KVDL Acoustic Consultants
PO Box 43
Dickson ACT 2602

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ACOUSTIC ASSESSMENT REPORT -

THE FITTERS' WORKSHOP

Date: 1 & 3 February 2012
Location: off Canberra Avenue, Kingston ACT
Present: Kimmo Vennonen and Duncan Lowe

Introduction:

This report endeavors to test and discuss the musical acoustic qualities of the Fitters' Workshop so that it may help frame the decision making process regarding its future use. It was found that the Fitters' Workshop in its current bare state, does not measure up well against current subjective criteria. This is is part due to the nature of the subjective criteria, which are primarily aimed at describing the qualities of concert halls in an attempt to standardise subjective judgements based on acoustic measurements. It is also due to the completely unfurnished nature of the space when we tested it.

The Fitters workshop, in its current bare condition, has a reverb time that is more than twice that of any of the other venues we tested for comparison. That fact alone means it is a unique acoustic space for music in Canberra.

Background:

We were asked to prepare a report on the Fitters' Workshop building, relating to its acoustic qualities with regard to music performance. It is understood that there is a decision making process requiring expert advice and that we were approached because of our expertise/experience with music and performance spaces in the ACT. We have decades of experience in sound recording and we have done acoustic assessment and work for Federal Government agencies, the ANU, houses of worship, radio stations and community organisations. Although we are not formally qualified in acoustics, we have built and operated long term successful music studios and are regularly requested to provide advice on matters related to music and performance.

Issues requiring advice:

The Committee requires a description and assessment of these points:
1. The acoustic qualities and characteristics of the Fitters' Workshop building, Kingston Arts precinct
2. Whether the building may have any identifiable unique acoustic qualities which make it a superior venue for live music and/or choral performance
3. Possible or likely alteration to any unique existing acoustic qualities that could result from changes (such as fitting out) to the current 'bare' nature of the building

Advice is in the form of this report as well as assistance with the work of the Committee afterwards.

Methodology:

We were given access to the Fitters' Workshop for several hours in the preceding week. This allowed detailed acoustic testing and analysis using the respected EASERA software made by SDA/AFMG in Berlin. This uses accurate equipment to generate specially designed sounds into the space, which are then recorded and analysed. We measured ambient noise levels as well.

A central question is how unique are the acoustic qualities of the Fitters' Workshop. This can only answered in relation to other comparable spaces in Canberra. Within the time limitations we chose six comparable venues to conduct the same acoustic tests as in the Fitters' Workshop. Nobody to our knowledge has done this in the past and all we have had up until now is subjective claims and conjecture. The EASERA software can extract musically relevant criteria from otherwise raw acoustic measurements and we have presented the results in a way that permits direct and meaningful comparison.

In parallel with this we also recorded a high resolution impulse-response "audio signature" of every space using Waves IR-1 software. This means that it is later possible to virtually recreate the acoustics of all the spaces and subjectively assess them aurally, using identical source material in a calibrated recording studio environment.

Finally based on our own measurements we have made a functional acoustic model of the space using EASE, also made by AFMG, which corresponds well to the actual acoustic results. In a broad way this enables us to predict the effect of internal building alterations and fitting out on the perceived sound.

Subjective Impression of the Fitters' Workshop acoustics:

Neither of us have attended a musical performance at the the Fitters' Workshop and as such all of our impressions are purely of the room and what we think it can do. We are not coloured by past experiences with the venue.

We were both very impressed with the reverb of the room - it is very long and smooth and is far and away the most notable feature of the room. The room sounded bright, open and airy. There we no discrete echoes or reflections but at some locations, generally close to the sound source, the reverb appeared to surge in slightly. As part of the testing procedure for all venues, Duncan read a standard piece of text. Reading aloud in the Fitters' Workshop was easy and enjoyable.

We found it difficult to talk casually and understand what each other was saying beyond three to five meters distance. It was just possible, but extremely difficult, to hold a brief conversation over the full length of the empty building but only if we spoke very slowly and carefully, took long pauses and spoke absolutely directly at each other.

An initial judgement on what we were hearing suggested that the room would be good for slower forms of music - Gregorian Chant or Enya for example. A public speech would be unintelligible beyond about 5 meters. Music of any complexity, speed or detail would simply be lost in the long reverb tail, thereby defeating the point of the music.

Fitters' Workshop results and discussion:

It is interesting to note that the ratio of internal dimensions of the Fitters' Workshop (2:3:10) is very close to an exact double of one of the classic "golden ratios" of concert halls (Volkmann's 2:3:5 proportion). This is a notable ratio as it results in very evenly distributed room modes, meaning low notes are not cloudy or muddied by an uneven distribution of room resonances.

Bearing in mind the space is currently empty with no designated stage area, we tested both the north-south and the east-west axis, corresponding to the classic "shoe-box" concert hall shape ("stage-end") as well as

an alternative orientation (“stage-side”) that might suit smaller or more intimate audiences. The sound source was placed in a typical performer’s position. This was monitored by microphone arrays in three representative audience positions as depicted in Table 1. The stage area was not actual, only hypothetical. Position 1 was chosen to be an ideal recording location at near front centre, position 2 was midway back and quite left, position 3 was at the rear and right of centre. Please refer to Table 2 for the results. As well as the measured values we have colour coded the fields to interpret the absolute values with regard to accepted standards where they exist and by our judgement where not. Please refer to Appendix 1 for more information about the criteria used.

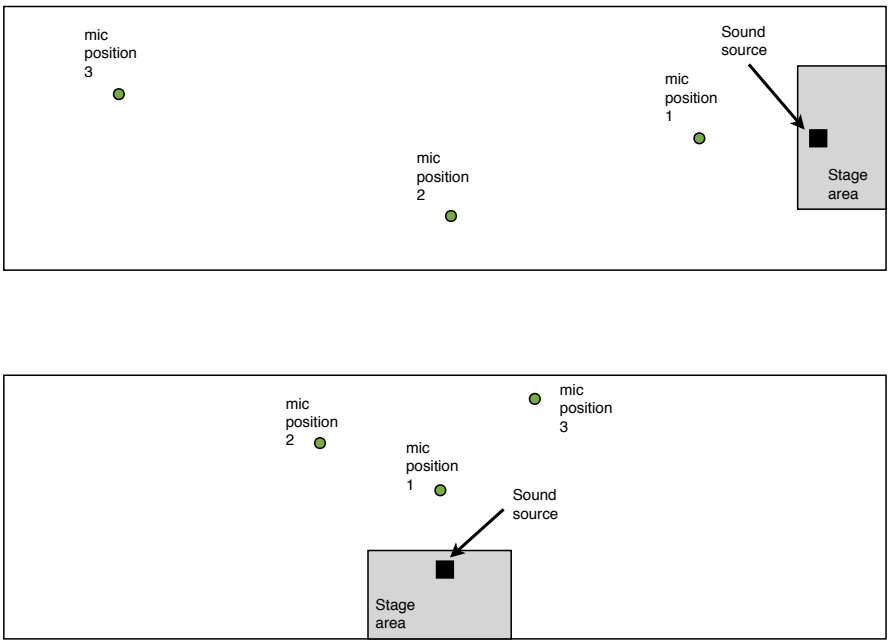


Table 1: testing layout

Category:	**Results:**	**Descriptor:** (App. 1)	**Location:**							
			source at end stage				**source at side stage**			
			mics at position 1	mics at position 2	mics at position 3	mics on stage	mics at position 1	mics at position 2	mics at position 3	mics on stage
Overall Criteria:	**RT_{20}**	(reverb time)	8.42s	8.59s	8.33s		9.09s	10.83s	7.28s	
	Echogram (App. 2)	(level of interfering echoes)								
	Frequency Response (App. 3)	(frequency smoothness)								
	Noise Level	(background noise)	53dBC				53dBC			
Speech Criteria:	**C_{50}**	(definition)	0.3dB	-3.4dB	-4.4dB		7.6dB	-5.2dB	-1.8dB	
	ALcons	(consonants intelligibility)	17.30%	26.33%	26.38%		8.59%	30.32%	21.07%	
	STI	(Syllable intelligibility)	0.42	0.35	0.34		0.55	0.32	0.39	
Music Criteria:	**Bass Ratio**	(bass fullness)	0.66	0.71	0.73		0.69	0.77	0.73	
	Centre Time 1kHz	(Clarity)	532.95ms	656.79ms	612.1ms		367.55ms	672.45ms	624.87ms	
	C_7	(directness)	-0.8dB	-6.7dB	-11.3dB		5.7dB	-12dB	-4.7dB	
	C_{80}	(temporal & register clarity)	1.3dB	-2.6dB	-2.6dB		7.9dB	-3.4dB	-0.7dB	
	Early IACC	(width)	0.78	0.38	0.27		0.93	0.32	0.34	
	Late IACC	(envelopment)	0.25	0.10	0.10		0.19	0.08	0.09	
	ST1	(performers hear each other)				-15dB				-15dB
	ST2	(performers hear room)				-12.4dB				-11.35dB
Interpretation Key:			not rated							
(Absolute ratings)			very poor							
			problematic							
			indifferent							
			fine							
			excellent							

