SOME THOUGHTS ON WHOLE STAGE IMAGING FOR THEATRES

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1 INTRODUCTION

Recent project experience has included work on several opera houses, with a performance brief which includes a range of genres that extend well beyond the realm of traditional western opera. These venues may present symphonic orchestras using a stage shell, ballet and contemporary dance with musicians in an orchestra pit, and an increasingly broad spectrum of amplified events.

This brings a multitude of demands to the acoustic design, and balancing of sometimes competing priorities. These include the use of early frontal reflections to highlight the spatial location of individual performers, and the preference for early lateral reflections for the envelopment preferred in an orchestral performance or western opera.

The early reflections have a significant effect on the sound quality by contributing to the clarity and spatial resolution for audiences.

One goal in the design of performance halls is to limit the variation of sound quality heard in different parts of the hall or from different parts of the stage.

Surfaces which create whole stage images can help preserve the spatial distribution of the early reflections from different parts of the stage, resulting in better control of image shift and more consistent temporal distribution in reflections.

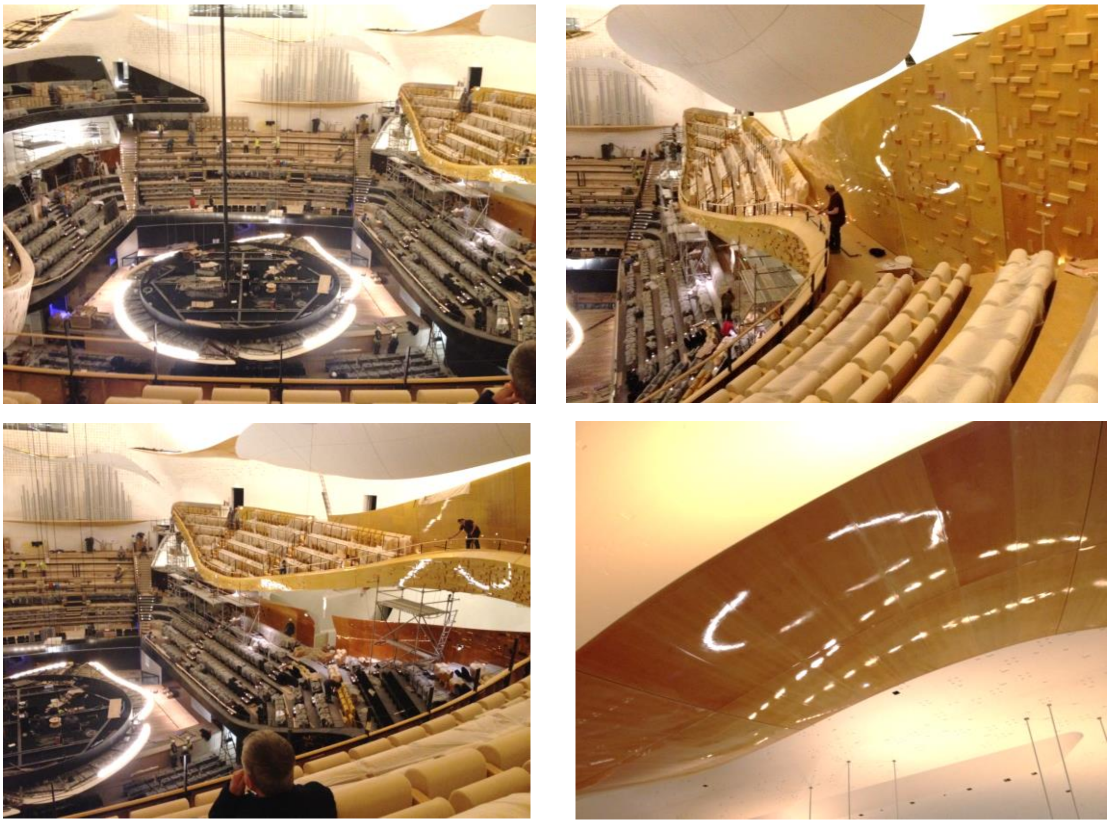
This paper describes the creation of 3D model images of the whole stage images referred to in an earlier presentation[1]. We then apply this process to provide a new analysis to a selection of earlier Marshall Day projects of different geometries.

Where provided the room acoustic parameters have been measured by us in general accordance with ISO:3382.

2 MOTIVATION

The visualisation of whole stage images was demonstrated in the Paris Philharmonie (opened 2015). Four days before opening the stage reflector with perimeter lighting was lowered and images were observed from the room surfaces including perimeter walls and the flown nuage reflectors. Some of these are shown in Figure 1.

