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THE CONTRIBUTION OF LATER SOUND IN THE ACOUSTIC PREFERENCES FOR SYMPHONY ORCHESTRA MUSICIANS

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ABSTRACT

Recent work on ensemble conditions for orchestral musicians has led to better understanding and the development of criteria and guidelines for the design of rehearsal and performance spaces.

In this paper we present observations based on three recent projects involving professional orchestral venues – the acoustic tuning of a 7500m^3 rehearsal studio in Brisbane with adjustable overhead reflectors and operable absorption banners, the tuning of an electro-acoustic stage shell in a 2,100 seat theatre in Auckland, and the renovation of a 2,400 seat concert hall in Melbourne.

Surveys completed by orchestral musicians, input from external listeners, and 3D room acoustic measurements using IRIS were employed to analyse the changes to the acoustic conditions during the tests.
We comment on the design of the rehearsal venue with reference to the guidelines provided in *ISO 23591 2021 Acoustic quality criteria for music rehearsal rooms and spaces*.

We then consider the role of the late sound in the preferred acoustic response from the orchestral musicians and discuss design implications for rooms for rehearsal and spaces for performance to a larger audience.

Keywords: *orchestra, musicians, preferred conditions, later sound*

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1. INTRODUCTION

Many experienced performers have commented on the value of hearing their own sound in a venue.

Renaud Capuçon – violinist – "I had a feeling of comfort. I felt surrounded by music…" [1]

Hélène Grimaud – pianist - "It's so nice to be in a space where you can have a physical experience of the sound - where the sound goes through you and envelops you at the same time." [2]

An experienced musician provided a description of how the late sound in a venue changed their perception of violinist Isaac Stern's sound in a new venue before a rehearsal "…he put his bow to the violin and began to warm up. I was startled as a gritty almost rough sound emanated from the instrument….. Stern continued playing as he walked away, and with a little distance, and the reverberation of the hall, I heard a beautiful, rich tone emerge as he filled the hall with a wonderful, robust, and vibrant sound that simply wasn't as apparent at close range." [3]

This paper considers these comments in reference to the working conditions for orchestral musicians.

2. THE ORCHESTRAL REHEARSAL VENUE

In 2022 Marshall Day Acoustics was requested to address the rehearsal room acoustic conditions for the musicians of the Queensland Symphony Orchestra (QSO), a full-time ensemble with 75 permanent musicians based in Brisbane, Australia.

We were asked to recommend changes to the acoustics of the space, to address the high on-stage sound levels, and the musicians' comments on the sound quality of the venue for orchestral rehearsal.

The Orchestra regularly rehearses in this rectangular, purpose designed venue, which has fixed raked seats at one end for an audience of 206. The nominal dimensions of the venue are 28m x 21m x 14m, with an estimated volume of 7500m^3.

The venue includes 4 gently curved 15m x 2.8m reflector panels installed over the musicians. These panels are mounted on chain motors and can be adjusted for height (up to 11m above floor level) and tilt.

The lower walls surrounding the musicians are treated with moderately diffusing timber panels, with operable drapes mounted on tracks behind and beside the rehearsal area. Operable absorption banners are installed around the upper walls of the room with a drop of up to 5.8. from the ceiling. The venue is shown in Figure 1.

Figure 1: The QSO rehearsal venue

3. VENUE TESTING

The room had regularly been used as shown in Figure 1, with all available absorption banners deployed, the overhead reflectors lowered to 7.5m above the floor, and the rear drapes partially deployed. This configuration produced strong early overhead reflections with the shortest reverberation time available using all operable absorption.

We believed that the high sound levels were resulting from the strong overhead reflections encouraging the musicians to play more loudly than normally required, and the available absorption was fully deployed to reduce the reverberance of the room as much as possible.

