Appendix 2 for material TL)

INSUL7 simulation results for the estimated sound levels within the main performance space:								
figure 5. Source	Octave Band Centre Frequency (Hz)							Overall
	62.5Hz	**125Hz**	**250Hz**	**500Hz**	**1K Hz**	**2k Hz**	**4k Hz**	
Incident Sound level (dBA)	*78*	*72*	*68*	*66*	*66*	*63*	*58*	*70*
Window Closed Sound Level (dBA)	76	56	42	33	28	24	23	51
Window Open Sound Level (dBA)	78	66	60	57	56	53	48	62

Base modeling in INSUL reveals the substantial impact of having an opening in the structures form. Observing the tabled information above we can see that having the opening has more of an effect on higher frequency sounds and almost no change at the lower frequencies. This suggests that a fully sealed environment is much more critical when attempting to control higher pitch noise.

BASE MODEL PERFORMANCE; ACOUSTIC QUALITY (USING CATT ACOUSTIC SOFTWARE)

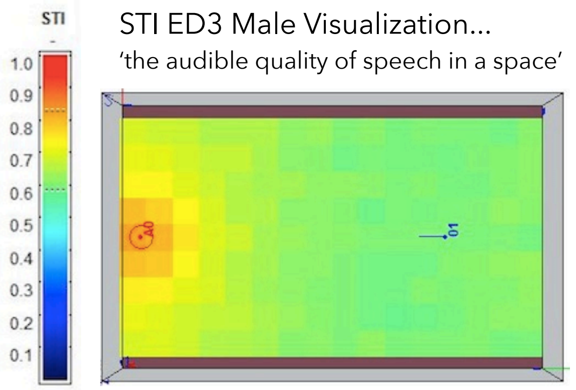
figure 6.



^ Simulated Ray-trace of Sound generated inside the space (10ms intervals)...

Red = 0 Order (Generated Sound), Green = 1st Order (Reverb 1), Blue = 2nd Order (Reverb 2), Yellow = 3rd Order (Reverb 3)

See R-Drive Hand-In (attached files for the video of this simulation and the resulting auralisation within the space itself)



STI ED3 Male Visualization...
'the audible quality of speech in a space'

^Based on background noise readings from figure 5 (see appendix 1)

figure 7.

Base Model Performance Summary...

1	Undue Noise Transmission (<25 dBA)	FAIL 81 dBA	**4**	Maximum Background Noise (<30 dBA)	FAIL 51 dBA
2	Performance Speech Quality (STI 0.7+ 90%)	PASS Avg. 0.71	**5**	Minimum Background Noise (>25 dBA)	PASS - -
3	Space RT/ Speech Clarity (0.4 - 0.6s)	FAIL 1.0 0.6	**6**	Acoustic Behavior (PNC 10-20)	FAIL - -

figure 7.1.

ACOUSTIC ISSUES ARISING FROM BASE MODEL TESTING

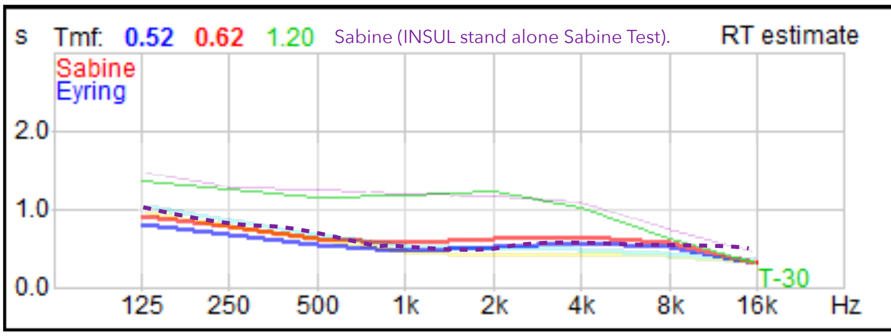
From this model the sound in this space is observed to be highly reverberant, uncomfortable to listen to and lacking clarity. Reverberation from around the room is seen to be over 50ms (from the ray-trace visualization) and has the potential to cause major sound clarity issues for cinema but not live performance facilities. Of most pressing concern in terms of Acoustic control is the prevention of noise generated within the cinema and/or performance space effecting the surrounding, mostly domestic, urban environment. This is indicated by the high amount of low frequency noise currently transmitting through the walls and is likely to be increased when we consider the digital base sound system of the cinema (figure 7.1).

BASE MODEL SIMULATION 'SIMPLIFICATION' AND LIMITATIONS

CATT Acoustic (v9.0c) has a limited ability to interpret a 3D geometry and then calculate specific acoustic conditions. For the space we are designing for (and almost all other spaces) simplifications need to be made in order for the simulated results to be possible. This means that smaller details like window frames, skirting boards and doorway surrounds/handles can be ignored, as their effect to the overall simulation is negligible (in-fact more likely to cause errors then add to the validity of the simulation). Likewise the simulation can be simplified right down to the internal space itself and all other faces, including adjoining rooms do not need to be modeled (unless they are connected by permanent openings).

Modeling Seating in CATT: (Significance and Relevance): To test the implications on the CATT Acoustic simulation of adding seating elements into the cinema space a separate simulation was carried out. Two things were changed. Seating was added to the space and the seating surfaces became 'the audience'. Results indicated that there was almost no change in deviation from having no seats to having seating in the space against the original stand-alone Sabine RT calculation. This means that for the time spent detailing and adding seating elements there is almost of no benefit modeling each row over a single plane and therefore in future simulations seats will not be added.

figure 8.



< Simulated Reverberation time of the Cinema Space with seating elements:
(over-laid) (T-30 with Seats) (Sabine with Seats) (Eyring with Seats)

Comparing the stand alone separate sabine calculation (see week 1, purple, dashed) against the CATT Acoustic Simulation (see section 1.2 of this report).

QUALITY ASSURANCE OF MODELING/SIMULATION PROCEDURES

From the base modeling specifications (page 2,3) we can mathematically test the accuracy of the CATT Acoustic simulation model using the Sabine 'reverberation time' (RT) calculation....

figure 9.