Figure 1: Lowered stage reflector in the Paris Philharmonie with images on surrounding surfaces



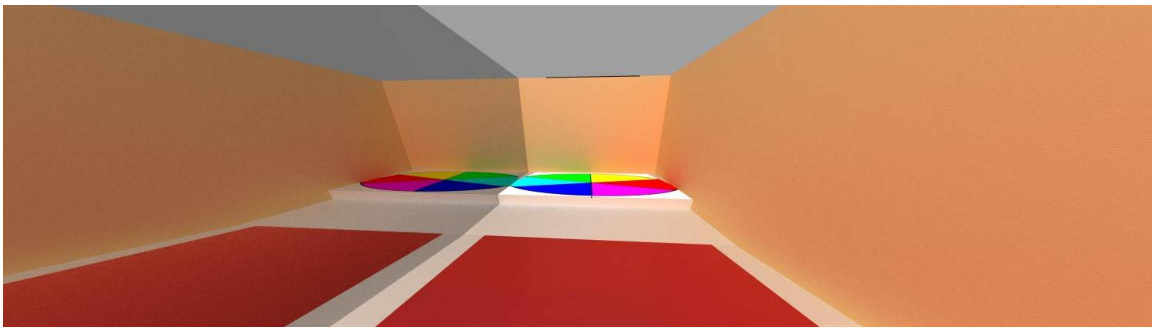
We developed a technique to study similar reflections using 3D models of other performance rooms.

3 MODEL STUDIES

The 3D rendering technique was developed from previous work with Thomas Scelo. This allows us to visualise the useful reflection surfaces for whole stage images. This has benefits when verifying the reflection paths and sharing the design journey with architects and clients.

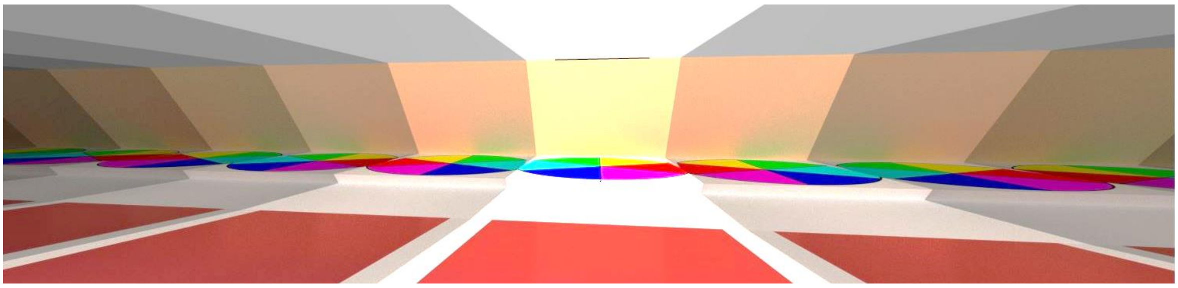
Consider a model of a simple rectangular room with a distinctive pattern on a stage area at one end. Figure 2 shows the rendering with a reflective material on one side wall to create the image of the whole stage.

Figure 2: Stage with an image reflection from a single side wall



By allowing the second side wall also to show reflections we can visualize the series of symmetrical higher order reflections, as shown in Figure 3.

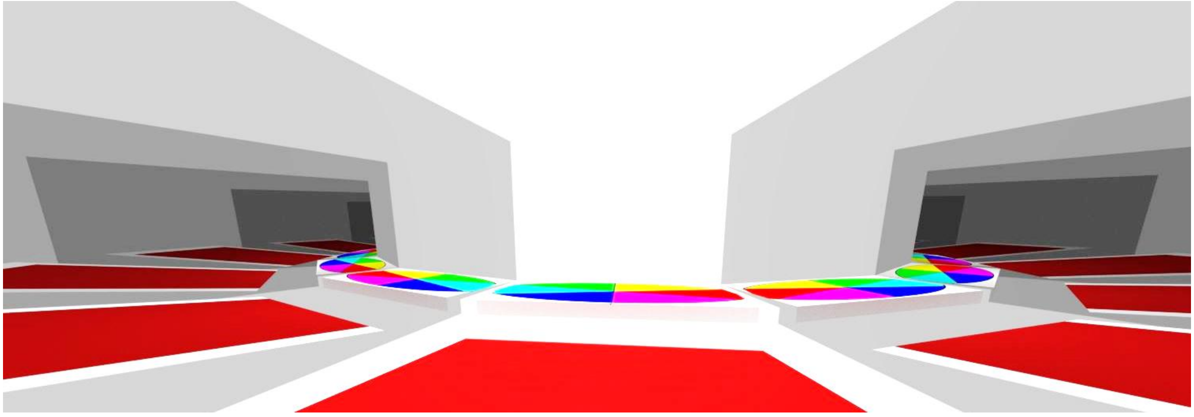
Figure 3: The distribution of higher order images from parallel walls



The image reflections appear in a line across the room. This corresponds to the higher order reflections contributing to the strong lateral component to the sound quality in shoebox halls.