Our strategy was to establish the orchestra's preferred acoustic conditions by varying the position of the overhead reflectors and the amount of absorption banners deployed in the room. We developed 4 configurations of the venue by adding temporary absorption at mid-level in the room above the timber diffusion panels, varying the extent of the upper-level operable banner absorption, and varying the height of the reflector panels. This was designed to change the reverberant level in the room, change the distribution of the reverberant energy, and vary the strength of the early overhead reflections.
The room configurations are summarised in Table 1.

Table 1: Measured reverberation time T30 in the tested configurations

Configuration	Reflectors	Operable Banners	T30(s)
1	Low 7.5m above floor	All banners fully deployed	1.1
2	High 11.0m above floor	All banners fully deployed	1.1
3	High 11.0m above floor	All banners fully retracted	1.6
4	Mid 9.0m above floor	All banners 50% deployed	1.3

The room acoustic parameters were measured with IRIS, our room acoustics measuring system, using the source and microphone positions shown in Figure 2.

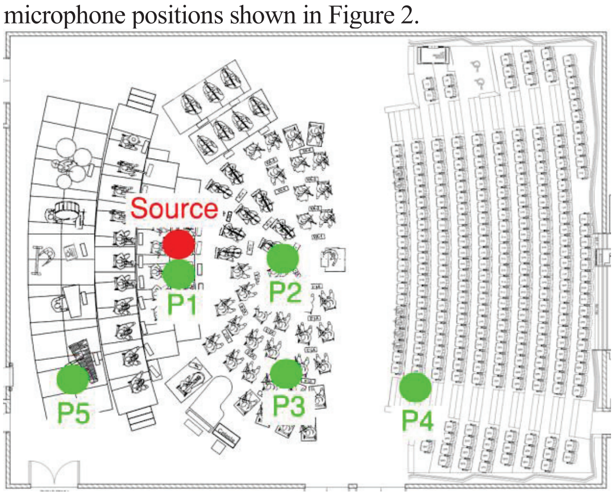

Figure 2: Source and microphone positions used for the measurements

Musicians performed a selection of familiar repertoire in each of the configurations. This consisted of:

- Mozart – Symphony No 41 – 1st movement
- Brahms – Symphony No 4 – 2nd movement
- Holst – Jupiter from The Planets.

Subjective assessment was made throughout the orchestra and in the audience area during the tests. Musicians and orchestral staff were asked to complete a short survey after playing and listening in each configuration, and this data was analysed. The survey included sliding scale responses to impressions of reverberance, clarity of self, section and whole ensemble, and overall level, with additional space for comments.

The subjective impression of the different configurations is summarized in Table 2.

Table 2: Summary of musician responses to the tested configurations

Configuration	**Impression**
1 Low reflectors Maximum absorption	Too dry to develop a blended sound Clearest sound quality but dead Moderate loudness
2 High reflectors Maximum absorption	Moderate reverberance Moderately clear Higher reflectors improve the blend of the sound
3 High reflectors Minimum absorption	Too reverberant, too loud Unclear and not suitable for rehearsal Preferred by the brass section who enjoyed the projection of their sound
4 Mid level reflectors 50% banner absorption	A more controlled sense of resonance Sound blend was improved without sounding muddy

Configuration 4 was found to be the preferred configuration for orchestral rehearsal.

4. COMPLIANCE WITH ISO 23591

ISO 23591 2021 Acoustic quality criteria for music rehearsal rooms and spaces is a valuable resource for the design of music rooms. Its principal guidelines for the design of large rehearsal rooms for loud acoustic music together with the corresponding data from the QSO studio are shown Table 3.

Table 3: Criteria from ISO 23591 compared with the features of the QSO rehearsal venue.