Table 2: Fitters’ Workshop results

Without doubt the most significant feature of the space is the exceptionally long reverberation time, measured at between 7.28 and 10.33 seconds depending on location. This is caused by every internal surface being hard, resulting in very little sound energy being lost when it bounces around the space. A classic “bathroom” effect is created which in this case can assist slow singing voices and slow music in general. Fast music would become very chaotic in such an environment. As different music requires different reverberation times we decided to leave this unrated in the table although we find it hard to think of too many forms of music that suit a 10 second reverb time.

The Fitters’ Workshop has many echoes which mostly blend together to create a homogenous effect. The echograms (Appendix 2) are a way of depicting the echoes and in this case they have a non-ideal “choppy” appearance due to the lack of diffusing objects in the empty space. The frequency response graphs (Appendix 3) show whether the listener hears all frequencies (musical pitches) evenly. The results are fairly good and smooth apart from a low frequency “bump” in most. There is the usual variation to be expected from one microphone position to another. The measured response with the source at the side stage position and microphones in the “perfect seat” position was exceptionally flat all the way to very high frequencies.

The extreme reverberation makes speech problematic or very hard to understand at greater than five metres distance. The poor results in most of the speech criteria like ALcons (Articulation Loss of Consonants) and STI (Speech Transmission Index) are numerical evidence of this. The only exception is the quite good C_{50} definition score for the closest source to microphone position at the favoured “perfect seat” facing the side stage orientation..

The music criteria are likewise affected by the very long reverberation. The poor bass ratio would seem to reflect the lack of absorbtion of mid frequencies normally occurring due to carpets and seats in other venues, rather than a lack of support of the low frequencies. Likewise centre time is very high due to the long reverb tail, causing a lack of musical clarity. Directness (C_7) and time/frequency clarity (C_{80}) are also marred by the strong reverb field. The measures of width and envelopment (IACC) are good, indicating a well diffused sound field in listening positions 2 and 3. We have disregarded results for position 1 as the microphone is close to the sound source and a de-correlated sound field does not occur normally there. Finally the Fitters’ Workshop scores well with how the performer on stage hears their own sound (ST1) as well as what comes back from the room (ST2). These values are on par with many good concert venues.

As an empty room, the general evidence is that Fitters’ Workshop is only suited to a very limited range of music and not to speech at all. There is at least one position that produces excellent results in some criteria.

Comparative study results and discussion:

The testing methodology used for the Fitters’ Workshop was applied to six other local venues, to identify if there are unique qualities that make it superior for live instrumental or choral performance. Of all the possible venues ranging from clubs, cafes, theatres and halls we chose spaces that were used for similar musical purposes. We used our prior recording experiences to guide us where appropriate. The chosen venues needed to be regarded as good for unamplified music meaning a minimum of absorbtion from soft seats or carpets reducing the sound energy in the room. It was also deemed important to choose some well known reference points and several potentially deserving venues were ruled out because they were not “on the map” due to poor accessibility to performers and audiences for various reasons. From the beginning we were clear that lack of time meant that the survey of local relevant venues could not be comprehensive.

Three venues ie. St Christopher’s Cathedral, St Andrew’s Church and Wesley Uniting Church have all been used for external musical performances for a long time. The latter has also had a successful history of acoustic improvements carried out in recent decades. All three are characterised by high ceilings and many hard surfaces making them very appropriate for choral music. We chose the Albert Hall because it is a well known mid-large size space which has been recently refurbished with performance in mind. The Llewellyn Hall at the ANU School of Music is a versatile “flagship” venue with purpose built acoustics and a diverse range of performers appearing there, sometimes amplified and sometimes not. The Larry Sitsky Room at the ANU School of Music completed in 2011 is a recent addition to the music scene, aiming at delivering an

Venue Details:				Overall Criteria:				Speech Criteria:		
Name	**Seating Capacity**	**Floor space**	**Volume**	**RT_{20}**	**Echo Rating**	**Frequency Response Rating**	**Noise Level**	**C_{50}**	**ALcons**	**STI**
				(reverb time)	(level of interfering echoes)	(frequency smoothness)	(background noise)	(definition)	(consonants intelligibility)	(Syllable intelligibility)
Albert Hall	**480**	**656 m^2**	**4917 m^3**	**3.16s**	**2**	**3**	**53dBC**	**4.3dB**	**10.14%**	**0.52**
position 2				3.37s	3	1		-1.8dB	18.55%	0.41
position 3				3.32s	3	3		-2dB	17.90%	0.42
FW stage end	**400**	**498 m^2**	**4052 m^3**	**8.42s**	**6**	**6**	**53dBC**	**0.3dB**	**17.30%**	**0.42**
position 2				8.59s	6	6		-3.4dB	26.33%	0.35
position 3				8.33s	7	8		-4.4dB	26.38%	0.34
FW stage side	**400**	**498 m^2**	**4052 m^3**	**9.09s**	**5**	**1**	**53dBC**	**7.6dB**	**8.59%**	**0.55**
position 2				10.83s	8	5		-5.2dB	30.32%	0.32
position 3				7.28s	8	6		-1.8dB	21.07%	0.39
Llewellyn Hall	**1336**	**940 m^2**	**14000 m^3**	**1.8s**	**8**	**8**	**57dBC**	**10dB**	**4.75%**	**0.66**
position 2				1.86s	7	2		1.6dB	11.20%	0.50
position 3				1.92s	4	7		3.0dB	8.18%	0.56
Sitsky Room	**120**	**188 m2**	**1000 m^3**	**1.43s**	**1**	**7**	**54dBC**	**3.9dB**	**6.66%**	**0.60**
position 2				1.41s	1	4		1.9dB	7.88%	0.57
position 3				1.44s	1	5		2.5dB	7.08%	0.59
St Andrew's Church	**600**	**550 m^2**	**6090 m^3**	**1.74s**	**7**	**2**	**56dBC**	**5.1dB**	**6.68%**	**0.60**
position 2				1.73s	5	8		1.8dB	10.29%	0.52
position 3				1.67s	6	2		2.7dB	9.12%	0.54
St Christopher's Cathedral	**700**	**655 m^2**	**6320 m^3**	**3.26s**	**4**	**4**	**59dBC**	**5.2dB**	**7.46%**	**0.58**
position 2				3.31s	2	7		-1.9dB	19.00%	0.41
position 3				2.94s	2	4		-2.0dB	17.55%	0.42
Wesley Church	**350**	**260 m^2**	**2367 m^3**	**1.77s**	**3**	**5**	**50dBC**	**4.2dB**	**7.12%**	**0.59**
position 2				1.76s	4	3		1.4dB	10.99%	0.51
position 3				1.65s	5	1		1.6dB	8.99%	0.54
Interpretation Key:	**Size:**			**Time:**	**In General:**			**For Speech:**		
	smallest	**smallest**	**smallest**	**shortest**	**worst**	**worst**	**loudest**	**worst**	**worst**	**worst**
	biggest	**biggest**	**biggest**	**longest**	**best**	**best**	**quitest**	**best**	**clearest**	**clearest**