We can similarly demonstrate the location of the image sources for a fan shaped room. The side walls in the model used in Figure 4 below have an included angle of 20 degrees and it is clear to see how the image sources form around a circle with the higher order images receding away from the listener. The lateral contribution reduces with these higher orders of reflection.

Figure 4: The higher order images in the fan shaped hall recede behind the stage



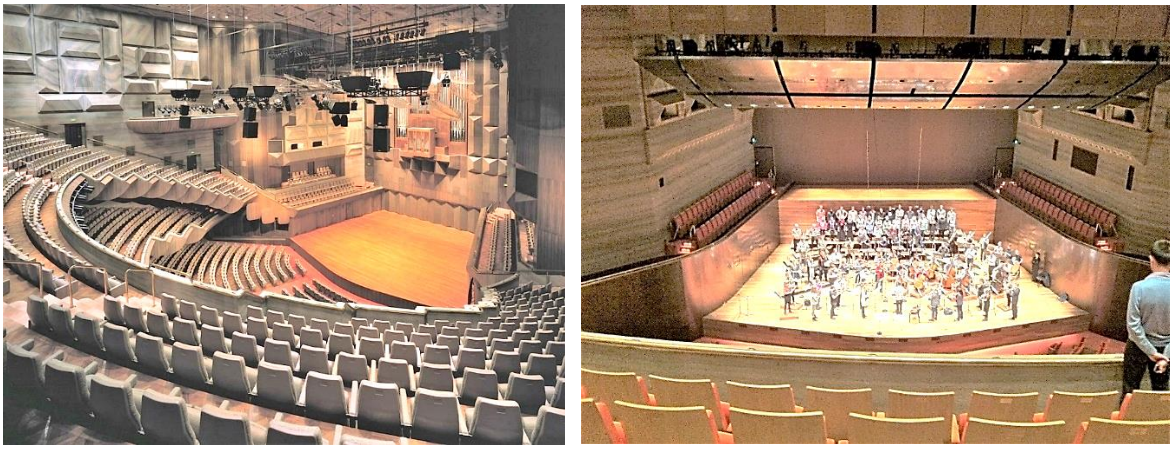
This corresponds with the common observation that fan shaped rooms are associated with less engaging acoustic conditions with lower lateral energy fractions.

We then revisited some previous projects to review their reflection strategies.

4 CONCERT HALL EXAMPLE

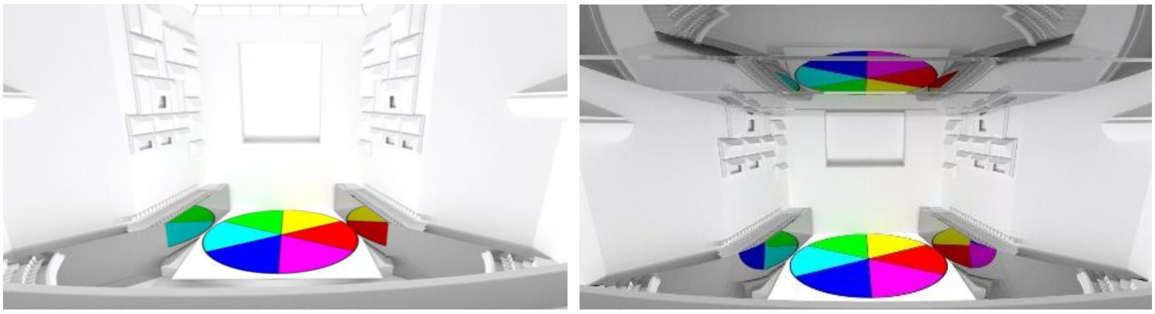
Marshall Day Acoustics collaborated with Kirkegaard Associates in the renovation of Hamer Hall, a 2,400 seat concert hall in Melbourne (re-opened 2012). One of the acoustic goals was to improve the acoustic connection between the stage and auditorium. Curved surfaces were installed at the sides of and above the stage to generate new sound paths within the hall.