	Recommended criteria	**QSO Venue**	
Number of musicians	>25	90	
Net volume	>30 x N m^3 ($2{,}700\ m^3$) >60 x N m^3 for extra loud groups ($5{,}400\ m^3$)	$7500\ m^3$	✓
Net area	≥ 120 m^2 + 2 x N m^2 ($300 m^2$)	$588 m^2$	✓
Net average room height	≥ 5.0 m	14m	✓
Room geometry	L/W < 1.6	1.3	✓
Acoustic treatment	Ceiling absorption Bass absorbers Diffusors Reflector Variable absorption		✓ ✓ ✓ ✓ ✓
Reverberation time T	1.2 s – 1.8 s	1.3s	✓

ISO 23591 includes a graph showing recommendations for the reverberation time Tmid relative to room volume. The

upper and lower limits for loud acoustic music are indicated in area 2.
We reproduce this graph with area 2 highlighted, and include the volume and measured T30 for the QSO rehearsal venue.

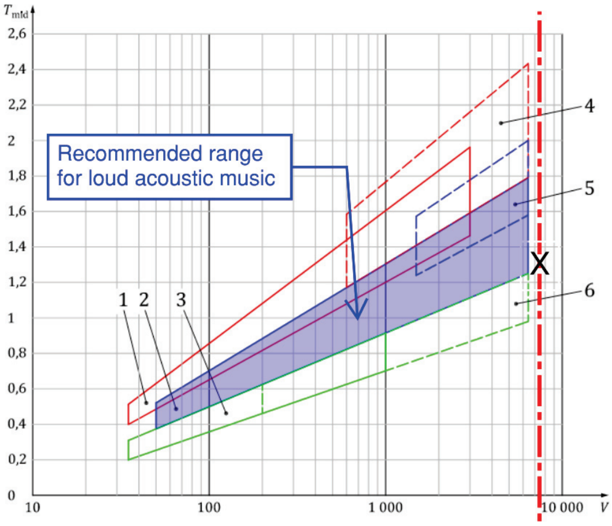

Figure 3: Image from ISO 23591, showing the recommended relationship between T_{mid} and room volume with values for the QSO rehearsal venue

The volume of the QSO reherasal venue is a little larger than the venues covered in ISO 23591, and the reverberation time T in the preferred configuration is close to the lower end of the range.

We conclude that the QSO rehearsal venue satisfies the recommended criteria in ISO 23591. However, the original height of the overhead reflectors and the extent and location of the operable absorption were not creating conditions preferred by the musicians.

Other measured room acoustic and stage support parameters are shown in Table 4.

All room parameter values are averaged for positions P2 to P5, and the stage support parameters were measured at P1 (refer Figure 2).

Table 4: Measured room acoustic parameter values

Config	T (s)	EDT /T	C80 (dB)	Ts (ms)	ST Early (dB)	ST Late (dB)
1	1.1	0.99	4.1	65	-12.8	-16.2
2	1.1	1.03	3.9	65	-17.0	-18.0
3	1.6	0.95	1.3	99	-16.4	-14.4
4	1.3	0.99	2.6	77	-14.5	-15.5

This data indicates that:

- the reverberation time (T) is strongly correlated with the extent of deployed absorption
- the variation of EDT is below the JND (0.1s)
- the clarity (C80) and centre time (Ts) are strongly correlated with the reverberation time (T)
- the early stage support (ST Early) is strongly correlated to the reflector height.
- the late stage support (ST Late) is weakly correlated to the extent of deployed absorption.

5. ENERGY DISTRIBUTION

Kahle[4] refers to "source presence" and "room presence" in reference to the early and late sound as perceptual factors of significance for musicians.

We looked for the changes in the late sound from the IRIS plots. These provide information on the arrival time of reflections after the direct sound by colouring the vectors according to the scale shown in Figure 4.

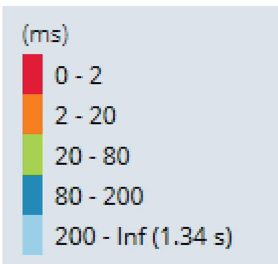

Figure 4: Colour code used to label the time delay of the measured reflections in IRIS

Analysis of the 3D IRIS plots for configuration 1 (the driest) and configuration 4 (preferred) for microphone position P2 provides some insight.
The red vector points to the sound source to the right of the image with the z axis vertical in the room.