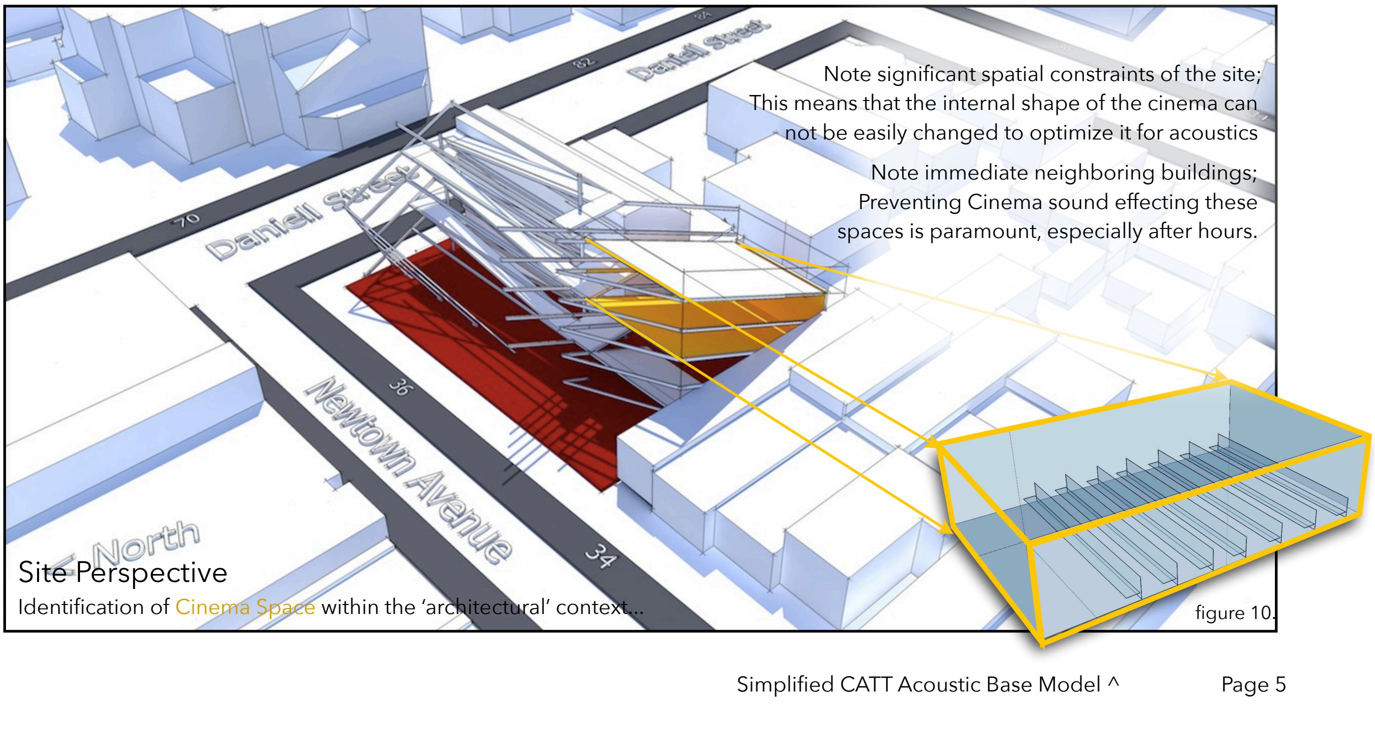
Estimated Reverberation Time of the Space (RT) in seconds (s) (using base model specifications):

	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Manual Sabine:	0.94	0.81	0.68	0.60	0.66	0.66
CATT Sabine:	0.92	0.78	0.65	0.58	0.63	0.63

Referencing figure 8. where this information is overlaid in a graphical form (dashed line) it is clear that the totally independent Sabine room reverberance calculations have strong correlation's. This suggests that the CATT base simulation can be trusted and further simulations can be modeled from this base. Small deviations could be a result of the manual Sabine calculations inability to factor sound loss through air and general rounding errors. See Appendix 1 for a detailed visualization of the manual Sabine calculation.

ACOUSTIC DESIGN INTEGRATION STRATEGIES

The implications of the design brief on the acoustic conditions within the cinema space is significant. This comes from the harsh spatial constraints imposed by the site forcing the stacking and integration of performance spaces. Critically one cinema (the area of concern within this report) will be required to be both a live performance space and movie theatre seating over 140 people. Such a capacity is not possible in a single level within the site dimensions and therefore the base model must be reconfigured into a multi-teared system. This further complicates a space that already requires two unique reverberation scales and a high quality of acoustic clarity. Based on a *Wenger Corporation* study removable panels have the potential to temporally redefine the acoustic reverberation times within a space on-demand (Wenger, 13). Fold down panels of sound cushioning material are tested to identify their potential to reduce the reverberation time when necessary. This dynamic method of acoustic control has the ability to respond to the desired intimacy of the event, attendance numbers and/or the performance type; achieving an acoustically comfortable and diverse performance space.



Site Perspective
Identification of Cinema Space within the 'architectural' context...

figure 10.

Simplified CATT Acoustic Base Model ^

Pt. 2 ACOUSTIC **TRANSMISSION CONTROL** DESIGN OPTIONS

ADDRESSING PERFORMANCE GOALS (fig 7.1) THEORY, SIMULATION AND COMPARISONS

This series of trials begins to identify which systems can be implimented to best reduce noise entering the wider urban environment and effecting neighboring domestic dwellings...

T1. BASIC

Duel Wall Isolation Approach

This system uses multiple phases of basic sound absorption materials to restrict the movement of sound waves across frequencies exiting the main cinema (Rossing, 400).

Theory: Providing a buffer zone between the source and area of concern (the neighboring apartment in this case) allows multiple barriers to disperse different wavelengths of sound and therefore reduce transmission on all bands (Rossing, 400). This will lower the noise levels observed by neighbors without compromising the design.

T2. INTERMEDIATE

Reverberation Reduction

Heavily absorbent materials will line all surfaces of the performance space to reduce reverberation time within the room and therefore reduce the emitted sound (Rossing 351).

Theory: Internal reverberation control is an attempt to constrain the emitted noise to just the main cinema by absorbing all waves that hit the surfaces before they can transmit into another area (Rossing, 351. ASC.). This reduces the acoustic impact of the cinema on its site while also providing a foundation for better clarity (Wenger, 13).