Figure 5: Hamer Hall before and after the renovation - both views from the top balcony



Following our visualisation procedure we generated the stage reflections from the old and new curved surfaces as shown in Figure 6 and Figure 7.

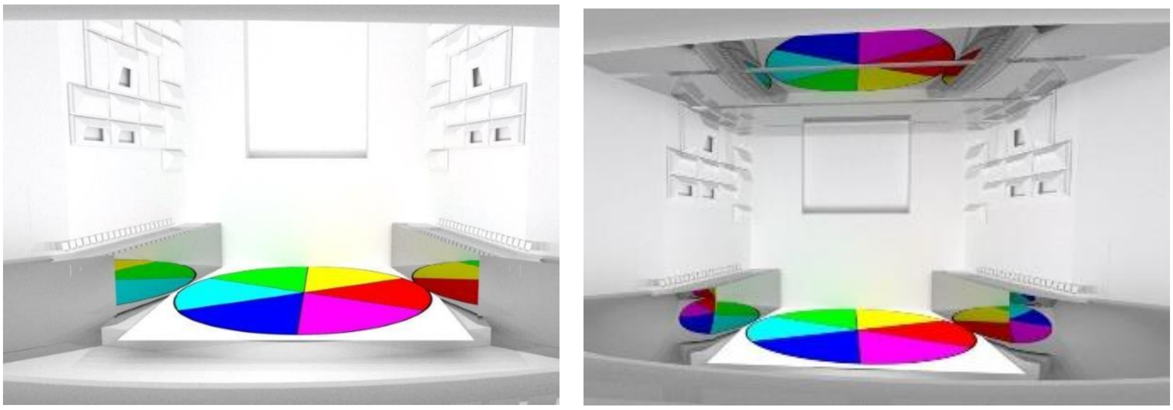
Figure 6: Hamer Hall stage reflections before and after the renovation viewed from the top balcony



The revised stage side walls each show some increase in reflection coverage to the upper balcony, and in combination provide coverage of the whole stage.

Each stage image in the renovated hall when viewed from the lower balcony is more complete.

Figure 7: Hamer Hall stage reflections before and after the renovation viewed from the lower balcony



The revised side walls each provide full stage images to the lower balcony.

The renovation resulted in a more uniform quality throughout the room with increased clarity and engagement, particularly in the lower balcony.

5 EARLY REFLECTION DESIGN FOR GRAND THEATRES

Our recent experience is that many new venues called either opera houses or grand theatres in China are intended to be used for a wide variety of performance types. Examples of these may include classical western opera, traditional Chinese opera, amplified musicals, ballet or dance with a live orchestra or to amplified soundtracks, and symphony concerts utilising a sound shell.

In creating the acoustic character of a venue the study of the early reflection paths is important.
We illustrate some strategies for realising early reflection distributions in large theatres.

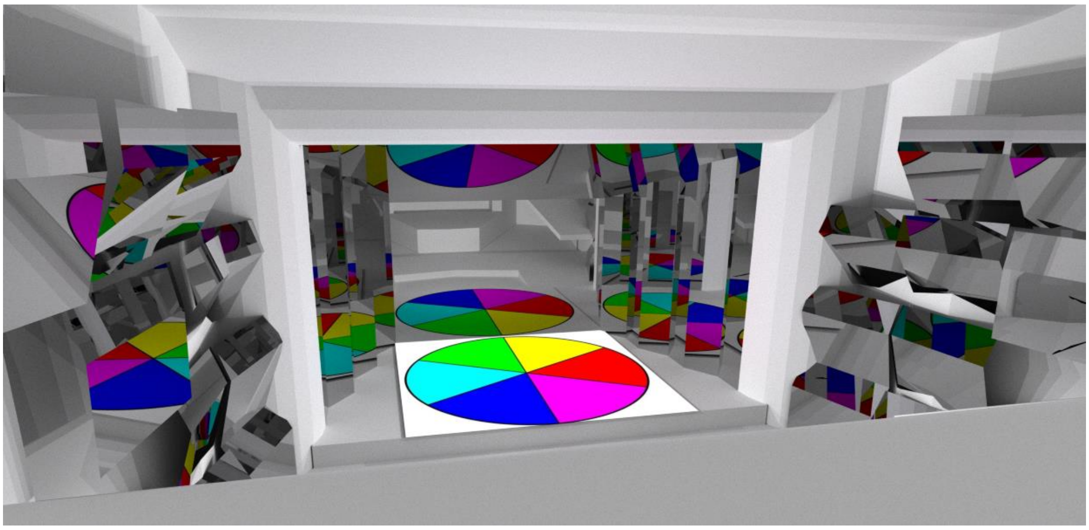
5.1 Added side wall features

The 1200 seat performance and recording studio for Beijing Television (opened 2009) used inclined QRD surfaces on the side walls to steer and distribute the early reflections.