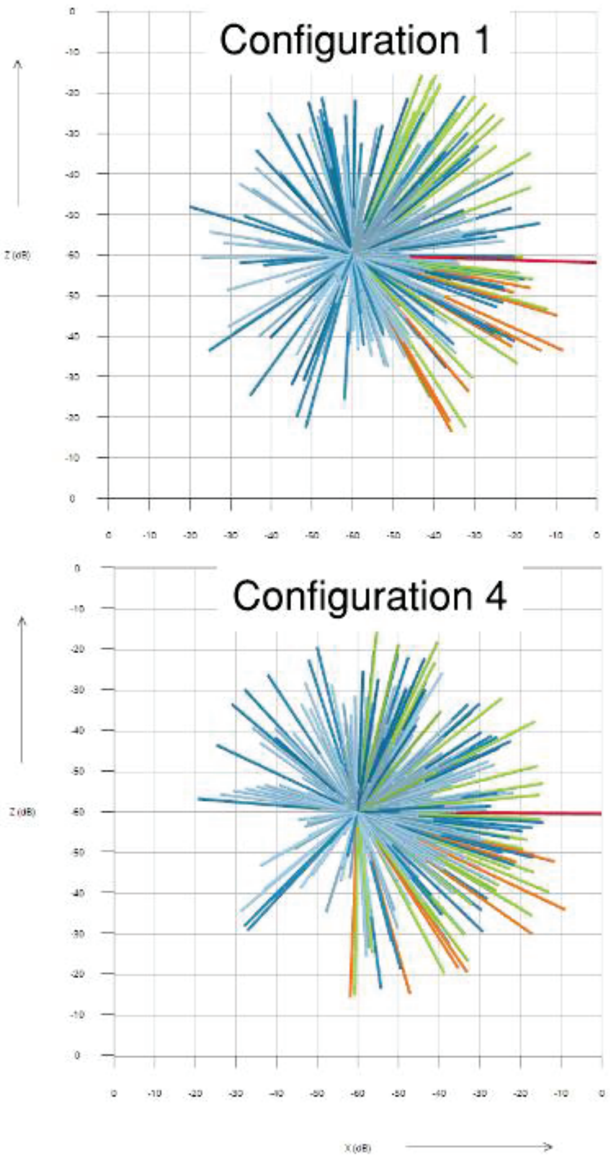

Figure 5: IRIS plots for microphone position P2 for Configurations 1 and 4

Figure 5 shows the same orientation of the direct sound (the red vector points to the source). Comparison of the plots shows that:

- raising the reflector from configuration 1 to configuration 4 has reduced the number of early overhead reflections (shown in green with arrival time 20 – 80ms after the direct sound)
- configuration 4 shows some increase in the density of later reflections (shown in light blue with arrival time after 200ms).

These trends are also observable at microphone position P4 at the edge of the orchestra.