T3. RADICAL

Acoustically Isolated Wall Systems

Using sophisticated spring based construction methods the cinema space will be isolated from the rest of the building to effectively control low frequency emittance (Rossing, 346, ASC).

Theory: Isolating the space from all other structures prevents vibrations from mounted speaker systems reverberating through solid materials (Rossing, 415). This prevents undue noise transmission into neighboring dwellings as well as reduces acoustic emissions into other cinema areas (Rossing, 415 - 361) .

SIMULATION SPECIFICATIONS - CHANGES FROM BASE MODEL

T1: The shell of the existing space is duplicated and expanded to enclose the space again 1m from the original construction. (There are no other changes).

T2: All walls and the roof are lined with plush acoustic fabric. Absorption:

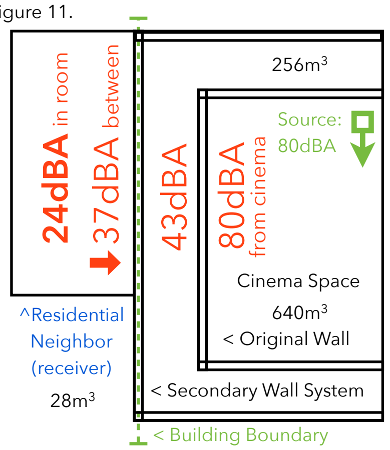
125	250	500	1000	2000	4000
0.1	0.12	0.35	0.48	0.39	0.36

T3: Rubber isolated steel clip rails connect the space to the supporting structure (see Appendix 2), all internal surfaces remain at base specifications.

CALCULATION RESULTS - (On building plans, see Appendix 2 for mathematics).

Resulting weighted dBA (average noise level) in each specific area after changes:

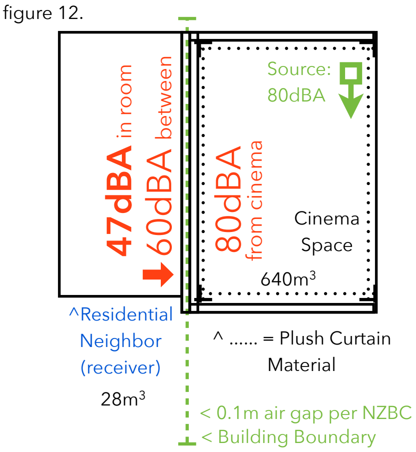
figure 11.



See Appendix 2 for all calculation details.

Result: 80dBA to 24dBA
from cinema to neighboring residential room

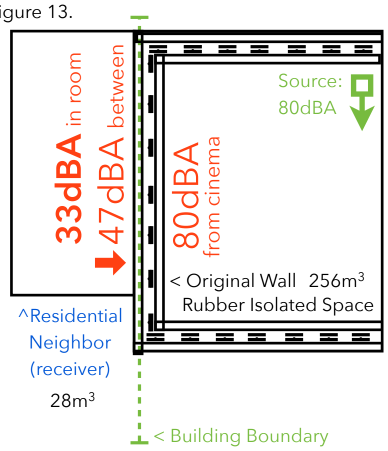
figure 12.



See Appendix 2 for all calculation details.

Result: 80dBA to 47dBA
from cinema to neighboring residential room

figure 13.



See Appendix 2 for all calculation details.

Result: 80dBA to 33dBA
from cinema to neighboring residential room

Pt. 3 ACOUSTIC **CLARITY** DESIGN OPTIONS

ADDRESSING PERFORMANCE GOALS (fig 7.1) THEORY, SIMULATION AND COMPARISONS

This series of trials begins to identify which systems can be implimented to best improve the acoustic quality within the main space for both cinema and live performance...

C1. BASIC

Absorption Lining Panels

Area of removable acoustic absorption linings with the remainder of the cinema fully acoustically sealed and all surfaces utilizing base model largely reflective materials.

C2. INTERMEDIATE

Reflective Lining Panels

Area of removable reflective linings with the remainder of the cinema fully acoustically sealed and all surfaces utilizing thick absorption material (see simulation parameters below).

C3. RADICAL

Multilevel Auditorium

Based on design demands a double height auditorium with stacked seating and raised performance area trusting into the audience utilizing all base model material definitions.

ACOUSTIC THEORY BEHIND SOLUTION

Absorption material works to decrease the reverberation time and therefore improve STI clarity and normalize acoustic conditions for a cinematic experience (Rossing, 371, AAE). These panels will shorten the audible lifespan of a wave in the space preventing delayed, destructive and/or inconsistent reception of sound (Wenger, 13)

Supplementing an acoustically 'dead' space with reflective panels increases the reverberation time of the space making it more suited to live performance (Rossing, 370). Sound waves reflect of the panels and therefore remain audible in the space for longer, very desirable for live musical performance (Wenger, 9)

Multilevel auditorium spaces with a raised stage allow direct transmission between sound source and receiver for a greater number of people. This dramatically improves clarity and acoustic behavior for audience members in all areas rather then forcing an elongation of the seating area (Wenger, 19, AAE).

SIMULATION SPECIFICATIONS

An effective area of 40m² is covered with an acoustic fabric.

125	250	500	1000	2000	4000
0.1	0.12	0.35	0.48	0.39	0.36

^**RQ**: Table of material absorption coefficients at a range of different frequencies (top) (Hz).

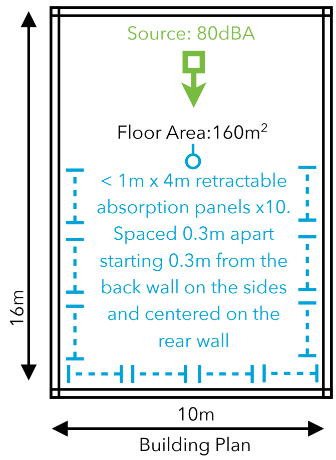
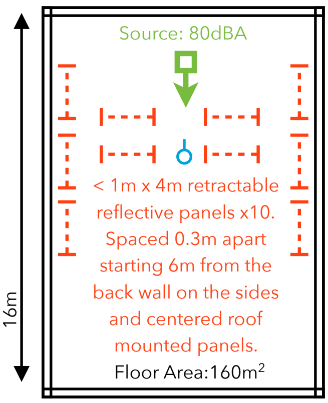


figure 14.