To achieve variable acoustic conditions between orchestral and amplified modes the ceiling lighting bridges can be lowered by 4m, and some of the side wall panels are hinged to reveal additional side lighting positions at the balcony front. These features allowed a reduction in room volume and additional absorption to be exposed at the rear and sides of the lowered ceiling panels.

Figure 8: Diffusing and reflective surfaces on the front walls of the Beijing Television Studio (left), then with lowered lighting bridges and exposed side lighting position (right)

Figure 9: Reflections from stage shell and added wall surfaces to balcony seating area



The measured parameter values for the unoccupied hall are shown in Table 1.

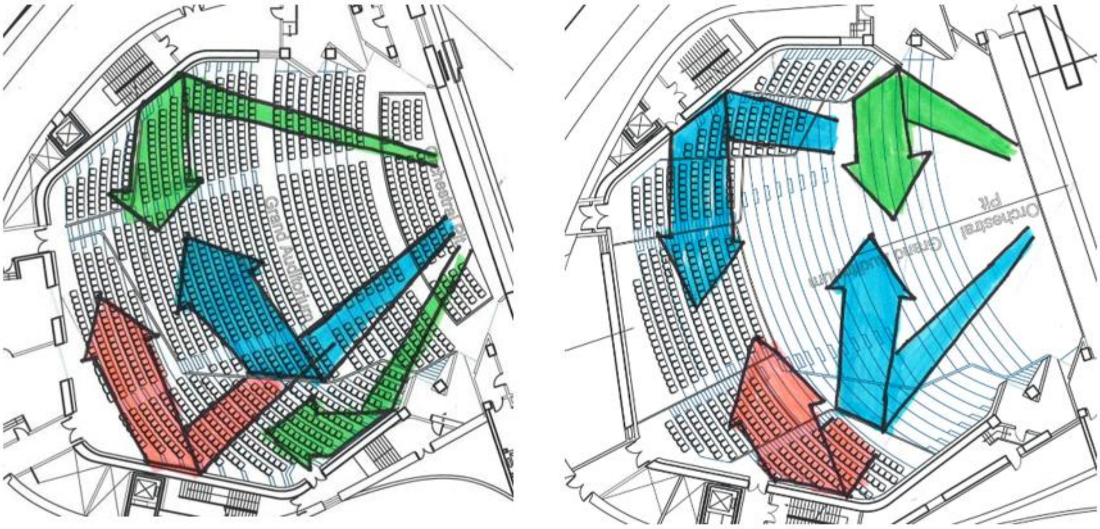
Table 1: Parameter values for the unoccupied Beijing Television Studio

Parameter	Orchestra with stage shell	Amplified mode
EDT(mid)	1.8seconds	1.4seconds
RT(mid)	1.8seconds	1.4seconds
Bass rise	0.9 x RT(mid)	0.9 x RT(mid)
Clarity C_{80}	+0.4dB	+1.5dB

5.2 Using balcony front and modified wall surfaces

As reported earlier[2], the acoustic design of the 1800 seat Guangzhou Opera House (opened 2010) included generating reflections from the asymmetrical walls and balcony fronts, with the strategy shown in Figure 10.

Figure 10: Early reflection strategy for the Guangzhou Opera House



This strategy leaves the surfaces closest to the proscenium free for the design team to incorporate side lighting bridges, surtitle screens and loudspeaker positions into their architectural statement.

Figure 11: Side wall surfaces in the Guangzhou Opera House with lighting bridges, a display screen and loudspeaker position around the proscenium

Visualisation of the stage shell, proscenium and wall reflections confirms that the shell and early frontal reflections add to the clarity from parts of the stage and source broadening, and the auditorium wall reflections also supply weaker whole stage images.