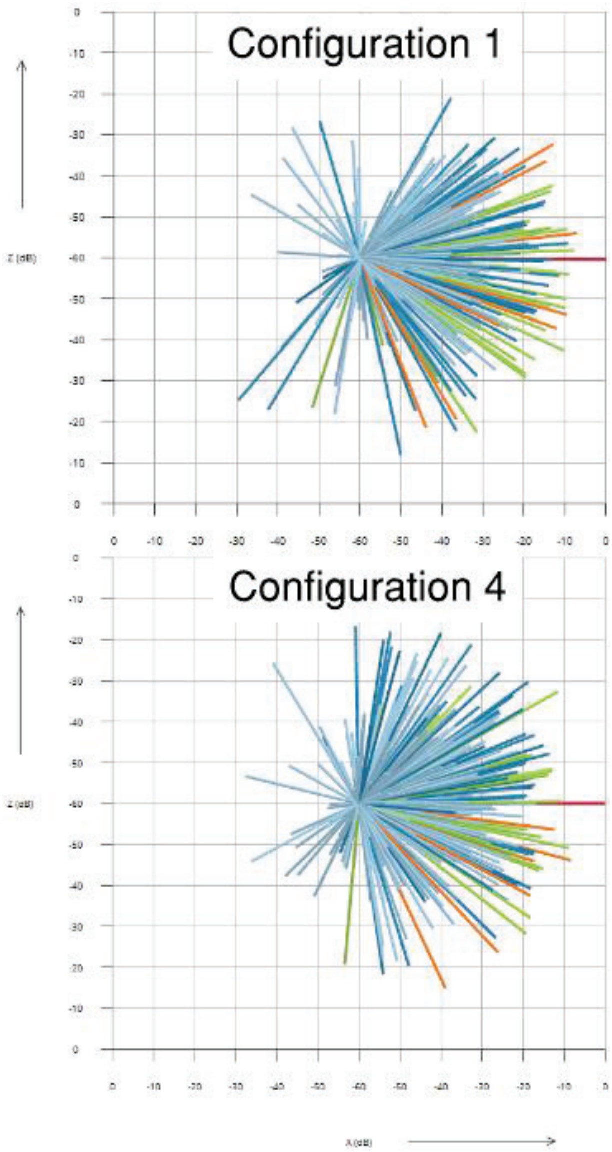

Figure 6: IRIS plots for microphone position P4

Figure 6 indicates a relative reduction of early reflection energy (orange and green) and an increase and fuller distribution of late reflections (dark and light blue), from configuration 1 to configuration 4. This is consistent with the measured increase in Ts and reduction in C80.

These changes result of raising the reflectors and reducing the area of deployed absorption at the top of the room above the level of the reflectors.

We can explain these results by visualizing a loosely coupled upper volume in the venue, created between the ceiling and the suspended reflectors, with a reduced absorption on the upper wall surfaces compared to the previous condition. We believe this is contributing to the increase in late sound energy in the room and providing more room presence on stage.

6. TUNING OF AN ELECTOACOUSTIC STAGE SHELL

A similar musician preference was observed earlier in another project.

In 2014 Marshall Day Acoustics assisted with the adoption of a Meyer electroacoustic system in the 2,100 seat ASB Theatre in Auckland, New Zealand. The venue was to be used for concerts given by the Auckland Philharmonic Orchestra.

The electroacoustic system created a virtual stage shell to allow the orchestra to perform on the main stage of the theatre under the fly tower without the use of a full set of flown ceiling and movable wall panels.

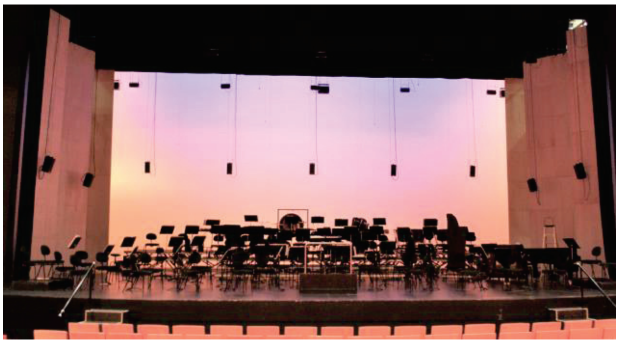

Figure 7: Illustration of the loudspeakers used to create the virtual shell above the orchestra

Our role was to recommend and monitor the adjustments in response to input from the orchestra over the four days of the tests. The feedback from the musicians was obtained from discussions and questionnaires.

Analysis of the preferred settings for the stage system was made using IRIS with the orchestral music stands and chairs in place.