An effective area of 40m² is covered with acoustic reflectors. Ab

125	250	500	1000	2000	4000
0.4	0.21	0.10	0.08	0.06	0.06

^Table of material absorption coefficients at a range of different frequencies (top) (Hz).



NB: ALL OTHER SURFACES USE "**RQ**" MATERIAL

See Appendix 1 for all calculation details.

figure 15.

The shell of the existing space is duplicated and moved directly 4m up from the original construction to form two tears.

Note: The angle of the top 16m roof span will be changed in trials to test its effect on improving speech clarity by reducing reflections in the rear of the space. See appendix 2 & Pg 10 for details.

Seat Capacity Increased (80 to 145)

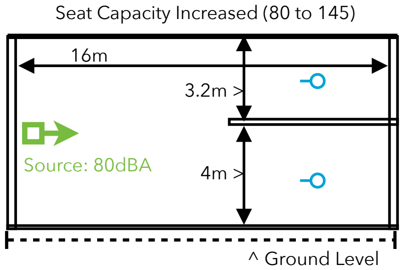


figure 16.

CLARITY SIMULATION RESULTS

BASE MODEL	C1. BASIC	C2. INTERMEDIATE	C3. RADICAL
Sound Transmission Index Simulation Visualization	Absorption Panels	Reflective Lining Panels	Multilevel Auditorium

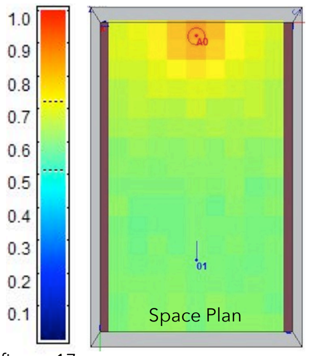


figure 17.

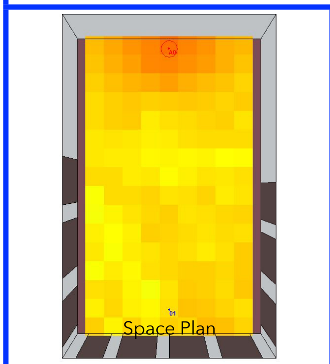


figure 18.

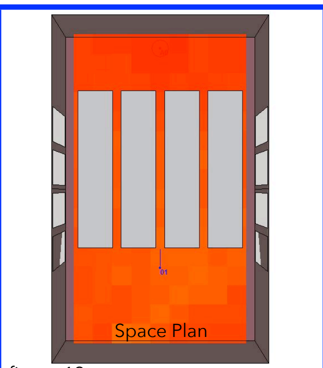


figure 19.

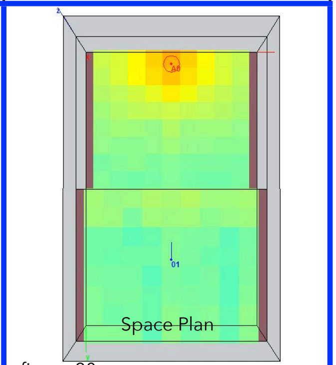


figure 20.

Simulated Reverberation time(s) (s) of the space in each simulation (T-30):

- Base Model
- C1. Absorption Panels
- C2. Reflective Linings
- C3.1 Multilevel Flat
- C3.2 Multilevel @ 20°
- C3.3 Multilevel Roof @ 30°
- Purple Zone = Desired Live RT
- Blue Zone = Desired Cinema RT

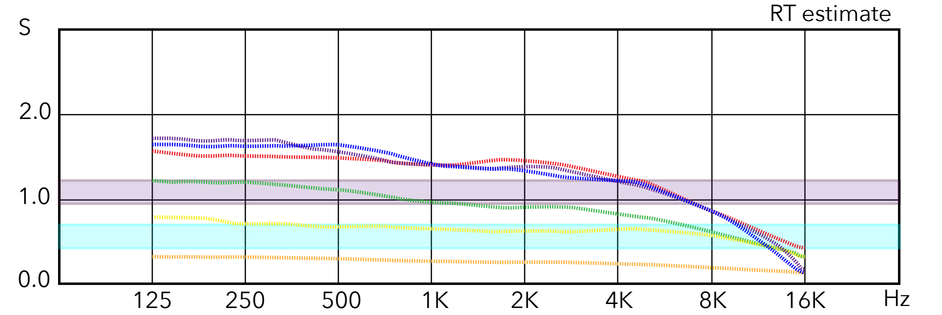


figure 21.

'Echogram' Space Reverb; Early Echogram (1kHz) (70db Range) (impulse response (ms))

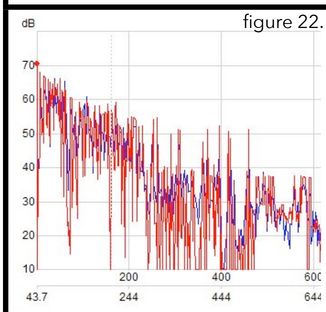


figure 22.

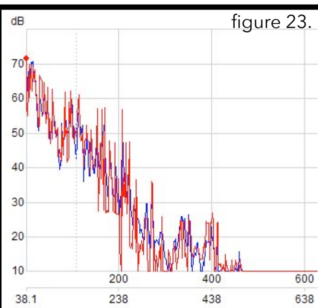


figure 23.

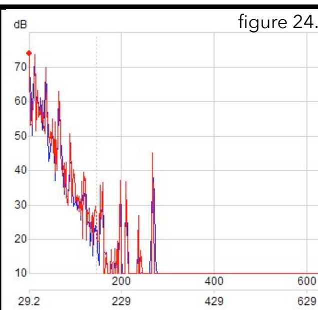


figure 24.

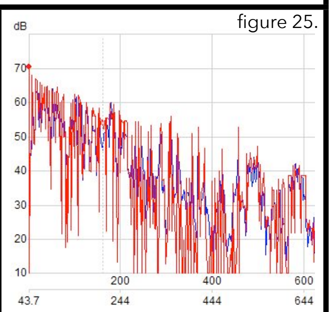


figure 25.