Table 3: Comparative study results

Venue Details:	Music Criteria:							
Name	**Bass Ratio**	**Centre Time 1kHz**	**C_7**	**C_{80}**	**Early IACC**	**Late IACC**	**ST1**	**ST2**
	(bass fullness)	(Clarity)	(directness)	(temporal & register clarity)	(width)	(envelopment)	(performers hear each other)	(performers hear room)
Albert Hall	**0.83**	**190.78ms**	**3.4dB**	**4.7dB**	**0.89**	**0.22**	**-18.05dB**	**-15dB**
position 2	**0.81**	255.81ms	-5.2dB	-0.1dB	0.32	0.10		
position 3	**0.81**	265.92ms	-9.4dB	-0.2dB	0.25	0.09		
FW stage end	**0.66**	**532.95ms**	**-0.8dB**	**1.3dB**	**0.78**	**0.25**	**-15dB**	**-12.4dB**
position 2	0.71	656.79ms	-6.7dB	-2.6dB	0.38	0.10		
position 3	0.73	612.1ms	-11.3dB	-2.6dB	0.27	0.10		
FW stage side	**0.69**	**367.55ms**	**5.7dB**	**7.9dB**	**0.93**	**0.19**	**-15dB**	**-11.35dB**
position 2	0.77	672.45ms	-12dB	-3.4dB	0.32	0.08		
position 3	0.73	624.87ms	-4.7dB	-0.7dB	0.34	0.09		
Llewellyn Hall	**1.27**	**69.08ms**	**9.2dB**	**10.6dB**	**0.90**	**0.38**	**-22.4dB**	**-19dB**
position 2	1.22	112.47ms	-1.4dB	3.2dB	0.63	0.18		
position 3	1.12	73.14ms	-1.8dB	4.8dB	0.17	0.10		
Sitsky Room	**0.75**	**105.93ms**	**0.1dB**	**5.3dB**	**0.47**	**0.16**	**NA**	**NA**
position 2	0.90	112.79ms	-2.7dB	4.7dB	0.31	0.17		
position 3	0.79	88.99ms	-6.3dB	5.4dB	0.17	0.11		
St Andrew's Church	**0.98**	**82.79ms**	**4dB**	**6.5dB**	**0.91**	**0.33**	**NA**	**NA**
position 2	**0.90**	156.9ms	-1.3dB	4.7dB	0.38	0.15		
position 3	**1.57**	143.22ms	-5.1dB	4.6dB	0.35	0.13		
St Christopher's Cathedral	**0.73**	**149.11ms**	**3.6dB**	**6.5dB**	**0.90**	**0.33**	**-14.85dB**	**-12.65dB**
position 2	0.77	294.27ms	-5.2dB	-0.5dB	0.41	0.09		
position 3	0.69	287.21ms	-6.2dB	-0.4dB	0.33	0.16		
Wesley Church	**0.76**	**101.45ms**	**2.5dB**	**6dB**	**0.86**	**0.29**	**NA**	**NA**
position 2	**0.74**	166.12ms	-1.9dB	3dB	0.41	0.09		
position 3	**0.75**	139.61ms	-4dB	3.3dB	0.33	0.16		
Interpretation Key:	**For Music:**							
	worst	**worst**	**worst**	**worst**	**worst**	**worst**	**worst**	**worst**
	best	**best**	**best**	**best**	**best**	**best**	**best**	**best**

excellent acoustic experience to a smaller audience. Although it can appear empty there is a lot of acoustic treatment on the walls and ceiling which controls reverberation and echoes.

Please refer to Table 3 for the results, ranked by colour code. Darker shades are intended to convey a better result. Whereas Table 2 uses colour to signify absolute correlation to accepted standards, in Table 3 the colour shading represents relative ranking. At a glance we can see that both the ANU School of Music venues score well according to the conventional concert hall criteria used in both speech and music categories. Both venues have a history of acoustic design and investment and they are intended to suit a diverse range of music while seating audiences in comfort. However Llewellyn Hall ranked less well from a performer's point of view whereas the Fitters' Workshop scored well there. The three churches perform reasonably well against the mainstream criteria even though they have been built to provide more specialised experiences. The Albert Hall had good frequency response and echogram results although the current stage may be reducing the performer related scores. The Fitters' Workshop performs relatively well for the IACC measures, no doubt because it has a lush reverberant sound field causing a wide and spacious sound.

Ambient noise is a real consideration especially in free standing spaces like churches and when recording or broadcast is happening. The Fitters' Workshop performed well for a free standing venue, better than a church like St Christopher's Cathedral in busy Manuka and also much better that Llewellyn Hall with its air conditioning noise. The Wesley Uniting Church had the quietest result.

The Fitters' Workshop is definitely unique among this group of spaces. Most notably its reverberation time is two to three times as great as all the other venues. This is also the reason it ranks poorly overall. The reverberation skews some of the other criteria like centre time and C_{50}. It is clearly not a standard concert hall and as is, it cannot fit conventional parameters.

St Christopher's Cathedral is a similar size and has similar wall, ceiling and floor surfaces, but measures dramatically differently. This can be attributed to presence of pews, rugs on parts of the floor, wall dressings and statuary, etc. Llewellyn Hall with its much greater volume has a lower reverberation time when empty, due to the use of carpets and soft seats. Introducing an audience into it would reduce the reverberation a little but not radically change its acoustic parameters.

Doing this study we have come to the opinion that the Fitters' Workshop cannot be usefully compared to other spaces, as it is the only untreated and totally empty space. It is acoustically highly sensitive to what is put into it. There is no doubt that if it had seating and other acoustically absorbing and diffusing elements like a stage and an audience, it would behave very differently. The measured acoustic parameters would be much improved by the real world absorbtion and diffusion of a musical event, the key factor being the number of people attending.

Evidence supporting this is in a CD supplied to us by the Committee of sound recordings made there with live audiences. In our opinion as recording practitioners, the perceived quality of the room is excellent and nothing like what we measured when it was empty. The reverberation time with audience etc is obviously not seven to ten seconds (as measured empty) and is subjectively about three to four seconds. Likewise we would expect the speech and music criteria to be improved with seating, audience and stage. The bottom end of these recordings is not loud which backs up the bass ratio we measured. But it open and clear and feels like it extends a long way down without sounding cloudy or muddy, possibly a result of the favourable ratio of internal dimensions.

Proposed basic fitout:

We are mindful that any proposed fitout as a performance space should preserve the current acoustics as much as possible to suit past successful uses, for instance for the Canberra International Music Festival. But also a space needs to be viable year round and this means being able to accommodate a wider range of uses. So as well as needing to preserve the current acoustics we must to be able to reduce the reverberation time on demand. A short list of internal alterations could be:

• Modular and movable acoustic treatment
• permanent electricity and lighting
• portable seating
• portable modular staging
• approved fire exits
• art hanging system

Externally these features can be added, in the knowledge that the internal acoustics would not be affected:

• toilets
• backstage space and/or green room
• storage space for chairs and other movable furnishings
• entrance foyer or ticketing space

It should also be noted that introducing a standard HVAC system would be detrimental to the acoustic. Noise generated by these systems and the resonant spaces that the pipes would create, would defeat the very thing that that is trying to be preserved. If climate control is a concern, there may be systems, such as hydronic heating and cooling of the slab (potentially silent as the boiler can be located well away from the building, and acoustically and physically invisible), that may be appropriate for this space. This is beyond the scope of this report but it is a factor that plays a role in the acoustic of any room. For now we have decided not to factor in heating and cooling.

We have created a virtual acoustic model in EASE software of the empty room and ensured that its predicted acoustic results conform to the measured values, within margin of error. Electricity, lighting and an art hanging system could be installed to have insignificant impact on acoustics so can be disregarded in the model. We are not qualified to comment on suitable fire exits but believe that replacing the doors (2% of the room's surface area) could also have a small impact on acoustics. This leaves portable seating and staging, modular acoustic treatments, potentially in the form of carpet or curtains, and an actual audience to be modeled as alterations to the current space.