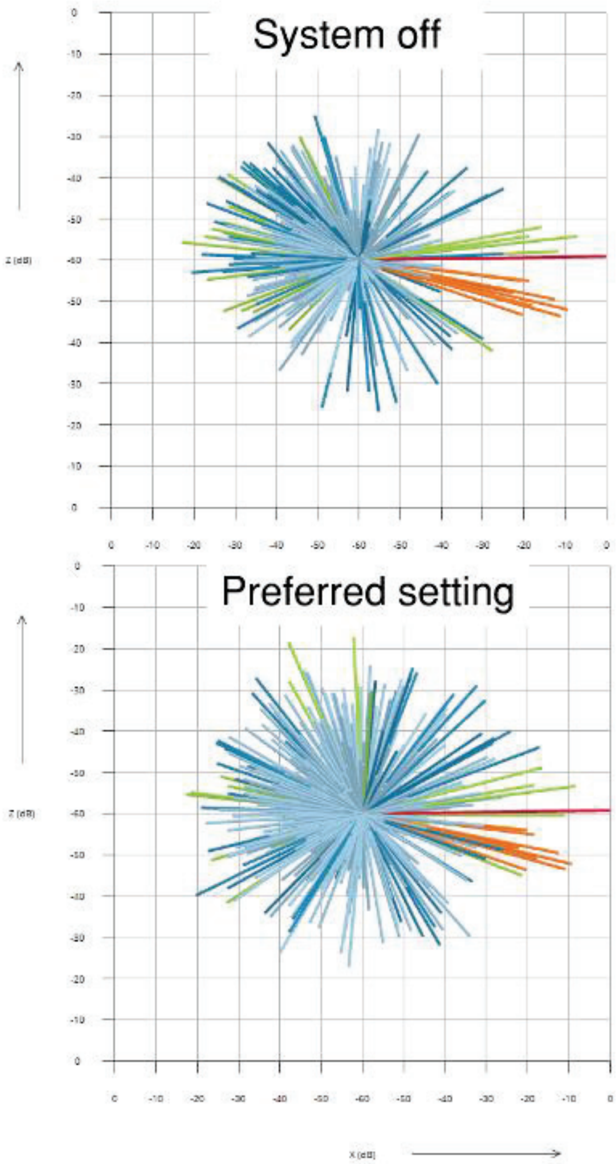

Figure 8: IRIS plots across the stage area with the electroacoustic system off (upper image) and with the preferred setting (lower)

The changes between the two images shown in Figure 8 are principally in the distribution and extent of the late reflections, coloured light and dark blue. We interpret this as a preference from the musicians for a perceptible contribution to the late sound field which supports their confidence in their sound projection as individuals and as part of the ensemble sound filling the auditorium.

Many of the early reflections are unchanged by the system (orange and green vectors) because these are the result of reflections off physical features, including the room boundaries, back-stage equipment and scenic elements around the stage area.

The measured parameter values across the stage are shown in Table 5.

Table 5: Objective measurements across the stage showing the changes due to the electroacoustic stage system

	EDT (s)	T (s)	C80 (dB)	Ts (ms)
System off	0.6	1.2	8.1	44
Preferred setting	1.4	2.0	3.5	81

As in the case of the QSO rehearsal venue the preferred conditions for the musicians included an increase in the later energy on stage.

7. DESIGN OF STAGE COUPLING FOR A 2,400 SEAT CONCERT HALL

In 2009 Marshall Day Acoustics was engaged jointly with Kirkegaard Associates to provide advice for the renovation of Hamer Hall, a 2,400 seat concert hall in Melbourne, Australia.

Part of the aim of the project was to improve the sound transfer between the stage and the audience areas. "Experienced listeners had previously reported a remoteness of the sound, often referred to as a veil between the platform and the orchestra." [5]

Changes to the room geometry and design of the stage canopy included curved wall and ceiling surfaces linking the stage and audience volumes in the venue as shown in Figures 9 and 10.