FINDINGS EVALUATION (RESULTS VS GOALS): PERFORMANCE CRITERIA CHECK

figure 26.

Performance Criteria	Base Model	C.1 Absorption Panels ($)	C.2 Reflective Panels ($)	C.3 Multilevel Space ($$)
Live Speech Quality:	✓	✓ - High STI values right across the room, as per figure 18.	✓ - Maximum STI value achieved in 91% of the space (figure 19).	✕ - STI beginning to become unacceptable @ L1 (figure 20).
Space RT/Speech Clarity:	✕	✓ - Room reverberation time is ideal for cinema (figure 21).	✕ - Low reverberation times only ideal for cinemas (figure 21).	✕ - Reverberation is uneven and inconsistent (figure 21).
Acoustic Behavior:	✕	✓ - PNC acoustic normalization is 11 18 across frequencies (Fig 21).	✕ - Sharp acoustic drop off causing the space to be acoustically dead.	✕ - PNC acoustic normalization is undefined, to poor to measure.
	Base Model	T.1 Duel Wall System ($$)	T.2 Reverberation Reduction ($)	T.3 Isolated Wall Systems ($$$)
Max. Background Noise:	✕	✓ - Effectively mediates all noise entering the space to sustain <26dBA.	✓ Effectively mediates all noise entering the space to sustain <30dBA.	✓ Effectively mediates all noise entering the space to sustain <24dBA.
Undue Noise Transmission:	✕	✓ - Achieves <25dBA in neighboring domestic structure.	✕ - Fails to isolate sound transmission into neighbors.	✕ - Fails to isolate sound transmission into neighbors.

Approximate Solution Implementation Cost: LOW ($), MEDIUM ($$) or HIGH ($$$) (See Appendix 3 for references).

CONCLUSIONS:

IMPLICATIONS OF FINDINGS

Collectively transmission control strategy one (T1) and clarity strategy one (C1) meet all performance goals for the area of concern. However, they fail to meet the design expectations of the brief in terms of providing a multipurpose performance and cinema space capable of seating 140 people with excellent acoustic properties. Clarity strategy three (C3) deals with this issue and the corresponding physical site restraints by adding second tier of seating above the existing rows (Wenger, 12). Within such a space testing reveals that increased reverberation times and greater distances from the source will produce clarity issues if no further changes are made (Rossing, 351). There is potential from this layered system to add absorption panels (T1) and dual external walls (T2) (as modeled above) to effectively meet all the performance goals while staying within the allotted building footprint. Such panels are most effective when placed at the rear of the space as sound is bounced off the front walls and then absorbed at the back, as it is undesirable for it to reverberate in great quantity (Rossing, 371. Wenger, 7).

AN INTEGRATED PROPOSAL

A multilevel auditorium space seating 140 people lined with duel cast in situ concrete envelope and adjustable cushioned curtain fabric system for optimal cinematic and live performance acoustics:

PRIMARY DIAGRAMMATIC BUILDING SECTION

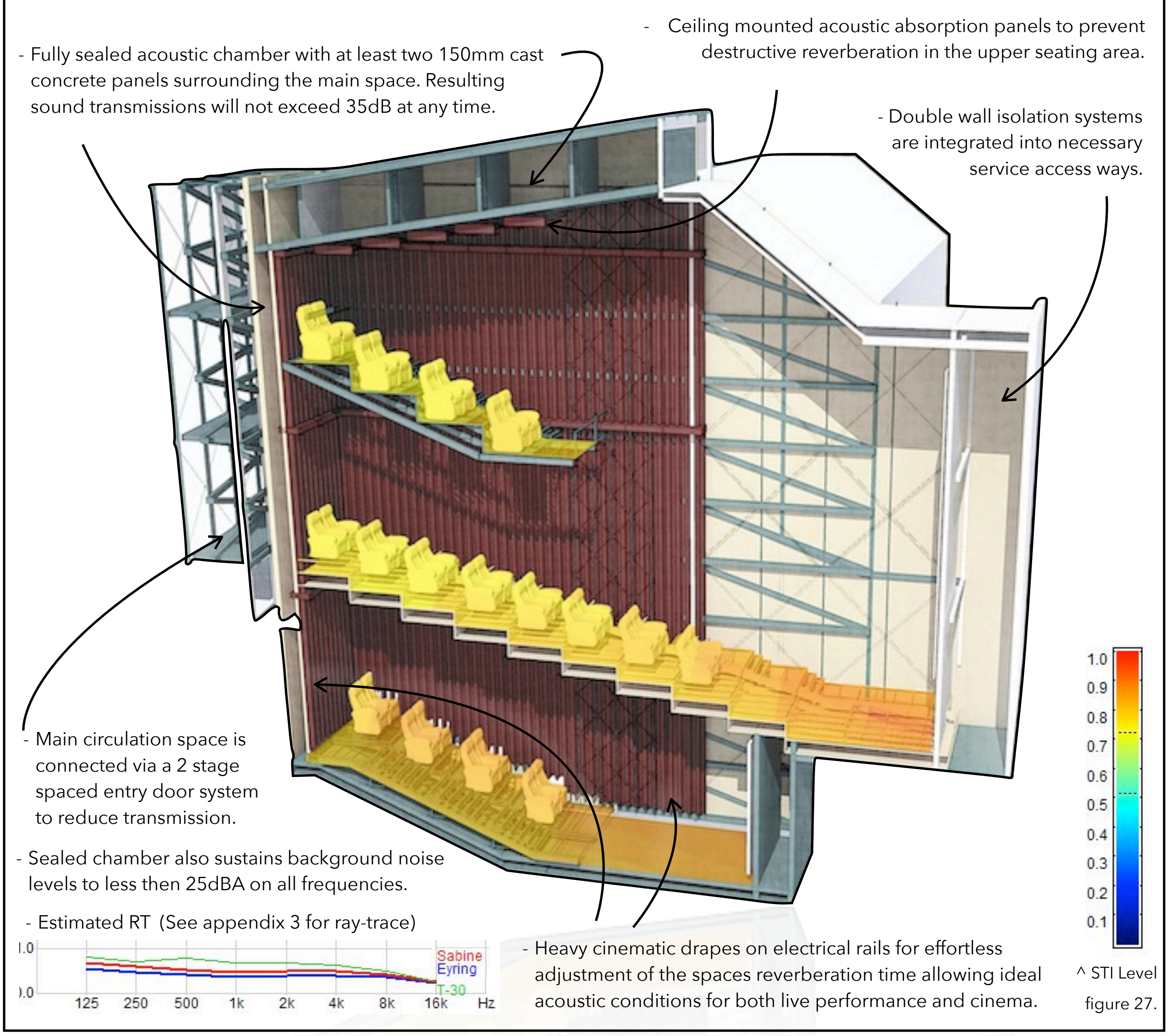


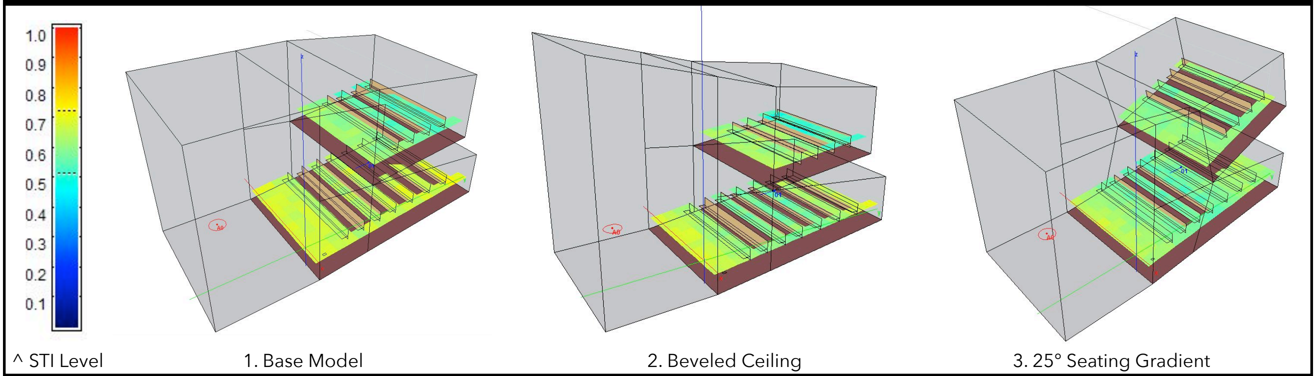
figure 27.

ONGOING ANALYSIS and RE-DESIGN POTENTIAL

Further investigations into the effect of audience seating arrangements, predominantly the impact of the gradient of a seating plane on the clarity of acoustics within a space, should be considered. Preliminary testing (see below) and acoustic theory indicates that this can substantially improve acoustic qualities (Wenger, 8). As an increased gradient allows each audience member to make more direct connections with the emitted sound we see clarity and PNC normalization improvements for all occupants (Wenger, 9). Such further investigation is relevant to the specific design demands of this project as there is no physical space for side wings or angled audience rows.

Speech Transmission Index Simulation (STI) Visualization of Seating Gradient Changes: figure 28.

See Appendix 3 for simulation details.



FINAL REMARKS

The findings of this report provide possible acoustic design solutions for a combined live performance and cinema space within a restricted building footprint. Proposed is adjustable clarity control solutions that can be changed for the two main uses of this auditorium space. This solution is perhaps not the most 'accurate' way of controlling acoustics, but for its implementation simplicity and fulfilling design integration potential, it is highly effective. When needed the railed curtain system can effectively minimize destructive reverberance (figure 23), negate audibility issues and eliminate all areas of poor speech transmission quality (figure 27). When desired the effective reverberation time of the space can increased from 0.6 - 0.8s (cinema levels) to a live performance friendly time of 1.4 - 1.1 seconds. Importantly this solution embraces the design brief by promoting the desired aesthetic qualities of the space while providing high level acoustic performance in both use cases (figure 27).

Ged Finch - 2014

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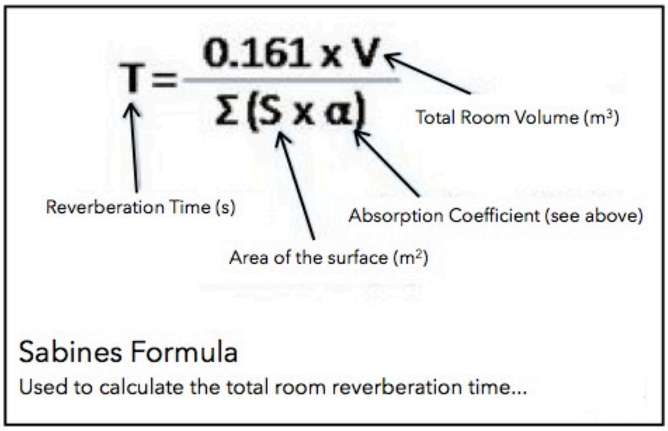
END OF FORMAL REPORT: APPENDIX FOLLOWS

APPENDIX 1: MANUAL SABINE CALCULATION

Overview of Building Parameters
(All Given in Figure 3):

Room Width = 10m,
Room Length = 16m,
Width of Aisles = 1m
Average Height of all walls = 4m.
Room Volume = 640 meters cubed.
Wall Area = 206 square meters.
Floor, Ceiling Area = 160 square meters.



From: Sabine, Wallace. "Collected Papers on Acoustics". Repressed Publishing LLC, 1922. (republished 2012).