When thinking of how to make alterations to the Fitters' Workshop, we can look to the Wesley Music Centre as a interesting model. Although it is a much smaller space, in an empty state we have verified it is highly reverberant, but it can also achieve a much more controlled acoustic. Its design by Garth Mansfield and the late Eric Taylor is characterised by variable acoustic elements which are easily adjusted to suit the occasion and audience numbers. Although different techniques would need to be used for the Fitters' Workshop, the idea is the same, that is, variable acoustics. For instance this could be achieved with a combination of movable carpets, portable chairs, a modular stage and curtains that tuck or roll away to become acoustically insignificant when not needed.

Fitters' Workshop acoustic modeling :

We took detailed internal measurements of the space and turned this into a three dimensional model in EASE. We then incorporated the existing room materials into this model and confirmed that the predicted results for reverberation time were suitably close to the actual measured results. This then enabled us to put alterations like chairs into the model and see how the reverberation times at different frequencies were affected.

In Appendix 4 we include graphs of the reverberation times of the actual measured empty room, a predicted empty room, a predicted room with chairs and curtains and finally an audience of 280-300 people added. The latter option has significantly reduced reverberation times and we would expect that it would sound similar to the CD recording we heard. The modeling proves that with simple additions the Fitters' Workshop acoustic is transformed. At 1kHz the predicted reverberation time with alterations and audience is 2.4s, compared to the measured empty room which is 9.1s at 1kHz. It is still a unique live and airy space, and without the liability of excessive reverberation. It could be termed "luxurious" instead of "out of control". There would be a broader range of music that would sound very good in the altered Fitters' Workshop.

Our modeling also indicates that this venue could give a relatively similar listening experience (C_{80} is -4dB) to 70 - 75% of an audience. More modeling would need to be done to determine the uniqueness of this fact but initial cursory examinations of a previous project show a maximum of around 25 - 45% get a similar experience. According to Ahnert and Schmidt the predicted C_{80} clarity measure is fine for slower classical music like Brahms or Wagner but not appropriate for faster passages in Mozart or Haydn for instance.

The speech criteria are not radically changed by the alterations. For most places in the audience area the STI (Speech Transmission Index) is 0.38 which is judged as satisfactory according to conventional criteria. The ALcons (Articulation Loss of Consonants) measure remains troublesome as over 65% of seats would have a loss figure of over 20% which is considered unsuable.

Conclusion:

The Fitters Workshop is undoubtedly a unique acoustic performance space in Canberra. In its empty state it is initially a curiosity, and it is acoustically problematic, especially for speech. With at least chairs and audience present it is highly suited to slower, ambient, and sparsely instrumented forms of music. The recordings demonstrate subjectively that for these genres it can be superior to local churches and other venues.

It is not the purpose of this report to decide whether the Fitters Workshop be kept as a music venue but to provide information that may help form that decision. If it is decided that it should be used as a music venue then how exactly the space will be utilised is the next question that needs to be addressed.

Whether there are the performers, material and audience to support an ongoing music program of a style appropriate to the acoustic is a matter for someone else to determine. If the answer to this question is no, then the issue of using the space as a multi- purpose and modular space should be investigated.

In either case the current “blank slate” condition of the space should be preserved lest we destroy the unique acoustic we are trying to preserve and as such, any treatments that need to be introduced to alter the room acoustic in order to make it suitable for other uses and any furnishings to make it habitable need to be modular in nature, moveable and on the whole temporary. This would open the space up for a greater variety of music performances and also to a range of other possibilities such as exhibitions, large scale art installations and as a creative development or workshop space. With simple alterations, the Fitters’ Workshop can retain all the acoustic qualities known and experienced already by audiences, but also be put to other uses.

Our modeling work in this report should be seen as indicative of directions worth pursuing. If a decision is made to retain the Fitters’ Workshop in its current form, there needs to be an acceptance of its acoustics with a realism and clarity around what the space could be potentially used for. It is very likely that even after the proposed minimal alterations it can never be made to suit all forms of music, media or performance.. Even with an audience it may have a longer reverberation time than other venues tested. Further acoustic modeling of the space should be central feature of any design process.

With a space having such sensitive acoustics as the Fitters’ Workshop we urge that any alterations should be made and assessed carefully. If it is retained the space may need to be tried out for a variety of uses and we need to learn from that real world experience. After a year or two it is quite possible that a second round of alterations would become advisable.

Finally, we have come to the view that the Fitters’ Workshop has merit as a venue for certain styles of music. If retained in its current form it could become a functional and complementary extension to the range and variety of venues in Canberra.

Disclaimer:

This report is for the benefit and use of the client the ACT Legislative Assembly. The information and assumptions used in writing this report have been provided to us by the client and by direct measurements in the field. Although every care has been taken to ensure the accuracy of our findings and to provide a good appraisal of the acoustic spaces for the client, this report does not contain results or recommendations that can be implemented without further consultation.

KVDL Acoustic Consultants
Kimmo Vennonen
Duncan Lowe

Appendix 1: Descriptions of Criteria

RT_{20} (reverb time) The reverberation time RT is the time taken by a stopped sound to reduce to one millionth (or 60dB) of its initial volume. In our case to get the most reliable readings we chose the RT_{20} method. According to ISO 3382 the sound pressure is measured as it drops from -5dB and -25dB and then this drop of 20dB is extrapolated to arrive at the figure of how long it would take to drop 60dB. Rooms with long reverberation times sound "lush" to the point of being "washy" if to long, whereas too short a time can make something sound "dry" or even "tunnelly".

Echo Rating (level of interfering echoes) We examined an echogram from each position and venue and compared them to each other to rate them best to worst. The echogram is a graph of the volume of a stopped sound (typically an "impulse") versus time, allowing any echoes to be identified. A good echogram would look very smooth, ideally a straight line sloping downwards as the sound level decays. An average one would look like a saw blade, (ie many insignificant small echoes) and a bad one would have obvious large bumps representing audible echoes.

Frequency Response Rating (frequency smoothness) Ideally every room is a level playing field for sounds, that is, it doesn't favour one note or octave over another. However in practice this is never the case. Measured responses are graphed as volume versus frequency so a flat line response is the best. The measurements we took are affected by sound source placement, plus the response of the source and the microphone as well. All anybody can do is compare one graph to another, factor out the test related variations and look for relative flatness.

Noise Level (background noise) Every venue has some level of background noise, expressed in dB. Too much noise can impair recordings and spoil the performance for a live audience. We use the dBC weighted scale which is more effective at measuring the effect of low frequency rumbles caused by traffic and air conditioning.

C_{50} (definition) This is a measure relevant to speech definition and is calculated from the log (or dB) ratio of sound energy arriving in the first 50ms versus all that follows. In other words a lot of late reverberation can mess up how we hear a stream of words. A value of -2dB is considered to be the minimum for good speech intelligibility.

ALCons (consonants intelligibility) The Articulation Loss of Consonants is and alternative measure to C_{50} for the assessment of speech intelligibility. Ideally, less than 3% of consonants are lost and a good result is 3% to 8%. 8% to 11% is still good intelligibility, 11% to 20% loss is poor and more than 20% loss is accepted as worthless intelligibility.

STI (Syllable intelligibility) This is a well known measure of how speech is conveyed from a source to a listener, taking into account background noise as well as room effects. A poor result is less than 0.3, whereas a satisfactory result is 0.3 to 0.45. The index is good from 0.45 to 0.6, very good 0.6 to 0.75 and excellent above that.

Bass Ratio (bass fullness) For music it is often desirable for the room reverberation times of low frequencies to be longer than for mid frequencies whereas for speech the opposite is true. A preferred bass ratio for music according to Beranek is 1.0 to 1.3. Too small a bass ratio would make low notes below about 350 Hz feel less "full" in the room than the "live" sounding notes higher up. However a low bass ratio in a room would not necessarily spoil the experience hence we have rated this as indifferent in the case of the empty Fitters' Workshop.