Figure 9: Hamer Hall prior to the renovation

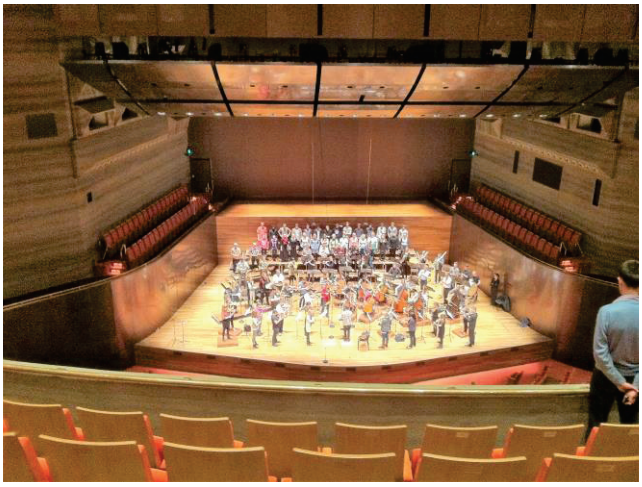

Figure 10: Hamer Hall post renovation

The revised curved wall and ceiling surfaces have enhanced the flow of late sound so that the room behaves more like a single volume. The musicians can more easily sense the sound of the orchestra filling the hall.

The distribution of these reflections is shown in Figures 11 and 12.

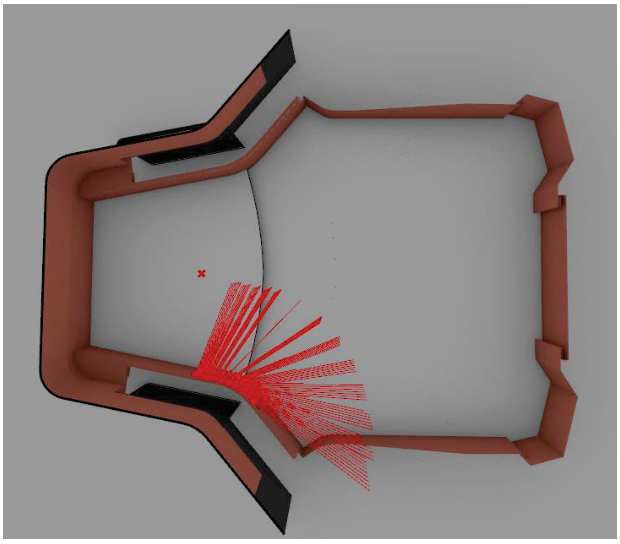

Figure 11: Hamer Hall stage wall reflection coverage

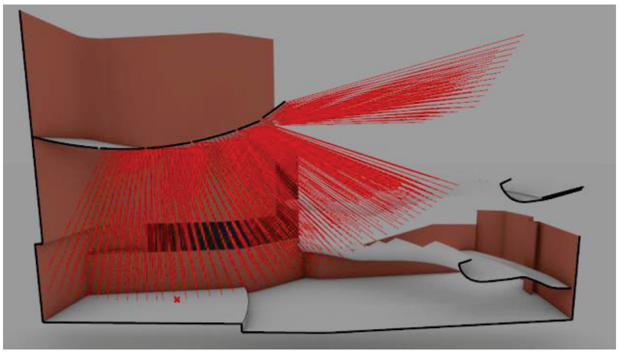

Figure 12: Hamer Hall overstage reflector coverage

As baritone Daneiel Sumegi described it:
"In the Hamer Hall you can actually sing *piano,* proper *piano*, and it will resound through the whole Hall. It's amazing." [6]

8. COMMENTS

Many experienced musicians have commented on the positive value of the acoustic support they feel from hearing the late sound in a performance venue.

Orchestral section principals are often required to play instrumental solo passages in their performance in addition to contributing to the sound of the whole ensemble. The reassurance from hearing the late response from the room provides confidence in the projection and control of a musician's own sound.

In small rooms it is difficult to design for a late response because a sound front will traverse the space many times before it can contribute to the late sound field. But in a larger rehearsal or orchestral performance space the late acoustic response has a place in the musician's preferred conditions.

The design larger music spaces can include some control of the late to early sound balance, by creating zones to store reverberant energy, by adding later energy to the room with loudspeakers, or directing the way sound moves in a room with reflecting surfaces.

Further developments on these design techniques could add to the useful guidance of ISO 23591 to the design of music spaces.

9. ACKNOWLEDGMENTS

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10. REFERENCES

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