Figure 12: Stage reflections from the orchestra shell and wall surfaces to the balcony in Guangzhou

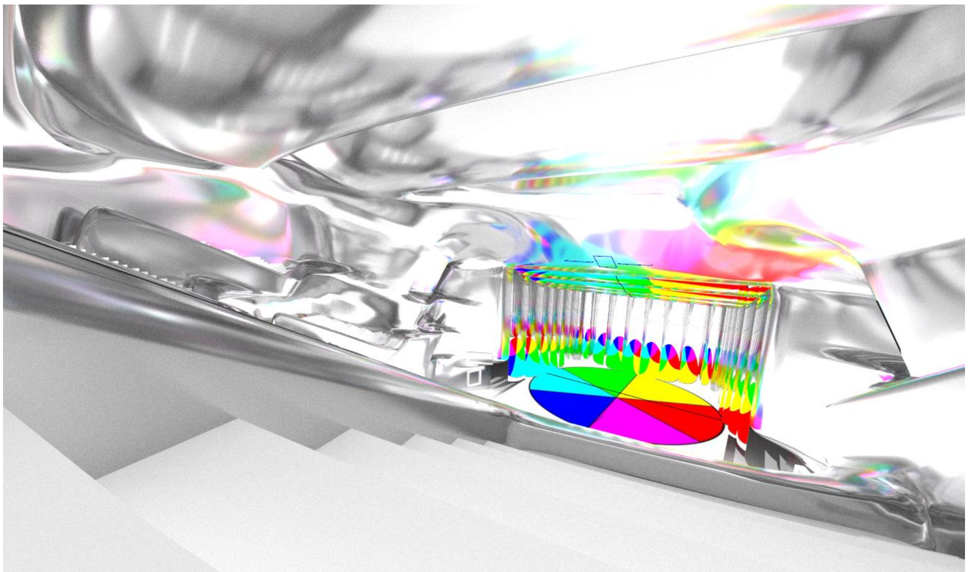


Table 2: Measured parameter values for the Guangzhou Opera House (unoccupied)

Parameter	Orchestra with stage shell
EDT(mid)	1.7seconds
RT(mid) orchestra	1.9seconds
Bass rise	1.1 x RT(mid)
Clarity C80	+1.5dB

5.3 Utilising walls between the side lighting positions

The acoustic design of the 1600 seat Zhuhai Opera House (opened 2017) followed a different strategy with reflection surfaces integrated with the front walls to contribute stage images.

Figure 13: Zhuhai Opera House during an early test performance with an orchestra on stage

Applying the visualisation allows us to analyse the effectiveness of the design of the front wall panels in creating stage reflections. The results are shown in Figures 14 and 15.

Figure 14: Side wall reflections for the Zhuhai Opera House viewed from the rear stalls

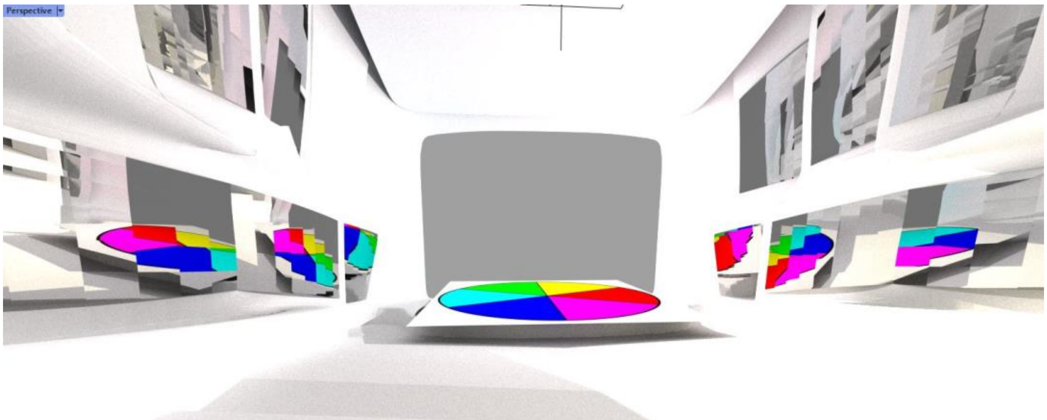


Figure 15: Side reflections for the Zhuhai Opera House viewed from the rear balcony