Centre Time 1kHz (Clarity) This measure corresponds to the point in time when the sound energy received before then is equal to the energy received after then. A long centre time makes music sound more "spacious" and for concert halls a value of 70 to 150ms is considered best.

C_7 (directness) It can be useful to know the ratio of the sound level coming directly from a source, compared to all the reverberation and reflections afterwards. This is done by expressing in dB the value of sound energy received in the first 7ms divided by all the later energy. With the C_7 measure according to Ahnert it is

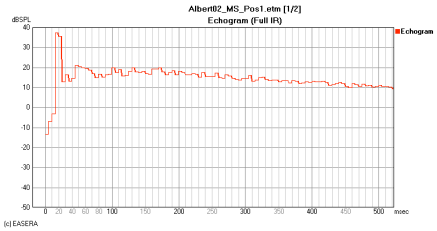
said that the direct sound level should not fall below a range of -10 to -15dB. It is to be expected that listeners further back from the sound source will hear less direct sound and more room reflections and reverberations.

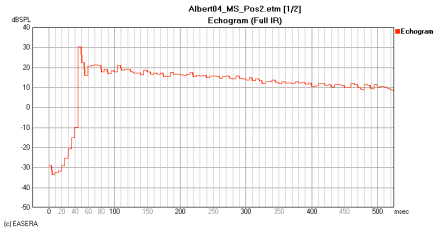
C_{80} (temporal & register clarity) This is a useful measure of clarity for music especially when it has fast passages. It is calculated similarly for C_{50} except that the relevant time is 80ms. According to Abdel Alim classical music like Mozart and Haydn requires a C_{80} figure of more than -1.6dB, but Brahms and Wagner need greater than -4.6dB. A compromise figure for all classical music is said to be -3dB but for slow sacral music a C_{80} of -5dB is acceptable.

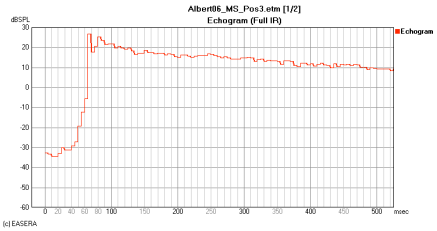
Early IACC (width) & **Late IACC** (envelopment) Interaural Cross Correlation according to ISO 3382 is a measure of the spatial aspects of music corresponding to percceptions of width (o to 80ms) of the sound source and being enveloped (80 to 500ms). It is measured using binaural dummy head microphones and low correlation values are considered good. According to Beranek an excellent to superior concert hall has an early IACC of 0.28 to 0.38, good to excellent halls are 0.39 to 0.54 and fair to good halls are 0.55 to 0.59. In our measurements the close ones in position 1 could be disregarded for IACC purposes as there would be too much direct sound causing high correlation.

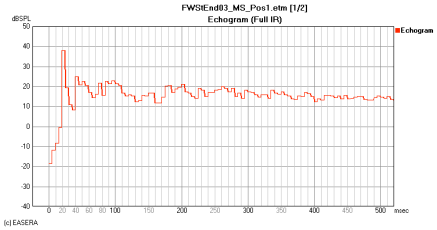
ST1 (performers hear each other) and **ST2** (performers hear room). These are both measures of room support for musicians and are measured on stage. Typical ST1 values for European concert halls are between -15dB and -12dB. ST1 is important as musicians need good acoustics on stage to hear each other clearly. There is no consensus on what the ideal ST2 value is, but lower means less sound coming back from the room to assist the performer to make creative judgements.