Transmission Loss of Sound through a specific material in dBA: (sound reduction) (ref. CTC, 17, SAE)						
	125Hz	**250Hz**	**500Hz**	**1K Hz**	**2k Hz**	**4k Hz**
Cast in Situ 150mm Concrete Walls	*31*	*36*	*43*	*49*	*55*	*59*
300mm Concrete Pad on grade (insulated)	*40*	*45*	*52*	*59*	*63*	*67*
Joist and Rafter Timber Roof system.	*17*	*29*	*42*	*50*	*50*	*41*

CATT ACOUSTIC ASSUMPTIONS

Location of Source for all trials: *laterally centered on the screen wall, 2m up, 0.5m from the surface.*
Location of Receiver for all trials: *laterally centered in the room, 1m up, and 4m from the back wall.*
Location of accidence plane for all trials: *1.0m from ground level (approx. sitting hearing height).*
Explanation of 'audience plane' material theory: *Approx. representation of a seated, human audience.*
Simulation and Ray Tracing Parameters: *10,000 Rays unless stated otherwise at 1kHz, (44.1Hz for Auralisations)*

BACKGROUND NOISE

Simulation Assumptions: (for construction assumptions see 1.2) (INSUL 7 SOFTWARE)
- Noise Generator Traffic (ISO 717) (Weighted Level of 70)
  - (77.9, 71.8, 68.3, 65.9, 65.7, 62.5, 57.7)
- Plane facade Shape Level Difference (on all elements) (0).
- Transmission Loss (See Appendix Two, 150mm of cast in situ Concrete)

Base Simulation Results (window closed):

	Octave Band Centre Frequency (Hz)							Overall dBA
Source	63	125	250	500	1k	2k	4k	
Incident sound level (freefield)	78	72	68	66	66	63	58	70
Receiver								
Room volume (-10Log V) [640 m3]	-28	-28	-28	-28	-28	-28	-28	
Reveberation time (s)	2	1	1	1	1	1	1	
RT (+10Log T)	4	1	0	-1	-2	-1	-2	
Equation Constant	11	11	11	11	11	11	11	
Room sound level	76	56	42	33	28	24	23	51

Resulting 'Background Nose' in the space ^

APPENDIX 2 - EVIDENCE OF TRANSMISSION CONTROL CALCULATIONS

From: Sabine, Wallace. “Collected Papers on Acoustics”. Repressed Publishing LLC, 1922. (republished 2012).

T1. Double Wall Case

Reverb-Reverb Transmission				63	125	250	500	1k	2k	4k	8k		
RT (seconds) as function of Freq					0.9	0.8	0.7	0.6	0.7	0.6			
Lprev1					85	81	77	74	71	69		80	dBA
			(-6dB)	-6	-6	-6	-6	-6	-6	-6	-6		
Room2 Vol	256.0	m3	(14-10logV)	-10	-10	-10	-10	-10	-10	-10	-10		
RT2	0.7	sec	(10logRT)	-2	0	-1	-2	-2	-2	-2	-2		
Partition Area	64.0	m2	(10logA)	18	18	18	18	18	18	18	18		
TL (-ve)					-29	-39	-45	-52	-60	-70			
Lprev2				0	58	43	32	22	11	-1	0	43	dBA
Design Requirement		dBA		21	11	4	-2	-5	-6	-6	-4	0	dBA
Atten Required				-21	47	39	34	27	17	5	4		

Reverb-Free Transmission (Hemisph radiation)				63	125	250	500	1k	2k	4k	8k		
Lprev					58	43	32	22	11	-1		43	dBA
			(-6dB)	-6	-6	-6	-6	-6	-6	-6	-6		
Distance	0.1	m	(10log2pi.d^2)	12	12	12	12	12	12	12	12		
Partition Area	64.0	m2	(10logA)	18	18	18	18	18	18	18	18		
TL (-ve)					-29	-39	-45	-52	-60	-70			
Lp2				24	53	28	11	-6	-25	-47	24	37	dBA
Design Requirement		dBA		21	11	4	-2	-5	-6	-6	-4	0	dBA
Atten Required				3	42	24	13	-1	-19	-41	28		

Free-Reverb Transmission				63	125	250	500	1k	2k	4k	8k		
RT (seconds) as function of Freq					0.5	0.4	0.4	0.4	0.4	0.4			
Lpinc					53	28	1	-6	-25	-47		37	dBA
Room Vol	28.0	m3	(14-10logV)	0	0	0	0	0	0	0	0		
Reverberation Time	0.5	sec	(10logRT)	-3	-3	-4	-4	-4	-4	-4	-3		
Partition Area	32	m2	(10logA)	15	15	15	15	15	15	15	15		
Source Sound Diffus	Yes			-3	-3	-3	-3	-3	-3	-3	-3		
TL (-ve)					-22	-36	-41	-46	-50	-54			
Lprev				8	40	0	-32	-44	-67	-93	8	24	dBA
Design Requirement		dBA		21	11	4	-2	-5	-6	-6	-4	0	dBA
Atten Required				-13	29	-4	-30	-39	-61	-87	12		

- Incident sound level (Lprev1) is based on average acoustic output of a blockbuster film (JBL Prof.) (Musicof).
- Room reverberation time comes from original sabine calculation for the space (see figure 9).
- Transmission Loss through 150mm of cast in situ concrete walls (SAE).
- 0.1m is the NZBC minimum space between two walls in a urban space (NZBC).
- Transmission Loss through timber stud wall with weather board cladding (SAE).

T2. Acoustic Absrobtion

Reverb-Free Transmission (Hemisph radiation)				63	125	250	500	1k	2k	4k	8k		
Lprev					80.75	71.28	50.05	39.92	44.02	44.06		67	dBA
			(-6dB)	-6	-6	-6	-6	-6	-6	-6	-6		
Distance	0.1	m	(10log2pi.d^2)	12	12	12	12	12	12	12	12		
Partition Area	64.0	m2	(10logA)	18	18	18	18	18	18	18	18		
TL (-ve)					-29	-39	-45	-52	-60	-70			
Lp2				24	76	56	29	12	8	-2	24	60	dBA
Design Requirement		dBA		21	11	4	-2	-5	-6	-6	-4	0	dBA
Atten Required				3	65	52	31	17	14	4	28		
			COE		0.05	0.12	0.35	0.48	0.38	0.36			
			Lprev		85	81	77	74	71	69			
			Rslt_Lvl		80.75	71.28	50.05	39.92	44.02	44.06			

Free-Reverb Transmission				63	125	250	500	1k	2k	4k	8k		
RT (seconds) as function of Freq					0.5	0.4	0.4	0.4	0.4	0.4			
Lpinc					76	56	29	12	8	-2		60	dBA
Room Vol	28.0	m3	(14-10logV)	0	0	0	0	0	0	0	0		
Reverberation Time	0.5	sec	(10logRT)	-3	-3	-4	-4	-4	-4	-4	-3		
Partition Area	32	m2	(10logA)	15	15	15	15	15	15	15	15		
Source Sound Diffus	Yes			-3	-3	-3	-3	-3	-3	-3	-3		
TL (-ve)					-22	-36	-41	-46	-50	-54			
Lprev				8	63	28	-4	-26	-34	-48	8	47	dBA
Design Requirement		dBA		21	11	4	-2	-5	-6	-6	-4	0	dBA
Atten Required				-13	52	24	-2	-21	-28	-42	12		

- Transmission Loss through 150mm of cast in situ concrete walls (SAE) with the absorption of a thick plush fabric (JBL. Prof).
- Absorption coefficient of fabric material included in calculation based on Wegner Incorporated studies.
- Approximate size and reverberation time of neighboring structures room taken from council plans.