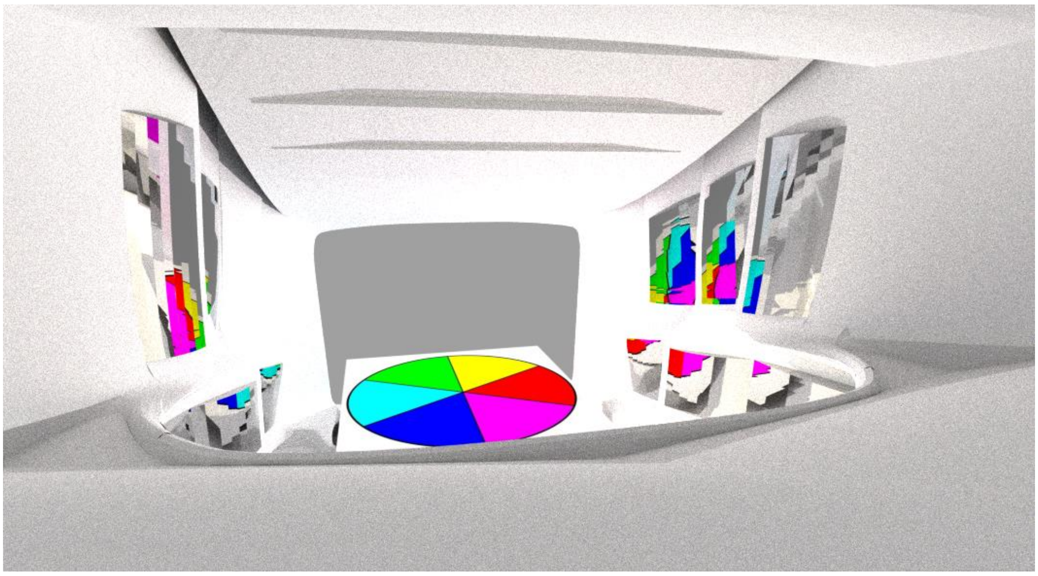


Table 3: Measured parameter values for the Zhuhai Opera House (unoccupied)

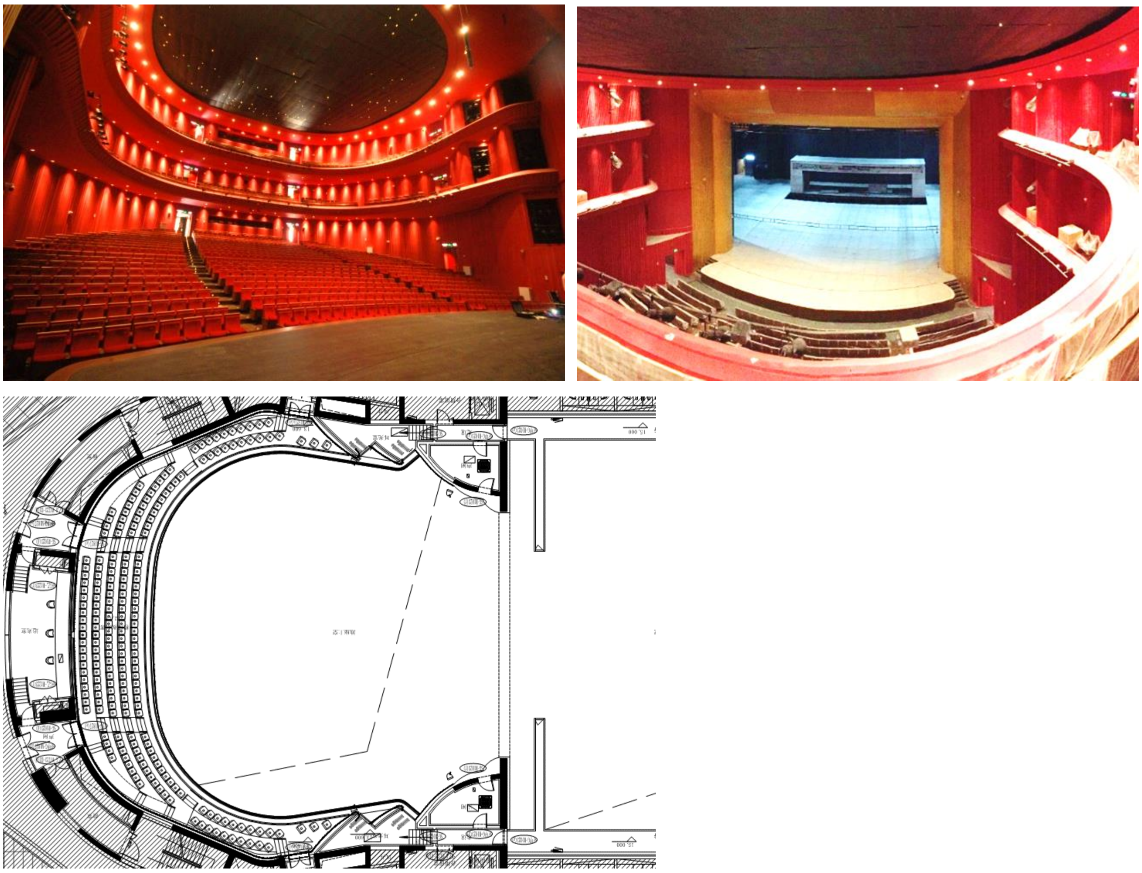
Parameter	Orchestra with stage shell	Amplified mode
EDT(mid)	1.9seconds	1.8seconds
RT(mid) orchestra	1.8seconds	1.7seconds
Bass rise	1.1 x RT(mid)	1.1 x RT(mid)
Clarity C_{80}	+0.1dB	+1.5dB
LF80	0.18	0.17