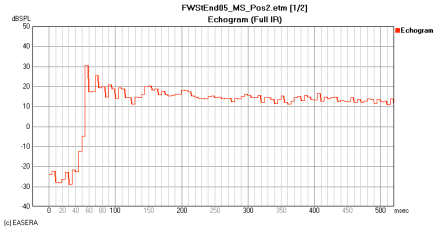
Appendix 2: Echograms

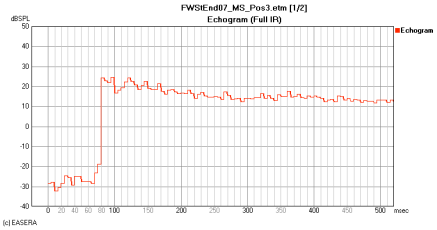


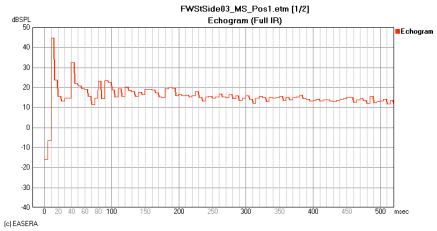


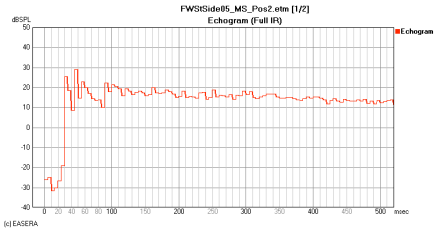


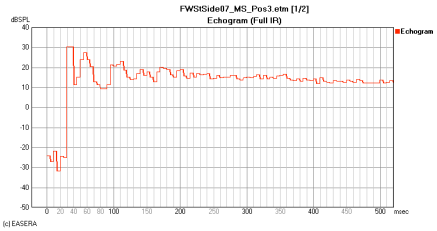


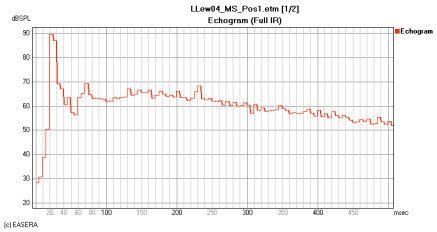


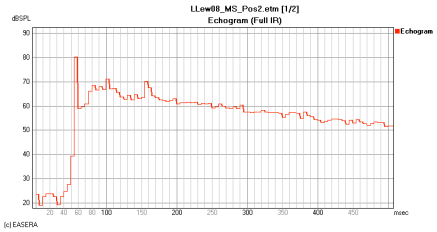


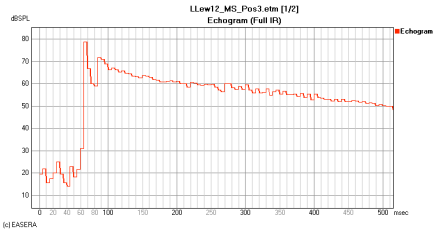


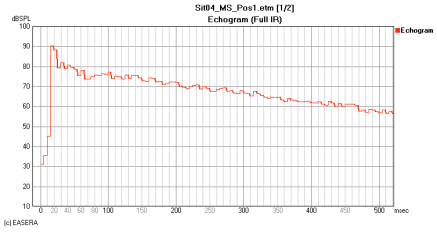


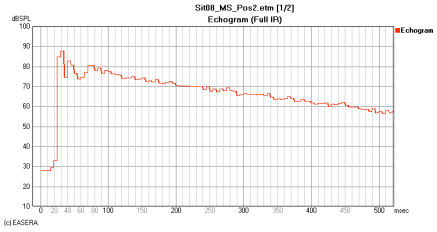


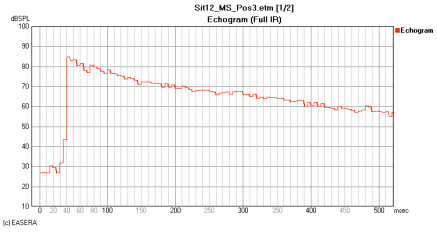


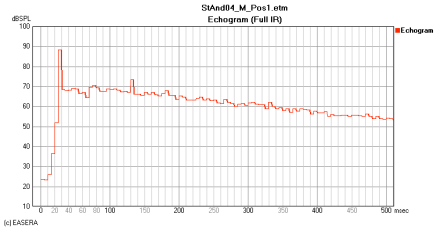


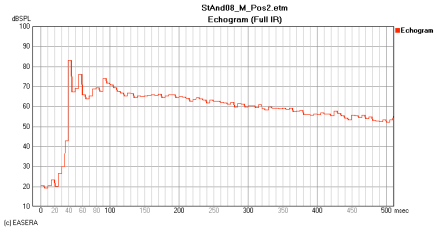


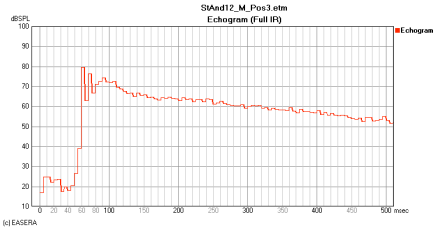


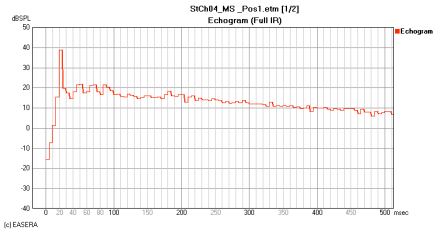








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Echogram
msec
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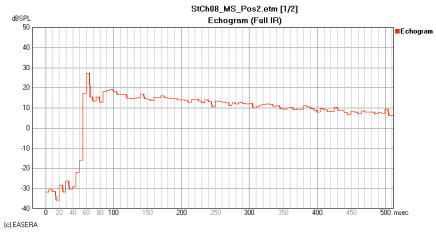
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msec
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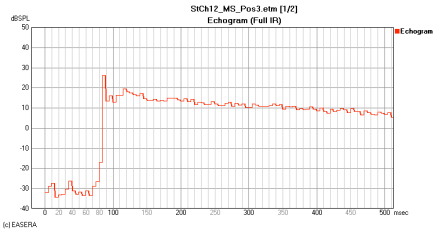
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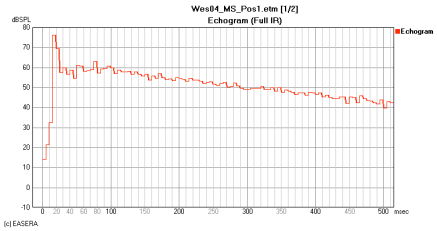
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dBSPL
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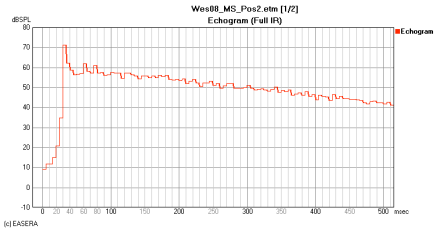
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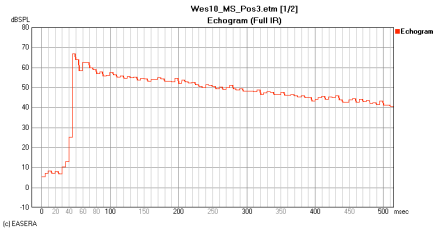
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dBSPL
Echogram
msec
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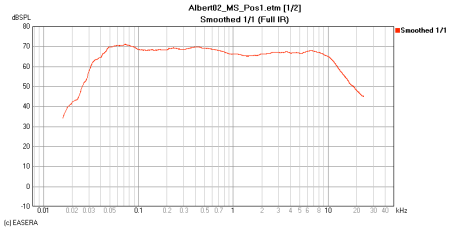
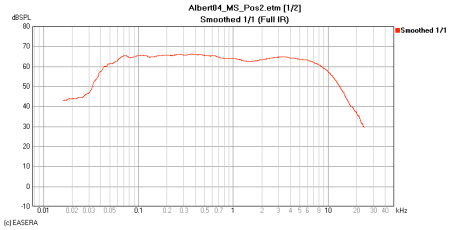
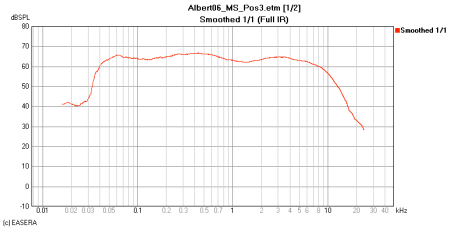
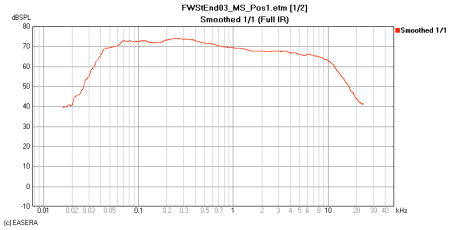
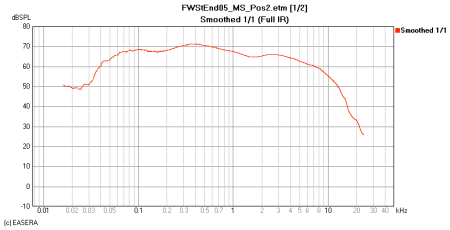
Appendix 3: Frequency Response