T3. Acoustic Isolation

Reverb-Free Transmission (Hemisph radiation)				63	125	250	500	1k	2k	4k	8k		
Lprev					85	81	77	74	71	69		80	dBA
			(-6dB)	-6	-6	-6	-6	-6	-6	-6	-6		
Distance	0.1	m	(10log2pi.d^2)	12	12	12	12	12	12	12	12		
Partition Area	64.0	m2	(10logA)	18	18	18	18	18	18	18	18		
TL (-ve)					-47	-56	-68	-75	-75	-74			
Lp2				24	62	49	33	23	20	19	24	47	dBA
Design Requirement		dBA		21	11	4	-2	-5	-6	-6	-4	0	dBA
Atten Required				3	51	45	35	28	26	25	28		

Free-Reverb Transmission				63	125	250	500	1k	2k	4k	8k		
RT (seconds) as function of Freq					0.5	0.4	0.4	0.4	0.4	0.4			
Lpinc					62	49	33	23	20	19		47	dBA
Room Vol	28.0	m3	(14-10logV)	0	0	0	0	0	0	0	0		
Reverberation Time	0.5	sec	(10logRT)	-3	-3	-4	-4	-4	-4	-4	-3		
Partition Area	32	m2	(10logA)	15	15	15	15	15	15	15	15		
Source Sound Diffus	Yes			-3	-3	-3	-3	-3	-3	-3	-3		
TL (-ve)					-22	-36	-41	-46	-50	-54			
Lprev				8	49	21	0	-15	-22	-27	8	33	dBA
Design Requirement		dBA		21	11	4	-2	-5	-6	-6	-4	0	dBA
Atten Required				-13	38	17	2	-10	-16	-21	12		

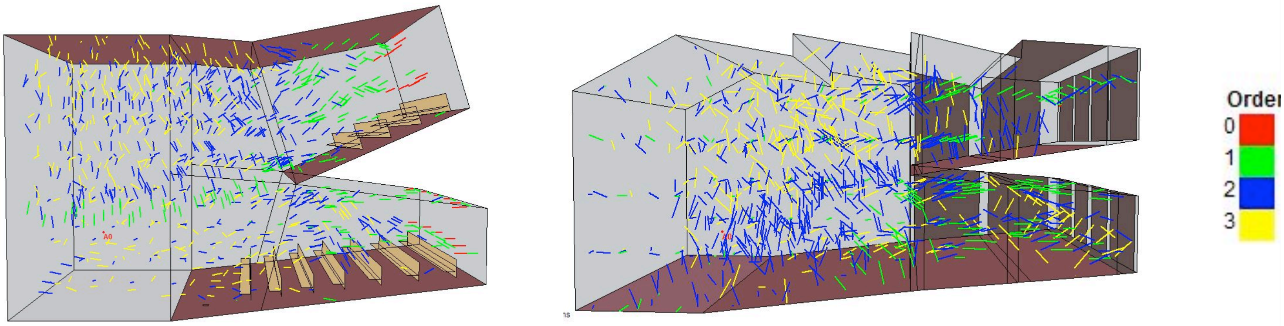
- Transmission Loss through 150mm of cast in situ concrete walls (SAE). Then transmission through rubber isolation system based of Westpac VIII and Marshall Day Acoustics page 5.

APPENDIX 3

CATT RE-DESIGN SIMULATION 'Gradient Changes'.

First sound rays only reaching rear wall at 60ms creates the possibility of destructive reverberation (Wenger, 12).

More early reflections ensure that sound rays reach the rear wall in less then 42ms (Wenger, 12).



- CATT Acoustic TUCT Ray Trace Software Screenshots based on 1kHz Order Simulations with 1000 rays present -

Associated research files (.avi) show progressive visualizations of this effect. The second image is used as part of the integrated proposal found on page 9 of this report. The simulation here utilizes the same rear absorption curtains (fully extended) and double height space parameters however with a substantially redesigned ceiling based on earlier simulations. This ceiling re-design is essential for the space to fulfill its design and performance abjectness in terms of acoustic clarity relative to reverberation time and background noise levels.

ROUGH STRATEGY COSTING - FOR REAL WORLD VIABILITY ANALYSIS

From THX Certified Cinema Consultants (professional), James-Hardie Construction New Zealand Limited, Precast Solutions and BellaTEX Stage Curtains Incorporated.

Heavy Acoustic Theatre Drapes with automated rails, approx 80 Sq M = NZD $40,000
<http://bellatex.com/how-to-buy-stage-curtains/how-much-will-it-cost/>

80 SqM of removable Reflective lining panels (Seal 17mm plywood sheeting) = NZD $4,000
<http://www.branz.co.nz/cms_show_download.php?id=3f39d7ce2cadfdb0310a41cc7dff7bc451f7b612>

Dual Lined Wall 150mm concrete wall system (with integrated design mediation) = NZD $45,000
<www.cellecta.co.uk/PDFs/E-FC-8.pdf>

Double Heigh Cinema/Performance Space (Increased room volume and seating) = NZD $70,000
<http://www.building.co.uk/cost-model-multiplex-cinemas/1779.article>

Note: These numbers indicative for the means of practicality only and do not represent accurately the real world cost and constructing the space. These figures were only as a way of eliminating or identifying outrageously impossible solutions that have no real world relevance. This is a process to further validate and put into perspective the findings of the report.

APPENDIX(S) END