5.4 The Horseshoe form

At first glance the surfaces available for whole stage imaging in a horseshoe form opera house appear limited to the balcony fronts and surfaces surrounding the side lighting positions.

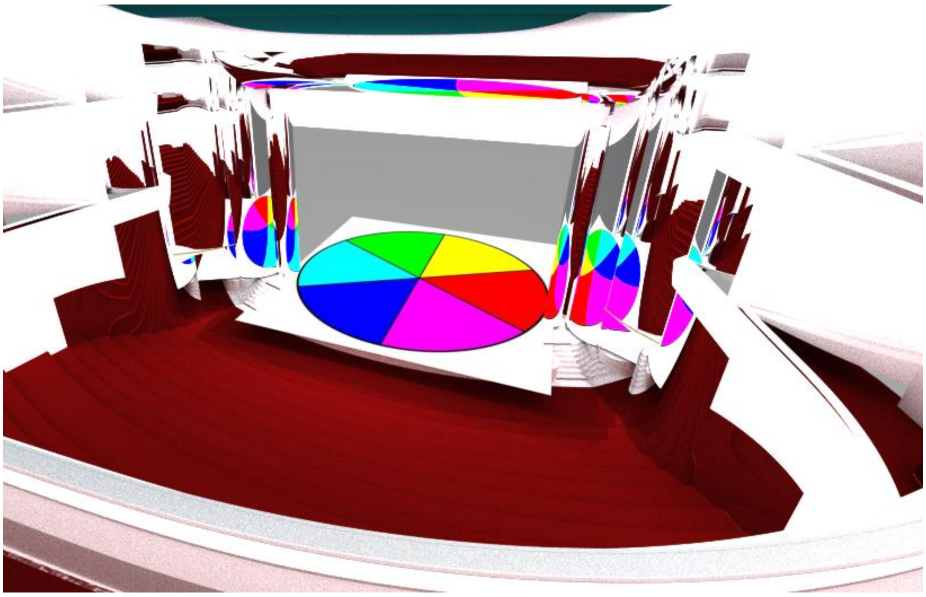
However, with negotiation and coordination with the design team it is possible to create some useful surfaces for whole stage images close to the proscenium. To show this we use the 1600 seat Opera House for the Chengdu City Concert Hall project (opened 2019). The hall is shown in Figure 16.

Figure 16: The opera house for the Chengdu City Concert Hall project



Applying the visualisation shows that the proscenium surround can be successfully used to provide supporting stage image reflections as shown in Figure 17.

Figure 17: 3D model of Chengdu opera house from the rear balcony showing the proscenium reflections.



The visualisation indicates that these early reflections can contribute to acoustic clarity, including overhead reflections to assist localization and side wall reflections for source broadening.

Table 4: Measured parameter values for the Opera House at the Chengdu City Concert Hall (unoccupied)

Objective parameter	Lowered fire curtain
EDT (mid)	1.7seconds
RT (mid)	1.8 seconds
Bass Rise	RT125Hz = 1.0 x RTmid
C80 (mid)	2.1dB
Mid frequency Lateral fraction	0.20

6 CONCLUSION

We have demonstrated a technique for visualizing whole stage images in concert halls and opera houses and applied post analysis to several previous projects.

Different seating layouts and room geometries offer a range of potential locations for early reflection surfaces. There can be competition in the design of theatres between the architects, theatre and acoustic consultants for the use of surfaces close to the stage. Larger reflection areas in this zone offer increased opportunities for creation of stage image reflections. This has implications for the clarity and envelopment in the room, and also for using the remaining sound energy to feed the reverberant field.

Further refinement of the stage image used in the study could yield more information on the reflection coverage for different sections of an orchestra or stage layout.

7 REFERENCES

1. Marshall, Exton and Scelo, Whole stage imaging for the control of sound strength in concert halls, ISRA 2010 Melbourne
2. Peter Exton, Harold Marshall, The room acoustic design of the Guangzhou Opera House, Proceedings of the Institute of Acoustics, Vol. 33 Pt.2 2011