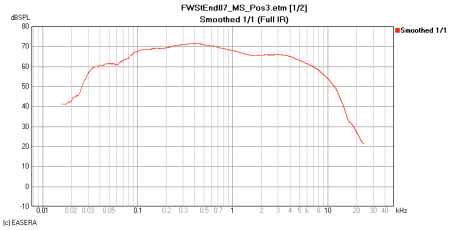


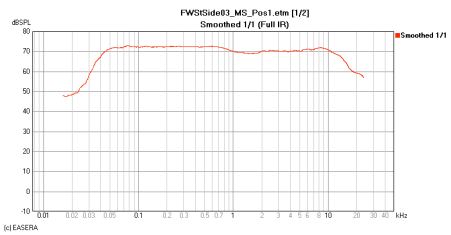


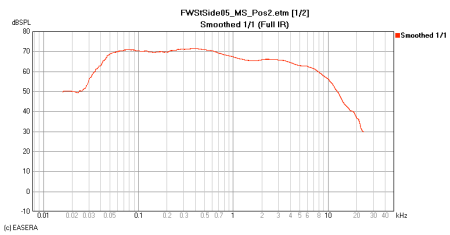


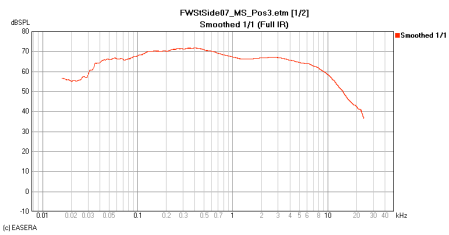


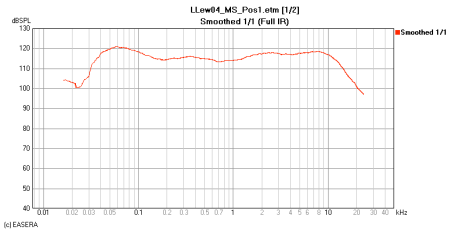


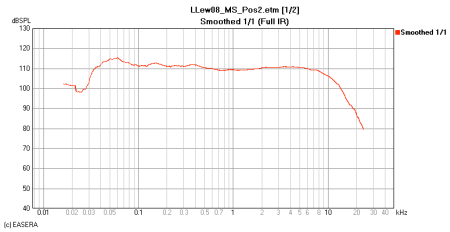


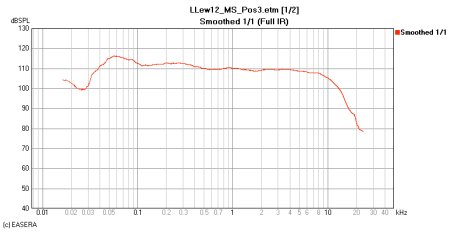


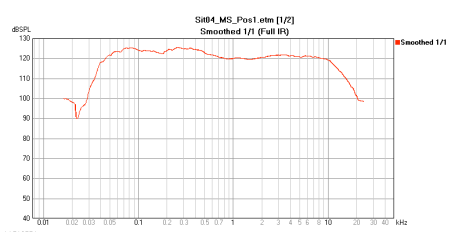


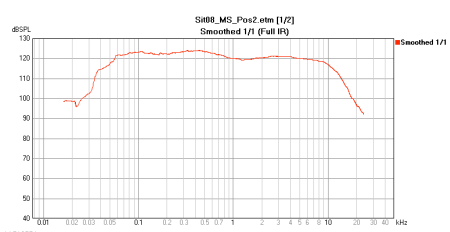


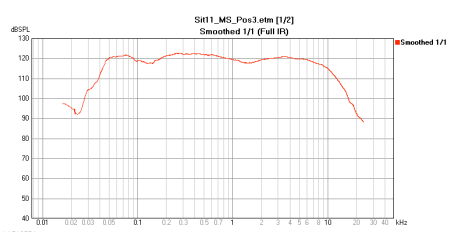


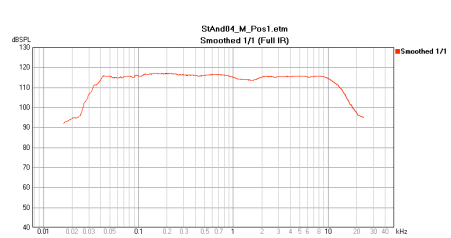


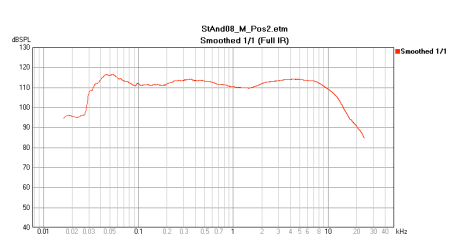


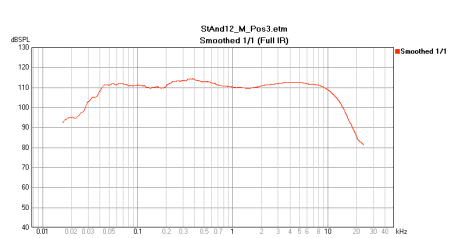


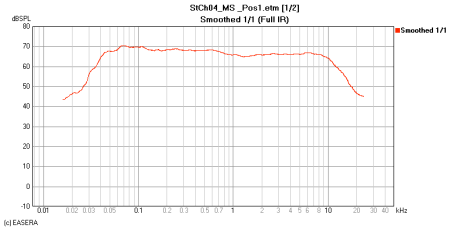








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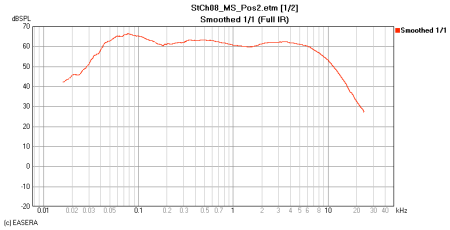
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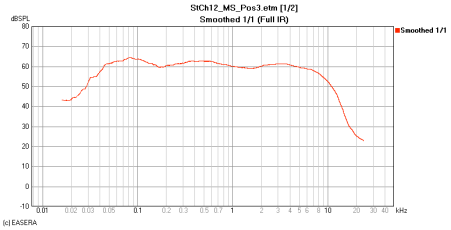
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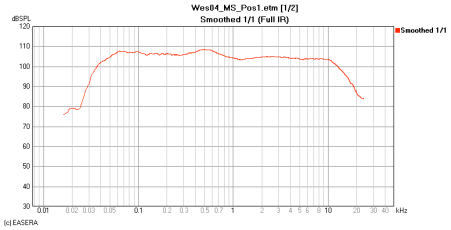
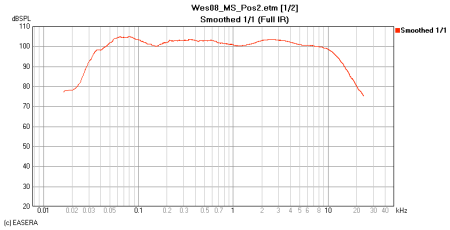
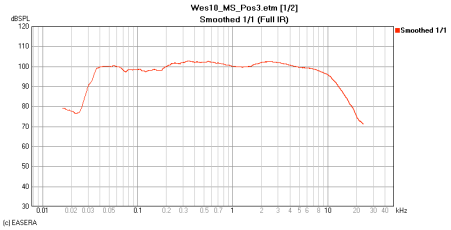
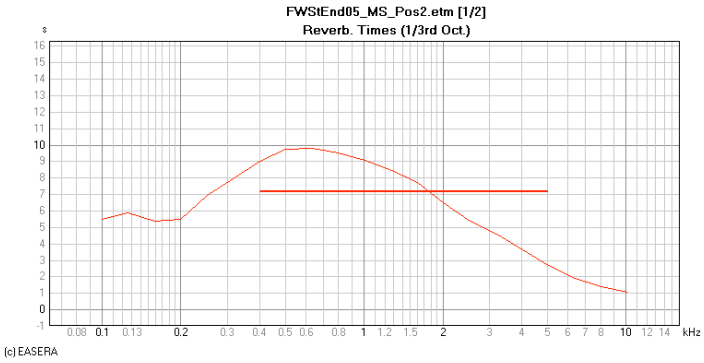
(c) EASERA


Wes04_MS_Pos1.etm [1/2]
Smoothed 1/1 (Full IR)
dBSPL
Smoothed 1/1
kHz
(c) EASERA

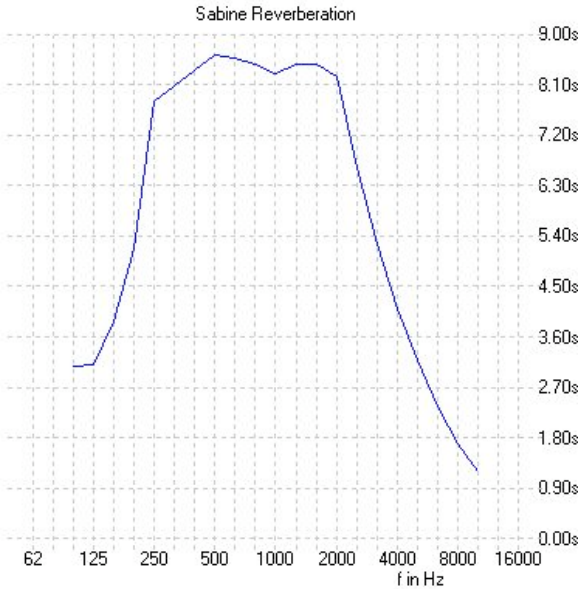

Wes08_MS_Pos2.etm [1/2]
Smoothed 1/1 (Full IR)
dBSPL
Smoothed 1/1
kHz
(c) EASERA


Wes10_MS_Pos3.etm [1/2]
Smoothed 1/1 (Full IR)
dBSPL
Smoothed 1/1
kHz
(c) EASERA

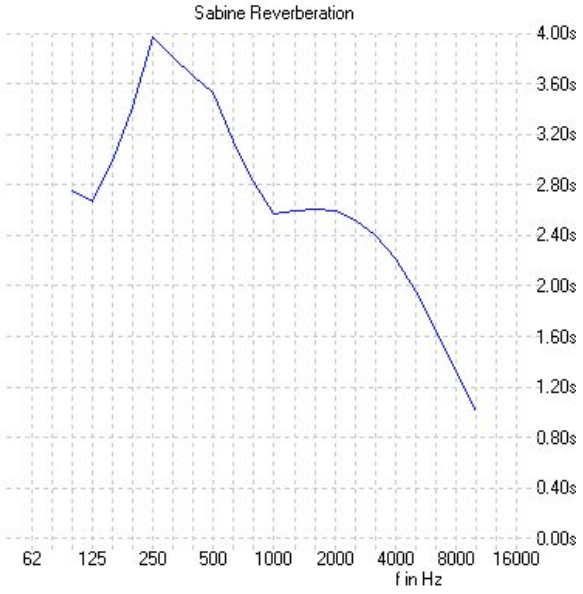
Appendix 4: Modeling Results



Measured Fitters' Workshop reverberation times - note 9s reverberation time at 1kHz



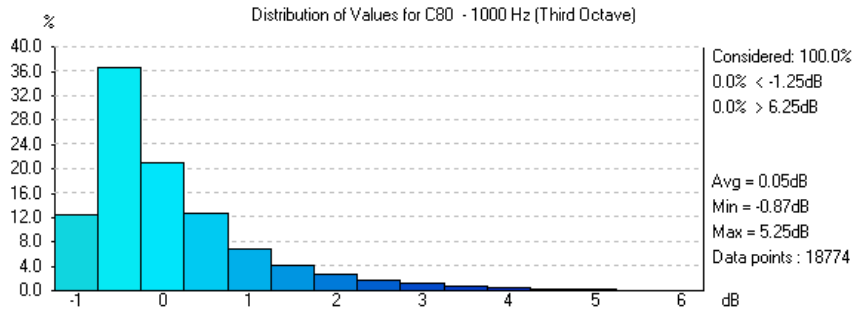
Modeled empty Fitters' Workshop



Modeled Fitters' Workshop with seats & curtains

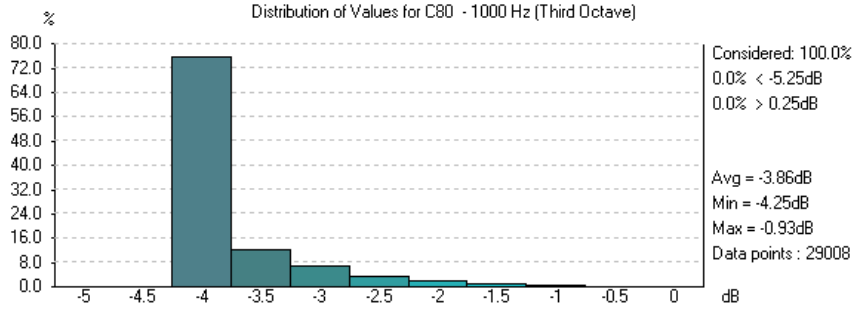
Modeled Fitters' Workshop with seats & curtains & audience of 280

18774 C_{80} values distributed around a previously modeled large room - note highest band at 36% of all values.



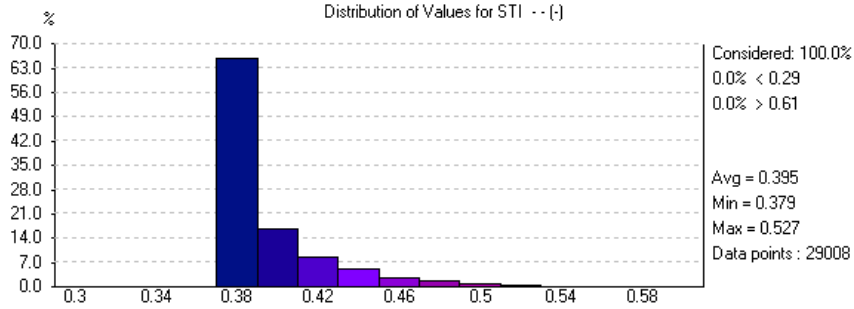
(c) EASE 4.3 / NCC Mix Desk Rear / 7/02/2012 8:21:42 PM / KVDL Acoustic Consultants Duncan Lowe

C_{80} values in altered Fitters' Workshop - note about 75% in the room have C_{80} = -4dB



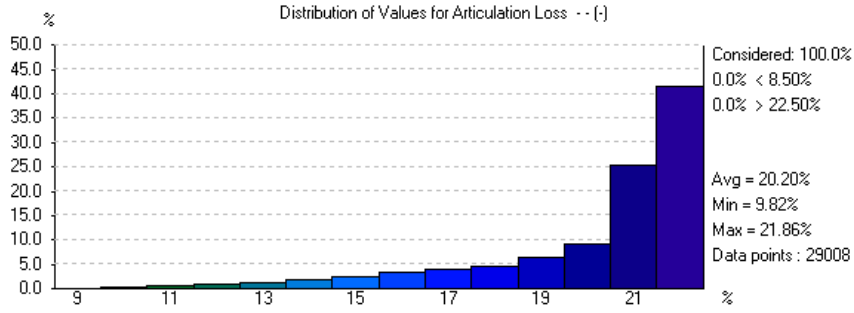
(c) EASE 4.3 / Fitters Workshop BasicModel +~280 People in WoodSeats / 7/02/2012 8:27:02 PM / KVDL Acoustic Consultants

STI values in altered Fitters' Workshop - note most places in the room have STI = 0.38.

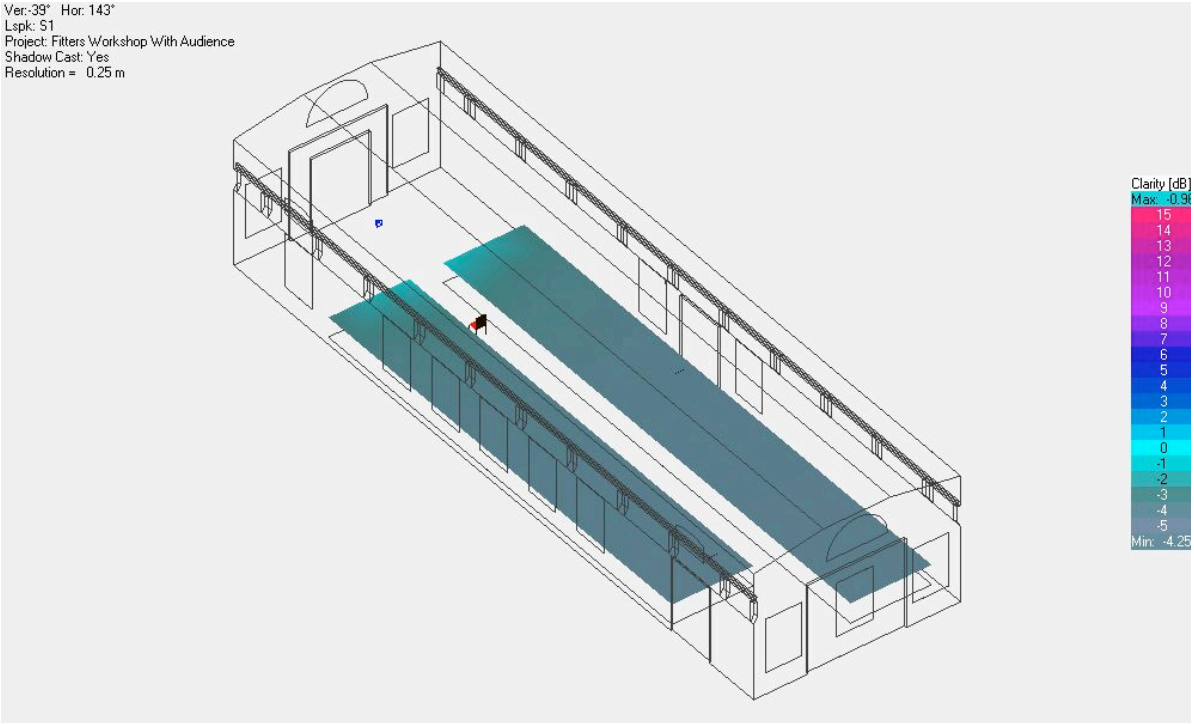


(c) EASE 4.3 / Fitters Workshop BasicModel +~280 People in WoodSeats / 7/02/2012 8:40:03 PM / KVDL Acoustic Consultants

Articulation Loss in altered Fitters' Workshop - note over 65% of seats have ALcons > 20% which is considered unusable for speech.



(c) EASE 4.3 / Fitters Workshop BasicModel +~280 People in WoodSeats / 7/02/2012 8:55:00 PM / KVDL Acoustic Consultants



An EASE model of the uniformity of the C_{80} criterion across the room. Note the audience areas in dark shade have almost uniform colour except at the very front, showing a very similar predicted clarity across the audience.